Buying from a Competitor: A Model of Knowledge Spillover and Innovation*

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September 15, 2024

Abstract

Many firms buy a production input from a competitor. However, managers often worry that this supply relationship may give their competitor valuable knowledge about new product innovations. We develop a two-period model in which a firm can buy an input from a competitor or a third party in each period. In order to innovate, the firm must invest in improving the input, which results in its supplier learning to produce a higher quality input. We show that buying from the competitor: (1) increases short-term profits by softening price competition; and (2) may reduce long-term profits by preventing investment in innovation. Our results imply that the classic hold-up problem, which leads to underinvestment in innovation, becomes more severe when a firm buys from its competitor who benefits from knowledge spillover.

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1 Introduction

Firms sometimes buy a production input from a competitor. For example, Apple and Samsung are the two largest competitors in the smartphone market, and yet Apple historically has purchased screens for its iPhone from Samsung (Lessin et al. 2013; Epstein 2017). Other examples include Hewlett-Packard buying laser printer engines from Canon (Braithwaite 2020), competing television manufacturers buying television screens from LG (Demers and Wiszniewska 2021; Porter 2021), car makers buying batteries for electric vehicles from Tesla (Wayland and Kolodny 2021), and watchmakers buying movement components from Swatch Group (Naas 2019).

A major concern for managers who buy inputs from a competitor is that their firm may need to share valuable information with the competitor (Arruñada and Vázquez 2006; Brandenburger and Nalebuff 2021). For example, in 2013, an industry analyst reported that Apple wanted to find a different supplier for iPhone screens because, “If you buy screens from your competitor, you will be sharing some key information on your next product” (Lessin et al. 2013). Nonetheless, Apple has continued buying screens from Samsung. In 2017, a news story on innovations in smartphone screens reported, “Apple apparently has something special brewing behind closed doors. In fact, it’s so special that the company supposedly thinks Samsung Display will steal its ideas and pass them off to Samsung Electronics, so Apple has turned to Samsung rival LG Display to help develop this new OLED screen technology” (Epstein 2017). More recent reports say this new innovation Apple and LG are developing is a foldable screen (Hardwick 2022).

In this example, Apple has the choice to buy foldable screens either from Samsung or from LG, and Apple also decides whether to continue investing in improvements in foldable screen technology. For example, Apple has invested in creating more durable folding screens that do not crease or crack in the area where the screen folds (Liberatore 2023). Thanks to Apple’s investment, its screen supplier will learn to produce these innovative new screens. Thus, Apple now works with LG instead of Samsung to prevent knowledge spillover to a competitor in the phone market (LG no longer makes smartphones (Li 2021)).

As another example, Hublot, a luxury watchmaker and part of LVMH Group, has a history of innovative investment in its movement components, for example, using different materials and designs to create more lightweight watches (Longet and Gabella 2023). Hublot could buy these components from Swatch Group, but instead it buys them from third party supplier Sellita (Koltrowitz 2020; Ho 2023). By sourcing from a third party, Hublot can invest in improving this production input while avoiding knowledge spillover to a competitor (Swatch Group owns high-end watch brand Omega, which competes with Hublot (Boyd 2022)).[1]

These examples illustrate a common problem with buying a supply input from a competitor. If a firm invests in improving an input, then the resulting knowledge spillover allows its supplier to produce a higher quality input in the future. If the supplier also happens to be a competitor in the product market, then this knowledge spillover strengthens the firm's competitor.

This paper builds a two-period model in which a firm can buy a production input either from its competitor or from a third party, with or without investing to improve the input. Formally, in our model, two competing firms sell a differentiated product. One of these competing firms has the ability to create a key production input for this product, whereas the other competing firm can purchase the input either from its competitor or from a third party supplier who does not compete in the product market. In each period, the two competing firms first engage in Nash bargaining over a two-part tariff that one firm pays to the other for the production input. If the firms do not reach a supply agreement, the focal firm buys the input from the third party. After this supply agreement occurs, product prices for the period are set and profits are realized. During the first period, the focal firm also chooses whether to invest in improving the input, which allows its chosen supplier to produce a higher quality

[1] Swiss authorities have a complex history of regulating sales of movement components, for a time requiring Swatch Group to sell these inputs to competitors, and more recently forbidding them from doing so (Naas 2019). However, current regulatory policy allows Swatch to make its own decisions about whether to sell to competitors (Koltrowitz 2020).

input in the next period.

Our results imply that competing firms can use an agreement in which one firm supplies an input to the other to help soften price competition in the product market. The competitor that supplies the input earns a profit from each unit of the good sold by the focal firm, so it has less incentive to undercut the focal firm's price in the product market. However, if the focal firm buys from the competitor and invests in innovation in the first period, the competitor then has a stronger bargaining position in the second period because it knows how to produce a high quality input, which provides the competitor with an advantage if the firms fail to reach an agreement and the focal firm has to source from the third party.

We show that these two forces – the price softening effect and the stronger bargaining position for the rival – give rise to three kinds of equilibrium supply arrangements, and under some conditions, the value of innovation has a non-monotonic effect on the focal firm's choice of supplier. If the value of the innovation is sufficiently low, the firm buys from its competitor and does not innovate. If the value of the innovation is sufficiently high, the firm buys from its competitor and innovates. However, if the value of innovation lies in an intermediate range, the firm buys from the third party so that innovation occurs in equilibrium.

Our analysis also implies that the degree of horizontal product differentiation in the consumer market affects the equilibrium supply arrangement. With a low level of product differentiation, the focal firm buys the input from the competitor to exploit the price-softening effect in the highly competitive product market. In this case, the focal firm invests in innovation if the value of innovation is sufficiently high relative to its cost. By contrast, if the products are sufficiently differentiated in the product market, the focal firm may buy the input from the third party to prevent the rival from obtaining a stronger negotiating position.

Another key factor in these investment decisions is the magnitude of investment costs. For example, Apple has invested $2.7 billion in LG's screen production facilities (Maggio 2017). Such investment is partly a financial transfer, but it also involves other investment costs that are not purely financial. Apple managers decide whether to assign key employees to spend time on research and development of better phone screens, and this discretionary investment by Apple is not easy for an outside company like LG to monitor. Therefore, Apple will make such investments of time and effort only if it expects that doing so will lead to a sufficient increase in its own profits.

In our model, as in many real world cases, certain aspects of the supply arrangement cannot be enforced with a formal contract. Similar to economic theory on incomplete contracts and hold-up problems (e.g., Grossman and Hart 1986; Hart and Moore 1988), firms cannot use a formal contract to require the focal firm to invest in innovation, because a court could not practically verify and enforce such a contract. For example, if Apple signed a contract promising to invest in making its supplier's foldable screens more durable and user friendly, it would be difficult for a judge to verify whether Apple has met its obligations under this contract. In addition, similar to previous literature on contract renegotiation (e.g., Hart and Moore 1988; Plambeck and Taylor 2007), the firms cannot commit to future prices for a second period input contract, because they do not yet have sufficient knowledge of future production costs and future demand. For example, the prices in Apple's supply contract for its foldable screens can only practically be specified for a limited amount of time, with managers understanding that firms will eventually need to negotiate new terms of their supply contract as costs and demand change over time. Our paper derives conditions in which these non-contractible aspects of the supply arrangement result in the focal firm choosing a third party instead of a competitor as a supplier, or choosing a competitor as a supplier but refusing to innovate, in order to avoid strengthening the negotiating position of its competitor in the second period.

Our results imply that the classic hold-up problem, which leads to underinvestment in innovation, becomes more severe if a firm buys from its competitor. If the extent of knowledge spillover to the competitor is large, we show that the range of costs for which the firm would invest in the third party's input is at least twice as large as the range of costs for which the firm would invest in the competitor's input. Thus, there is a smaller set of parameter values for which the firm will invest if its supplier is also a competitor. This increased severity of the hold-up problem if the firm buys from a competitor can cause it to choose a third party supplier to ensure innovative investment occurs.

To summarize, our two-period model shows that, in the first period, the focal firm faces a trade off between the short-term benefit and the long-term cost of buying from a competitor. The short-term benefit to firms is that choosing a competitor as a supplier leads to less intense price competition. However, the long-term drawback is that buying from a competitor discourages investment in innovation by the focal firm. Under some conditions, we find that the increased severity of the hold-up problem when investing in a competitor's input causes a firm to buy from a third party, despite the price softening benefit of sourcing from a competitor.

Section 2 discusses related literature. Section 3 presents the model set-up. Section 4 derives results. Section 5 presents several model extensions. Section 6 presents conclusions. The appendix contains all formal proofs and additional model extensions.

2 Related literature

There is a literature that has examined some of the implications of buying an input from a rival. Previous papers have studied how economies of scale can affect the firm's sourcing decision (Heese et al. 2021), whether the focal firm or its rival should be responsible for investing in improvements to the production process (Pun 2014), the effects of competition on the sourcing decision in a Stackelberg quantity choice framework (Chen et al. 2011), the effects of capacity constraints on the sourcing decision (Ghamat et al. 2018), and how firm-level capabilities determine the sourcing decision of a firm with the threat of the supplier as a potential competitor (Lim and Tan 2010). Literature in supply chain management has also established that information sharing is an essential ingredient of a successful supply relationship (e.g., Lee and Whang 2000; Cachon and Fisher 2000; Lee et al. 2000) and shown that firms may want to limit the amount of information they share with rivals (Li 2002; Ha and Tong 2008; Li and Zhang 2008; Anand and Goyal 2009). Another related research stream investigates the distribution strategy for a manufacturer of a proprietary component, which can either act as a sole entrant or also license its component to a competitor (Venkatesh et al. 2006; Xu et al. 2010; Yang et al. 2018). These previous papers do not capture how buying from a rival affects the focal firm's future negotiating position in a dynamic setting, which is the focus of our paper.

To model the negotiation between the focal firm, the competitive supplier, and the third party, Heese et al. (2021) use a bilateral negotiation framework. However, their model is a one-period model, which does not capture how the competitive supplier's future bargaining position is affected by the focal firm's current choice of supplier and its investment decision. Moreover, Heese et al. (2021) do not consider investment in innovation and the possibility of knowledge spillover; their focus is on the role of efficiencies created via economy of scale. Furthermore, some previous papers find that buying from a competitor softens price competition (e.g., Xu et al. 2010), but they do not show how this effect interacts with the effect of innovation on future negotiating positions, as our paper does.

Previous literature has shown that incomplete contracts lead to opportunism (Williamson 1993), which can affect asset ownership decisions (Grossman and Hart 1986; Hart and Moore 1988; Gibbons 2005), pricing decisions (Bajari and Tadelis 2001; Nistor and Selove 2020), effort incentives in a relationship between firms (Baker et al. 2002; Levin 2003; Taylor and Plambeck 2007), and a seller's bilateral negotiation with multiple downstream firms (McAfee and Schwartz 1994). A common feature of these models is that hold-up problems occur when one party makes an investment and another party then negotiates to extract surplus created by this investment. For example, Stole and Zwiebel (1996a,b) develop a model in which a firm invests in employee training, and employees then become more valuable and can extract some of the benefits of their training through wage negotiation. Che and Hausch (1999) develop a model in which a supplier and a buyer can each make a cooperative investment that increases the profits of the other party, and each firm negotiates to extract surplus created by these investments. Similarly, in our model, the focal firm's investment in the competitor's input increases the competitor's profits, and firms then negotiate over how to split the resulting surplus, causing a hold-up problem.

A key difference between our paper and this earlier literature on hold-up problems is that the firms negotiating over an input in our model also compete in the product market. Furthermore, if the focal firm and its competitor fail to reach a supply agreement, the outside option is that the focal firm buys from the third party and the competitor continues making its own inputs. Therefore, investment in the competitor's input makes this outside option better for competitor and worse for focal firm. For example, if Apple helps Samsung make more durable folding screens, and these firms later fail to reach an agreement for a continued supply contract, then Samsung can continue using the improved screens whereas Apple needs to use unimproved screens from LG, which results in a product market advantage for Samsung. This effect on the outside option for each firm increases the severity of the hold-up problem and discourages Apple from investing in Samsung's screens. Thus, we show that the interaction of product market competition with uncontractible investments implies the hold-up problem becomes more severe when a firm buys from a competitor.

Another related stream of literature investigates the make-versus-buy decision (e.g, Williamson 2008; Arya et al. 2008), addressing whether a firm should outsource production of an input to another firm or invest in producing in-house. In our model, making the input in-house is infeasible for the focal firm, for example, due to high fixed costs of developing this expertise. Instead, we focus on the strategic aspects of buying an input from a rival versus a non-rival supplier and the implications for innovation.

Our paper is also related to marketing literature that uses game theoretic models to study channel coordination (e.g., Jeuland and Shugan 1983; Iyer 1998; Iyer and Villas-Boas 2003; Desai et al. 2004; Dukes et al. 2006; Amaldoss and Shin 2015). One firm in our model is both a supplier and a competitor, so the classic double marginalization problem studied in this literature benefits the firms in our model by softening price competition, in contrast with this earlier literature in which double marginalization reduces industry profits.

3 Model

There are two competing firms, Firm A and Firm S, producing a differentiated product and selling it in two time periods. Throughout the paper, we will call Firm A the "focal firm" and the Firm S the "competitive supplier." We model consumer preference heterogeneity and product differentiation using a Hotelling line with length one, where Firm A is located at $x = 0$ and Firm S is located at $x = 1$, with a unit mass of consumers uniformly distributed along the line. Denote consumer valuations for the products in period i by $v_{A,i}$ and $v_{S,i}$ and product prices by $p_{A,i}$ and $p_{S,i}$, where $i \in \{1, 2\}$. A consumer at location x derives utility $v_{A,i} - tx - p_{A,i}$ and $v_{S,i} - t(1-x) - p_{S,i}$ from purchasing from Firm A and Firm S, respectively, where t is the transportation cost, which captures the level of product differentiation in the market. In each period, a consumer purchases at most one unit of the product.

To produce their products, firms need a specific input. Firm S can produce this input in-house, but Firm A does not have the capability to do so. Firm A can buy the input either from Firm S or from a third party, Firm T. The input contracts consist of a standard two-part tariff. In period i, Firm A can purchase the input from Firm S for a per-unit price $w_{S,i}$ plus a fixed payment $F_{S,i}$, or it can purchase the input from Firm T for a per-unit price $w_{T,i}$ plus a fixed payment $F_{T,i}$. The variable component of these payments is non-negative, and we allow the fixed component to be either positive or negative (or zero). This type of contract allows the two parties who reach a supply agreement to choose a variable component to maximize their total equilibrium profits, while using the fixed component to transfer profits between them (Moorthy 1987).

In practical terms, the fixed payment helps cover costs for the supplier's production facilities. For example, Apple recently paid \$2.7 billion to help fund LG's factory for phone screens (Maggio 2017). In our model, if Firm A buys the input from the third party, then it makes a fixed payment of $F_{T,i}$ to help cover costs for this supplier's production facilities. If Firm A buys from the competitor, then it makes a fixed payment of $F_{S,i}$ to help fund this supplier's facilities. For notational simplicity, we normalize $F_{T,i}$ to zero and allow $F_{S,i}$ to be either positive or negative. Therefore, a negative value of $F_{S,i}$ means this fixed payment is less than $F_{T,i}$ but does not imply the fixed payment to the competitor is actually negative in absolute terms. In other words, the focal firm may make a smaller fixed investment in the facilities of its competitor than it would make in the facilities of the third party.[2]

Our goal is to understand the strategic implications of purchasing the input from the competitive supplier. For simplicity of exposition, we normalize the third-party supply contract to $w_{T,i} = F_{T,i} = 0$. However, the supply contracts between Firm A and Firm S (i.e., the equilibrium values of $w_{S,i}$ and $F_{S,i}$) are determined endogenously using a Nash bargaining model. In particular, in each period, Firm A and Firm S negotiate over the contract terms considering each firm's outside option, that is, the profits that would be realized if they did not reach an agreement. The Nash bargaining framework implies firms optimize the negotiation parameters (the per-unit input price and the fixed payment) such that total industry profits are maximized and the additional surplus generated by the agreement is divided equally between the two parties.[3] We later present a model extension with multiparty bargaining, in which the input contracts offered by both suppliers are determined endogenously.

We also allow the focal firm to make an investment in order to improve the input. This type of investment is common in many industries and leads to increased product value in the consumer market. Whereas previous research has modeled investments that firms make

[2]In principle, a fixed payment could also be made from the supplier to the buyer. Previous research on supply contracts has explored different real world mechanisms for fixed payments from suppliers to buyers, such as quantity discounts, free samples, or slotting allowances in a retail context (e.g., Piccolo and Miklós-Thal 2012).

[3]Extending the model to allow for different bargaining powers for each firm such that the firm with a greater bargaining power would take a larger portion of the surplus would not change our results qualitatively.

before they trade an input (e.g., Grossman and Hart 1986; Plambeck and Taylor 2007), we focus on investment that occurs after a firm has begun working with its supplier. Literature in supply chain management has documented that firms form close personal connections and shared cognitive understanding with their suppliers, which allows a buyer to make investments that improve the supplier's performance (Lawson et al. 2008; Leuschner et al. 2013; Palit et al. 2023). Our paper focuses on such investments, so the focal firm in our model can invest in the input only for the supplier it chooses in the first period. Furthermore, we focus on investment that is supplier-specific. For example, Apple's investment to improve LG's foldable screen is spent on equipment, laboratories, and professional staff integrated into LG's facilities; these investments are not easily transferable, at least completely, to Samsung's screen manufacturing facilities.[4]

In particular, Firm A can decide whether to invest an amount c in order to improve the input's quality, where $c > 0$. If this investment occurs, the resulting innovation allows the supplier to produce a higher quality input, which increases the product's value to consumers. It takes one period for Firm A's investment in the supplier's input to affect product values in the product market. Thus, if Firm A selects Firm T as the supplier in period one, invests in input improvement, and again contracts with Firm T in period two, Firm A's product value will increase from v_{AL} in the first period to v_{AH} in the second period, where $v_{AL} < v_{AH}$.[5]

The investment cost c includes the cost of non-contractible commitments, such as assigning elite employees to work on improving the input. Therefore, Firm A's investment decision cannot be included in the supply contract. One possible reason firms cannot use a formal contract to enforce the investment decision is that the innovation outcome is uncertain. Hence, it is possible that no innovation occurs even if Firm A invests. For

[4]Our findings would remain qualitatively unaffected if the focal firm could only partially transfer the innovation developed in period one with one supplier to the second period with the other supplier. We later develop a one-period version of our model (Appendix B.5) that does allow the focal firm to transfer its full investment value to either supplier, and in this case, we show the firm always chooses its competitor as a supplier to benefit from softer price competition.

[5]In principle, we could allow the investment to cause an immediate increase in product value and derive similar results, as this investment would still affect future negotiations over the supply contract.

modeling parsimony, the investment outcome is deterministic in our main model, but the appendix includes a model extension with uncertain innovation outcomes and shows that our results are qualitatively the same. Furthermore, the innovation outcome itself may not be verifiable by a court.[6]

If Firm A decides to buy its input from the competitive supplier Firm S and then decides to invest c to improve Firm S's input, the value of any product using an input from Firm S in the second period will increase. In this case, not only will Firm A's product quality rise in the second period (if it again chooses Firm S as the supplier), but the rival Firm S's product valuation will also increase from its initial level v_{SL} in the first period to v_{SH} in the second period, where $v_{SL} < v_{SH}$. Thus, buying the input from the rival and investing in input improvement may weaken the focal firm's market position by making the rival's product more valuable for consumers.

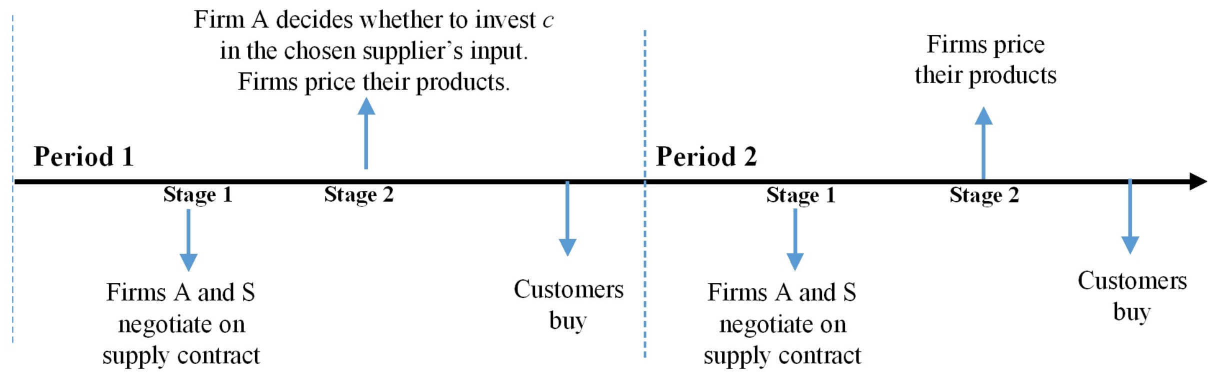
For parsimony, we let firms' product values be symmetric. That is, $v_{AL} = v_{SL} \equiv v_L$ and $v_{AH} = v_{SH} \equiv v_H$. Moreover, we normalize the initial product values to one ($v_L = 1$). Finally, let $\Delta \equiv v_H - v_L = v_H - 1$ denote the improvement in the firms' product values. We later present a model extension with incomplete knowledge spillover, so investment by Firm A has a larger effect on the value of its own product than on the value of the Firm S product.

The costs of producing the input and the product are normalized to zero. Similar to previous theory on competition in distribution channels (e.g., Dukes et al. 2006), our analysis focuses on a range of model parameters for which the market is covered and each firm has positive demand in equilibrium. In particular, the transportation cost parameter is low enough that $t < \frac{2}{3}$.

The game timing and decisions are as follows. There are two periods, each consisting of two distinct stages. In stage 1 of period i, Firm A chooses its supplier. In particular, Firm

[6]For example, a court could not practically verify that Apple is making large investments of time and effort into improving its supplier's smartphone screens, and also could not reliably verify how much these screens have improved. Therefore, a formal contract cannot force Apple to make such investments, and Apple will invest its employees' time and effort to improve the screens only if it expects that doing so will lead to a sufficient increase in its own profits.

Figure 1: The Sequence of the Game



A and Firm S engage in Nash bargaining over the supply contract terms $w_{S,i}$ and $F_{S,i}$. If they fail to reach an agreement, Firm A buys the input for the current period from Firm T. In Stage 2 of period i, Firm A and Firm S simultaneously price their products. Firm A also makes its first period investment decision at the same time firms set first period prices, and this investment decision affects product values in period two. At the end of each period, consumers make purchase decisions. Each firm seeks to maximize its total profits for the two periods net of any investment cost. Figure 1 illustrates the sequence of decisions.

3.1 Discussion of model timing

Our two period setup is motivated by the real world observation that knowledge spillovers naturally occur from a firm to its chosen supplier, as documented by a large literature stream in operations management (Lawson et al. 2008; Leuschner et al. 2013; Palit et al. 2023). In particular, after a firm chooses a supplier and begins receiving inputs from it, any investments the firm makes to improve the input naturally result in its chosen supplier learning how to produce these new superior inputs. This knowledge spillover to the supplier then affects negotiations over supply contracts in future periods. Furthermore, firms cannot practically commit to input prices for all future supply periods, for example, because rapid fluctuations in product value, costs, and technical specifications make it impossible to decide prices sufficiently far in the future (Hart and Moore 1988; Che and Hausch 1999). The appendix includes a model extension with uncertain innovation outcomes to illustrate how such uncertainty about the future can be formally incorporated into our model.

Thus, the focal firm has a short-term incentive to buy from the competitor in the first period to soften price competition, but the resulting knowledge spillover in the first period inevitably affects negotiation positions in the second period, which causes a hold-up problem and leads to under-investment. To further illustrate the importance of having two production periods, we explore one-period versions of our model in the appendix and show how the results differ (see section 5.5 for details).

Similar to previous literature on hold-up problems (e.g., Grossman and Hart 1986; Hart and Moore 1988), we allow the focal firm to invest after the first-period supply contract has already been signed. This model timing reflects that firms have ongoing opportunities for non-contractible investment after their initial supply contract is signed. For example, after the firms begin working together, the focal firm could continue to allocate a large number of elite employees to spend time improving the input, but they cannot formally commit to make such non-contractible investments at the time they sign the initial supply contract. In our model, both the focal firm and its supplier are forward-looking and anticipate that the focal firm will invest if and only if it has an incentive to do so after the first-period contract has already been signed. This investment incentive depends on the investment cost and anticipated second-period outcomes with and without investment.

Given that the investment does not affect product values until period two, our results do not depend on whether the investment decision occurs just before, at the same time, or just after first period prices are set.

4 Analysis

We use backward induction to solve the model. We start by characterizing product prices in section 4.1. We then derive the period two supply contract in section 4.2. We derive the

Table 1: Model notation

$i \in 1, 2$	Index of time periods
$v_{A,i}, v_{S,i}$	Value of Firm A and Firm S product in period i
$p_{A,i}, p_{S,i}$	Price of Firm A and Firm S product in period i
t	Amount of product differentiation
$v_L = 1$	Value of initial product
$v_H = 1 + \Delta$	Value of product using improved input
$w_{T,i}, F_{T,i}$	Per-unit and fixed fee for third party input in period i
$w_{S,i}, F_{S,i}$	Per-unit and fixed fee for competitive supplier's input in period i
c	Investment cost to improve the input

focal firm's investment decision in section 4.3. Finally, we solve for the period one supply contract in section 4.4. Throughout the paper, we use the notation $\pi_{A,i}$ to denote the focal firm's period-i profit, and $\pi_{S,i}$ to denote the competitive supplier's period-i profit. Moreover, Π_i denotes total industry profits in period i. Note that these firm and industry profits for period i do not account for the cost of investing to improve the input (if any). In section 4.4, we use Π to denote total industry profit across the two periods, which does account for this investment cost.

4.1 Pricing

This section derives equilibrium prices in period i given that customer valuations for products sold by Firm A and Firm S are, respectively, $v_{A,i}$ and $v_{S,i}$. We show that equilibrium product prices depend on whether Firm A buys the input from the third party Firm T or the competitive supplier Firm S. Lemma 1 derives the price equilibrium and corresponding profits. For the sake of parsimony, throughout the paper, we present results given the condition $\Delta < 3t$, which implies $|v_{A,i} - v_{S,i}| < 3t$, and both firms have positive market shares in equilibrium. The analysis and results if $\Delta \geq 3t$, which implies one firm may serve the entire market, appear in the proof of each lemma or proposition in the appendix.

Lemma 1. *If* $|v_{A,i} - v_{S,i}| < 3t$ *and* $w_{S,i} \in [0, \frac{1}{2}(v_{A,i} + v_{S,i} - 3t)]$, *equilibrium product prices are:*

$p_{A,i} = t + \frac{v_{A,i} - v_{S,i}}{3} + I_i w_{S,i}$

$p_{S,i} = t + \frac{v_{S,i} - v_{A,i}}{3} + I_i w_{S,i}$

Equilibrium profits are:

$\pi_{A,i} = \frac{1}{18t}(3t + v_{A,i} - v_{S,i})^2 - I_i F_{S,i}$

$\pi_{S,i} = \frac{1}{18t}(3t - v_{A,i} + v_{S,i})^2 + I_i(w_{S,i} + F_{S,i})$

which implies industry profits are:

$\Pi_i = t + \frac{1}{9t}(v_{A,i} - v_{S,i})^2 + I_i w_{S,i}$

where $I_i = 1$ *if Firm A buys the input from its competitor in period* i *and* $I_i = 0$ *otherwise.*

Lemma 1 implies, if Firm A buys from the third party Firm T, then equilibrium profits if Firm A and Firm S both have a low valuation ($v_{A,i} = v_{S,i} = 1$) are the same as if they both have a high valuation ($v_{A,i} = v_{S,i} = 1 + \Delta$) because price competition prevents firms from capturing the surplus generated by increased product values. In fact, given this supply decision ($I_i = 0$), industry profits are greatest if one firm has a high valuation and the other firm has a low valuation. By contrast, we show that, if Firm A buys from its competitor ($I_i = 1$), equilibrium industry profits are greatest if both firms have a high valuation.

If Firm A buys the input from its competitor Firm S, both firms set product prices that are higher by $w_{S,i}$ (the wholesale unit input price) than they would if Firm A bought the input from the third party. When buying from its competitor, Firm A sets a higher price because its marginal cost of purchasing the input is $w_{S,i}$ higher than if it bought the input from the third party. Firm S sets a higher price because it generates profits of $w_{S,i}$ from each unit of the product that Firm A sells and therefore it has less incentive to reduce its price to capture the marginal customer. Thus, a supply arrangement in which a firm buys an input from its rival mitigates price competition and increases industry profits.[7]

Note that, if Firm A and Firm S agree to a wholesale input price so high that

[7] If we allow $w_{T,i} > 0$, buying from the rival still mitigates price competition and increases industry profits because Firm S generates profit from each unit Firm A sells. See Lemma 10 for details of this case.

$w_{S,i} > \frac{1}{2}(v_{A,i} + v_{S,i} - 3t)$, then the condition in Lemma 1 no longer holds. In this case, equilibrium product prices are so high that the market is not fully covered, and the firms act as local monopolists. We show that industry profits are maximized by choosing the maximum possible wholesale price such that the market is fully covered.

Lemma 2. *If* $|v_{A,i} - v_{S,i}| < 3t$ *and Firm A purchases the input from Firm S in period* i*, industry profits are maximized by setting input wholesale price* $w_{S,i} = \frac{1}{2}(v_{A,i} + v_{S,i} - 3t)$*, resulting in industry profits* $\Pi_i = \frac{1}{2}(v_{A,i} + v_{S,i}) + \frac{1}{9t}(v_{S,i} - v_{A,i})^2 - \frac{1}{2}t$*.*

Thus, holding product valuations constant, industry profits are maximized if Firm A buys the input from Firm S at the wholesale price specified in Lemma 2. However, as we show below, in some cases buying the input from its competitor prevents Firm A from investing in the input due to its desire not to strengthen its rival's negotiating position. In such a case, Firm A may decide to buy the input from the third party in equilibrium.

4.2 Supply Contract in Period 2

We now derive the equilibrium supply contract in period 2. We compute the equilibrium for three feasible sub-games in the second period: (1) the focal firm has not invested in the input for either supplier, (2) the focal firm has invested in the competitor's input, and (3) the focal firm has invested in the third party's input. In the next section of the paper, we use backward induction to compute the first-period supply contract and investment decision.

If the focal firm did not invest for either supplier in period 1, then both competing firms have the same product valuation, $v_{A,2} = v_{S,2} = 1$, in period 2. In this case, the focal firm buys the input from its competitor in period 2 in order to benefit from softer price competition.

Lemma 3. *If Firm A did not invest in innovation in period 1, then, in period 2, it buys the input from its competitor, with contract* $w_{S,2} = 1 - \frac{3t}{2}$ *and* $F_{S,2} = -(\frac{1}{2} - \frac{3t}{4})$*, which results in profits* $\pi_{A,2} = \pi_{S,2} = \frac{1}{2} - \frac{t}{4}$*, and industry profits* $\Pi_2 = 1 - \frac{t}{2}$*.*

Lemma 2 implies that the wholesale unit input price $w_{S,2}$ stated in Lemma 3 maximizes industry profits given that each firm has a product valuation of 1. Under Nash bargaining, the fixed fee $F_{S,2}$ depends on the outside option of each firm, that is, the profits Firm A and Firm S would generate if their negotiation broke down and Firm A bought the input from the third party. Given that neither input has been improved, both firms would have the same product valuation, and Lemma 1 implies they would generate the same equilibrium profits, $\pi_{A,2} = \pi_{S,2}$, if Firm A sourced from the third party. Because they have the same profits under this outside option, the fixed fee stated in Lemma 3 splits profits evenly between to the two firms. Thus, if neither input has been improved, Firm A buys from its competitor Firm S in period 2 and both generate the same equilibrium profits in this period.

If the focal firm invested in the input for the competitor in period 1, it chooses the competitor as a supplier in period 2, in order to benefit both from the higher product valuation that comes from using an improved input and also from softer price competition, as shown in the following lemma.

Lemma 4. *If Firm A bought the input from the competitor in period 1 and invested in innovation, then, in period 2, it again buys the input from its competitor, with contract* $w_{S,2} = 1 + \Delta - \frac{3t}{2}$ *and* $F_{S,2} = -\frac{1}{2}w_{S,2} + \frac{\Delta}{3}$*, resulting in period-2 profits* $\pi_{A,2} = \frac{1}{2} - \frac{t}{4} + \frac{\Delta}{6}$ *and* $\pi_{S,2} = \frac{1}{2} - \frac{t}{4} + \frac{5\Delta}{6}$*, and industry profits* $\Pi_2 = 1 - \frac{t}{2} + \Delta$*.*

Because both firms use the improved input, the product valuation for each firm is $1+\Delta$. The wholesale unit input price stated in Lemma 4 maximizes equilibrium industry profits given this higher product valuation. The fixed fee depends on the outside option for each firm if their negotiation breaks down, in which case Firm S would use the improved input but Firm A would need to use the input from the third party, which has not been improved. Lemma 1 implies this sourcing outcome would result in equilibrium profits that are $\frac{2\Delta}{3}$ higher for Firm S than for Firm A. Under Nash bargaining, each firm's profits are equal to the profits it would generate under its outside option plus one half of the additional industry profits that are generated if they reach an agreement. Therefore, the fixed fee stated in Lemma 4 results in profits that are $\frac{2\Delta}{3}$ higher for Firm S than for Firm A. Thus, Firm A investing in the input for the Firm S input in period 1 results in a stronger negotiating position for Firm S in period 2, and this improved negotiating position (better outside option for Firm S than for Firm A) implies Firm S generates greater profits than Firm A in period 2.

We now compute the equilibrium for the subgame that occurs if Firm A invests in the input for the third party.

Lemma 5. *Suppose in period 1 Firm A bought from Firm T and invested in improving its input. In period 2, if* $\frac{\Delta^2}{9t} > 1 - \frac{3t}{2}$*, Firm A buys the input from the third party, resulting in period-2 profits* $\pi_{A,2} = \frac{t}{2} + \frac{\Delta}{3} + \frac{\Delta^2}{18t}$ *and* $\pi_{S,2} = \frac{t}{2} - \frac{\Delta}{3} + \frac{\Delta^2}{18t}$*, and industry profits* $\Pi_2 = t + \frac{\Delta^2}{9t}$*. Otherwise, Firm A buys the input from its competitor, with input contract* $w_{S,2} = 1 - \frac{3t}{2}$ *and* $F_{S,2} = -(\frac{1}{2} - \frac{3t}{4}) - \frac{\Delta}{3}$*, which results in profits* $\pi_{A,2} = \frac{1}{2} - \frac{t}{4} + \frac{\Delta}{3}$ *and* $\pi_{S,2} = \frac{1}{2} - \frac{t}{4} - \frac{\Delta}{3}$*, and industry profits* $\Pi_2 = 1 - \frac{t}{2}$*.*

In this case, Firm A's sourcing decision depends on the magnitude Δ of the value increase from using an improved input. Lemma 1 implies that industry profits increase by $\frac{\Delta^2}{9t}$ if one firm uses an improved input instead of an unimproved input. Lemmas 1 and 2 imply that industry profits increase by $1-\frac{3t}{2}$ if Firm A buys from its competitor instead of from the third party (while both firms use the unimproved input). In equilibrium, Firm A makes whichever sourcing decision leads to greater industry profits. If it does source from its competitor, then the wholesale unit price maximizes industry profits, and the fixed fee depends on the profits each firm would generate if they failed to reach a supply agreement. Because Firm A would use the improved input and Firm S would use the unimproved input if they did not reach an agreement, Firm A has a stronger negotiating position, and the fixed fee stated in Lemma 5 results in higher profits for Firm A than for Firm S. Thus, investing in the third party's input in period 1 results in a stronger negotiating position for Firm A in period 2.[8]

[8] In this section, we are computing the equilibrium of each feasible subgame, and we will then use backward induction to compute the equilibrium of the entire game. We show below that, under some conditions, Firm A buys from Firm T in both periods in equilibrium. However, the case in which Firm A buys from Firm T in period 1 and then buys from Firm S in period 2 does not occur on the equilibrium path.

4.3 Focal Firm's Investment Decision

Having solved the equilibrium supply contract in period 2, we derive the focal firm's investment decision given its chosen supplier in period 1. The following lemma holds for $\Delta < 3t$, which ensures both firms have positive demand in equilibrium. The formal proof in the appendix also derives the outcome for $\Delta \geq 3t$, in which case one firm may serve the entire market in period 2.

Lemma 6. *If Firm A buys the input from Firm S in period 1, it invests in innovation if and only if* $c < \frac{\Delta}{6}$. *If Firm A buys the input from Firm T in period 1, it invests in innovation if and only if* $c < \frac{\Delta}{3} + \frac{1}{2}\Big(max\{\frac{\Delta^2}{9t} - 1 + \frac{3t}{2}, 0\}\Big)$.

Given the period 1 supply arrangement, this lemma states the conditions required for investment to occur in equilibrium. One important observation is that the maximum cost that allows the focal firm to invest is lower if it buys from the competitor in period 1, as the focal firm anticipates that investing in its competitor's input will result in a weaker negotiating position for the focal firm, whereas investing in the third party's input will result in a stronger negotiating position for the focal firm. Thus, all else equal, contracting with the competitor decreases the focal firm's incentive to invest in the input. Also note that the condition for investing if the firm buys from the third party depends on which supplier it would then choose in period 2 based on Lemma 5.

4.4 Supply Contract in Period 1

In this section, we derive the equilibrium supply contracts in period 1. This is the last step of our backward induction process. When negotiating the supply contract in period 1, Firm A and Firm S will strategically take into account the impact of their agreement on the investment decision and period 2 outcomes. For example, when investment cost c is sufficiently low, both firms correctly anticipate that the investment will indeed occur (see Lemma 6). Thus, if Firm A and Firm S contract in both periods, total industry profits across the two periods would be $\Pi = (1 - \frac{t}{2}) + (1 - \frac{t}{2} + \Delta) - c$. However, if Firm A and Firm T contract in period 1, total industry profits would be $\Pi = t + (t + \frac{1}{9t}\Delta^2) - c$ or $\Pi = t + (1 - \frac{t}{2}) - c$ depending on whether Firm A continues to buy from Firm T in period 2 or switches to Firm S.

Note that, if investment does occur and $\Delta < 3t$, total industry profits are higher in both periods if Firm A and Firm S contract because the condition $t < \frac{2}{3}$ implies $1 - \frac{t}{2} > t$, and the condition $\Delta < 3t$ implies $\Delta > \frac{1}{9t}\Delta^2$. Together, these conditions ensure industry profits conditional on investment occurring, as stated above, are higher if Firm A buys from Firm S. Therefore, if investment cost c is sufficiently small, Firm A and Firm S contract in both periods and investment occurs. If c is higher, two other types of equilibria can occur: one in which Firm A contracts with Firm S in both periods but does not invest, and another in which Firm A contracts with Firm T in both periods and invests. The following proposition characterizes the equilibrium of the full game for the case $\Delta < 3t$.

Proposition 1. *If $\Delta < 3t$, (i) Firm A buys from Firm S in both periods and invests in Firm S's input if $c < \frac{\Delta}{6}$. (ii) Firm A buys from Firm S in both periods without investing in the input if $\max\{\frac{\Delta}{6}, \frac{\Delta^2 - 18t + 27t^2}{9t}\} < c$. (iii) Firm A buys from Firm T in both periods and invests in Firm T's input if $\frac{\Delta}{6} < c < \frac{\Delta^2 - 18t + 27t^2}{9t}$.*

Under Nash bargaining, Firm A and Firm S reach a supply agreement in period 1 if doing so leads to greater total industry profits for the two periods than would occur if Firm A sourced from Firm T in period 1. As long as the cost of investing in the input is less than the resulting value improvement ($c < \Delta$), Lemmas 1 and 2 imply the maximum feasible industry profits occur if Firm A buys from Firm S in both periods and invests in the input in period 1. However, Firm A will invest only if doing so increases its own period 2 profits by more than c, the investment cost. When deciding whether to invest, Firm A anticipates that the period 2 supply agreement will not allow it to capture the full increase in industry profits that result from the investment. In fact, Lemmas 3 and 4 imply that investment in Firm S's input increases Firm A's period 2 profits by only $\frac{\Delta}{6}$ while increasing Firm S's second-period profits by $\frac{5\Delta}{6}$ because Firm S has a stronger negotiating position after it learns how to produce the improved input. Thus, Firm A will invest in the Firm S input only if $c < \frac{\Delta}{6}$. Furthermore, because we are focusing on an investment that only Firm A has the expertise to make and which cannot be enforced with a formal contract, it is not possible for Firm S to subsidize this investment to ensure innovation occurs.

If the cost of investment is too large for Firm A to invest in the Firm S input ($c > \frac{\Delta}{6}$), one possible outcome is Firm A buys from Firm S in both periods without investing, in order to benefit from softer price competition. Another possibility is Firm A buys from Firm T in both periods and invests in Firm T's input to benefit from the resulting value improvement. The equilibrium outcome depends on which of these two possibilities generates greater total industry profits based on Lemma 1.

Figure 2: Equilibrium Regions for Firm A Supply Strategy

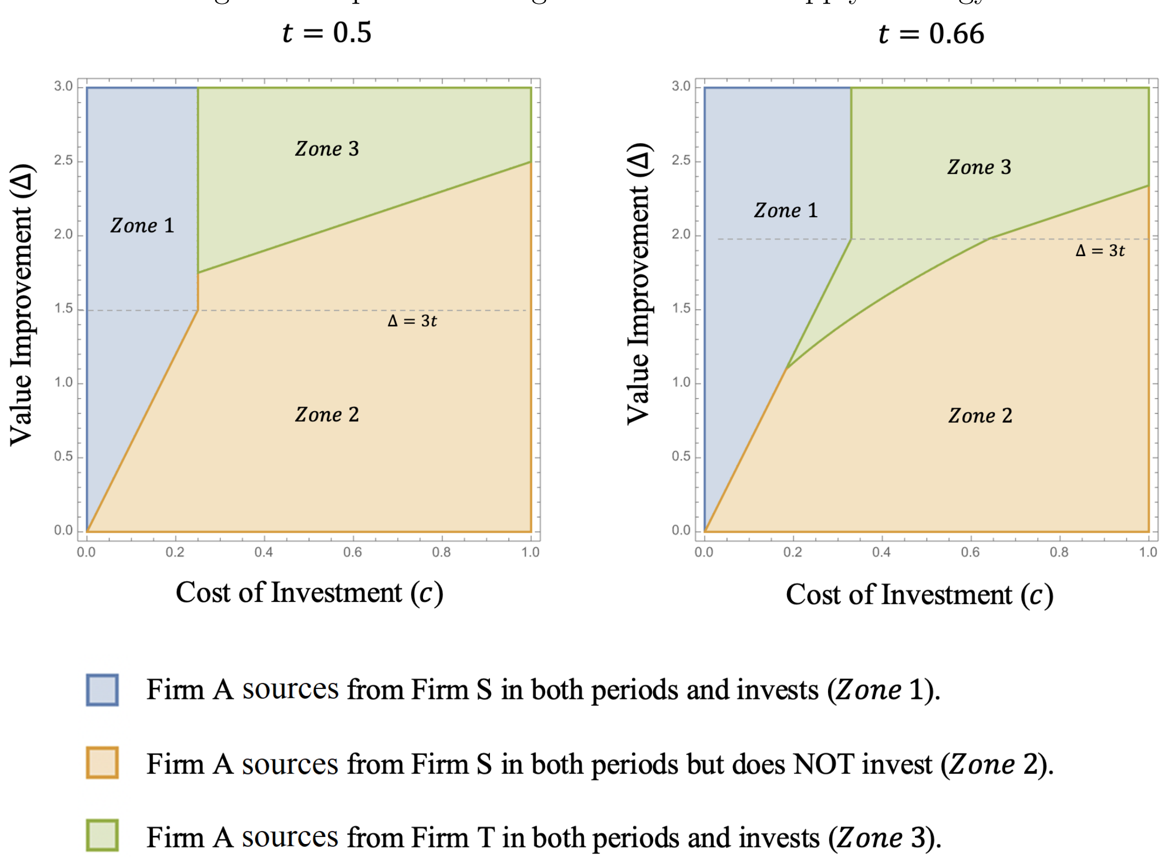


Figure 2 illustrates the regions for the three equilibrium outcomes as a function of the value improvement Δ and the investment cost c for two levels of product differentiation t. If the improvement in product value Δ is low, the focal firm contracts with the competitive supplier (zones 1 and 2 in the lower part of Figure 2). In this case, the focal firm will invest in the competitive supplier's input if the cost c is sufficiently low.

However, if the value improvement from investment is high, the focal firm may decide not to source from its rival. Zone 3 in Figure 2, for which Firm A sources from the third party, emerges if both the cost and the benefit of investment, c and Δ, are sufficiently large. If $\Delta > 3t$, contracting with the third-party and investing can allow the focal firm to serve the entire market in period 2 because difference between rivals' product values become large (zone 3 above the dashed line $\Delta = 3t$). For some parameter values, the choice of supplier is non-monotonic in the value of innovation. In particular, the focal firm may buy from its competitor if the value of innovation is sufficiently low or high (zones 1 and 2) but buy from the third party for intermediate values innovation (zone 3).

Horizontal product differentiation (t) also affects the focal firm's supply and investment strategy. Price competition becomes more intense with low product differentiation (low t). Thus, the price softening effect becomes crucial for both firms' profits when t is low. Consequently, the focal firm always buys from the rival to ensure the benefit of mitigated price competition (which explains the absence of zone 3 below the dashed line $\Delta = 3t$ on the left panel in Figure 2). However, if products are more differentiated, the price softening effect becomes less important, and Firm A may not agree to buy from Firm S because of concerns about giving the competitive supplier a stronger negotiating position in period 2 (which explains the presence of zone 3 below the dashed line $\Delta = 3t$ on the right panel in Figure 2). The following proposition states these results formally.

Proposition 2. *If $\Delta < 3t$ and product differentiation is low ($t < \frac{4}{7}$), Firm A contracts with the rival Firm S in both periods. If product differentiation is high ($t \geq \frac{4}{7}$), the focal firm may buy its input from the third party. In this case, higher differentiation increases the range of other parameter values for which the focal firm buys input from the third party.*

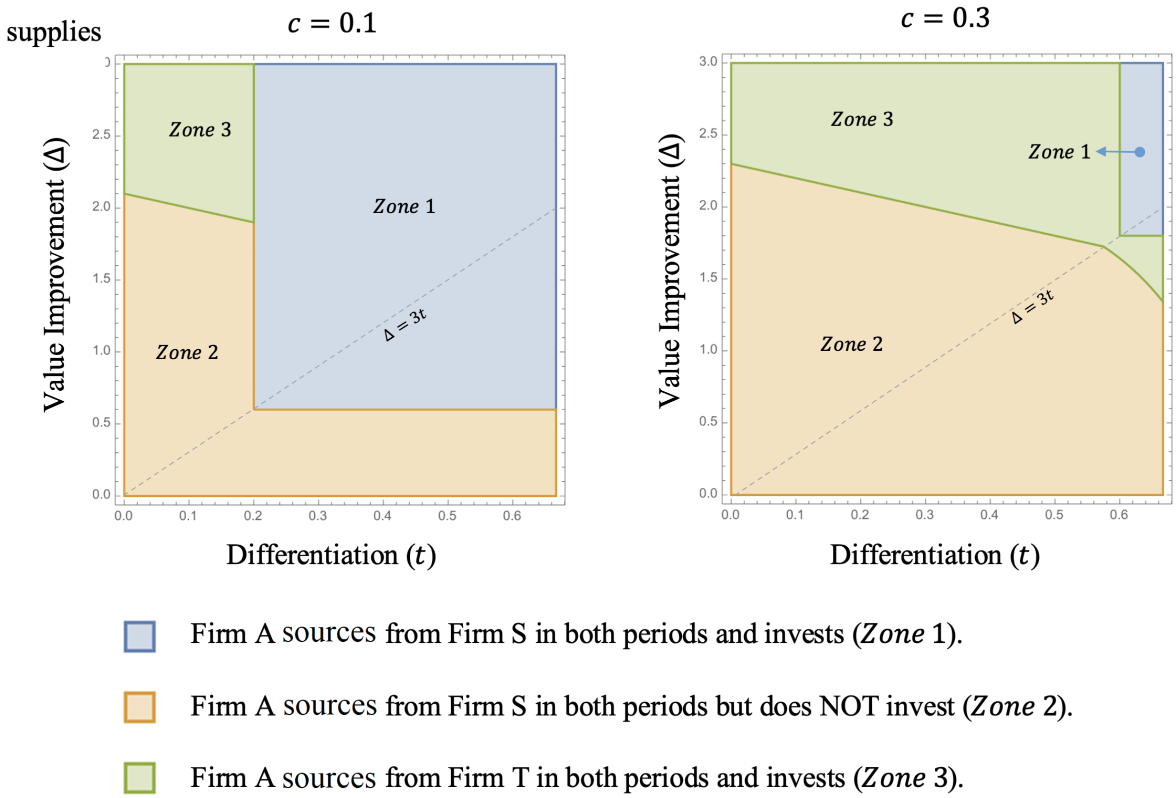
Proposition 2 states that the range of the value and cost parameters for which the focal firm buys from the third party expands when products are more differentiated (zone 3 in Figure 2 expands with t). Hence, with higher differentiation, sourcing from the third party (zone 3) occurs for smaller values of Δ. If the focal firm buys from the rival, per Lemmas 1 and 2, the two firms agree to the maximum possible wholesale price for which the market is covered ($w_{S,i} = \frac{1}{2}(v_{A,i}+v_{S,i})-3t$) to earn the maximum possible industry profit ($\pi_{A,i}+\pi_{S,i} = \frac{1}{2}(v_{A,i}+v_{S,i})+\frac{1}{9t}(v_{A,i}-v_{S,i})^2-\frac{t}{2}$). The wholesale price and industry profits are both decreasing in t. Thus, profits can decrease as product differentiation increases when the focal firm buys from the rival. By contrast, Lemma 1 implies that when Firm A buys from the third party, industry profits increase with t. These results explain why Firm A is more likely to buy from the third party when t increases. Our results also imply that equilibrium industry profits can be non-monotonic functions of product differentiation, as profits decrease with t in zones 1 and 2 but increase with t in zone 3.

In the Apple and Samsung example discussed in the introduction, less differentiated products might improve industry profits if Apple bought its input from Samsung. With less differentiation, the indifferent customer's utility would be higher, enabling Samsung to demand a higher wholesale price for each unit of input and both firms setting higher prices, which in turn improves total industry profit and the shares of each firm.

Figure 3 depicts the equilibrium outcomes as a function of value improvement Δ and product differentiation t for different values of investment cost c. If t and c are both large, the focal firm's sourcing strategy is not monotonic in Δ. In particular, the focal firm buys from its competitor if the value of investment is low or high, but it buys from the third party when the value of innovation lies in an intermediate range.

The proof of Proposition 1 in the appendix also derives the fixed payments in each period. When Firm A buys from its competitor Firm S and invests, these fixed fees are $F_{S,1} = \frac{1}{12}(9t-6-8\Delta)$ and $F_{S,2} = \frac{1}{12}(9t-6-2\Delta)$. Given that $t < \frac{2}{3}$, these fixed payments are negative in relative terms, that is, they are smaller than the fixed payment Firm A

Figure 3: Equilibrium Regions for Firm A Supply Strategy



would make to Firm T. In practical terms, Firm S can effectively make a transfer to Firm A by assuming a large share the fixed costs of joint investment in production facilities, for example. Furthermore, $|F_{S,1}| > |F_{S,2}|$, which implies that the competitive supplier makes a smaller fixed transfer to the focal firm in the second period. The competitive supplier's bargaining position becomes stronger in the second period due to Firm A's investment in its input. Hence, a relatively smaller transfer from Firm S can convince the focal firm to buy from Firm S in the second period.

5 Model Extensions and Variations

In this section, we introduce model extensions that relax or change some aspects of the model set-up. Our goal is to assess the robustness of our main findings and to uncover new insights about sourcing from a rival.

5.1 Multiparty Negotiation

In the main model, the supply contract negotiation occurred only between the focal firm and the competitive supplier. In particular, the contract offered by the third-party supplier was set to $w_{T,i} = F_{T,i} = 0$. In reality, third-party suppliers may also have bargaining power, and the focal firm's decision to invest in the third-party's input in period 1 can affect the contract negotiation with this supplier in period 2. In this section, we extend our base model to incorporate a bilateral negotiation framework in which Firm A negotiates with both Firm S and Firm T in both periods. This bilateral negotiation framework has been used in previous game theory literature on supply chain contracts (e.g., Shaffer and Zettelmeyer 2002; Dukes et al. 2006; Heese et al. 2021).

In this framework, the negotiation among the three parties can be described as an infinitely repeated sequence of negotiations between Firm A and each of the two suppliers, Firm S and Firm T. In each iteration, Firm A first negotiates with one supplier (say Firm S) using the contract offered by Firm T to determine the disagreement payoffs, and then negotiates with Firm T using the contract offered by Firm S to determine disagreement payoffs. This negotiation process converges to contract parameters for which one supplier is no longer willing to offer a better contract to the focal firm given the other supplier's offer. Thus, the outside option for each firm in the bilateral negotiation framework is determined endogenously.

We follow the same backward induction process as in the main model. We first derive the equilibrium product prices. Then, we derive the period 2 supply contract. Next, we derive the focal firm's investment decision. Finally, we derive the period 1 supply contract, leading to the equilibrium of the entire game. We show that equilibrium profits change compared with the main model, but the parameter regions in Figures 2 and 3 for supplier choices and investment decisions remain the same.

5.1.1 Renegotiation-Proof Contracts

Following a standard approach in contract economics (e.g., Dewatripont 1988; Coughlan and Wernerfelt 1989), we restrict contracts between the focal firm and each potential supplier to be renegotiation-proof. In each stage of the negotiation process, we do not allow two firms to agree to a contract if they could secretly renegotiate a new contract that would make both parties better off. We show that renegotiation-proof contracts imply per-unit input prices $w_{T,i}$ and $w_{S,i}$ have the same equilibrium values as in the main model. The multiparty negotiation process then determines the equilibrium levels of the fixed fees $F_{T,i}$ and $F_{S,i}$.

When Firm A and Firm T negotiate, they may want to commit to a per-unit price above marginal cost ($w_{T,i} > 0$) in order to commit Firm A to set a higher product price and thus compel Firm S to set a higher product price. However, Firms A and T would then have an incentive to secretly renegotiate a new supply contract with $w_{T,i} = 0$, which would allow them to generate greater joint profits. See the formal proof in the appendix.

Lemma 7. *The contract between Firm A and Firm T is renegotiation-proof if and only if* $w_{T,i} = 0$.

The result that Firms A and T cannot credibly commit to $w_{T,i} > 0$ is similar to the finding by Coughlan and Wernerfelt (1989) that a retailer and a manufacturer cannot credibly commit to a wholesale unit price that leads to a higher product price than they would set as a single integrated firm. By contrast, the restriction to renegotiation-proof contracts does not affect the equilibrium choice of $w_{S,i}$, which is the per-unit price if the focal firm buys from its competitor. Firm A and Firm S choose the per-unit fee $w_{S,i}$ to maximize industry profits (given that Firm T does not compete in the product market) and they have no incentive to renegotiate this fee.

Given that $w_{T,i} = 0$ as stated by Lemma 7, the equilibrium pricing outcomes are the same as in the main model (see Lemma 1). Similarly, the level of wholesale price that maximizes total profit in Lemma 2 remain unchanged.

5.1.2 Supply Contract in Period 2

Similar to our base model, there are three sub-games to consider: no investment in period 1, investment in the Firm S input, and investment in the Firm T input. For each case, the best possible supply contract Firm T is willing to offer is $w_{T,2} = 0$ and $F_{T,2} = 0$. If buying the input from Firm S generates higher industry profits than buying from Firm T, then the equilibrium outcome of the multiparty negotiation is that Firm T offers this contract with fixed and per-unit fees equal to zero, and Firm S offers the same contract as in the main model. Thus, Lemmas 3 and 4 still hold, and the equilibrium outcome in period 2 following no investment or investment in the Firm S input is the same as in the main model.

However, the fixed fees offered by each supplier if Firm A buys from Firm T are different in the multiparty negotiation model than in the main model. In this case, Firm S offers the lowest fixed fee that makes it indifferent between Firm A buying from Firm S and Firm T. This offer then determines the disagreement payoffs in the negotiation between Firms A and T. Thus, Firm T has negotiating power that may allow it to generate positive profits in period 2 following an investment in its input during period 1. We formalize this result in the following lemma.

Lemma 8. *Suppose in period 1 Firm A invested in the Firm T input. In period 2, if* $\frac{\Delta^2}{9t} < 1 - \frac{3t}{2}$*, Firm A buys the input from its competitor with the same contract as in Lemma 5. Otherwise, Firm A buys the input from the third-party with fixed fee* $F_{T,2} = \frac{1}{2}(\frac{\Delta^2}{9t} - (1 - \frac{3t}{2}))$*, which results in profits* $\pi_{A,2} = \frac{1}{2} - \frac{1}{4}t + \frac{1}{3}\Delta$*,* $\pi_{S,2} = \frac{1}{18t}(3t - \Delta)^2$*, and* $\pi_{T,2} = \frac{1}{2}(\frac{\Delta^2}{9t} - (1 - \frac{3t}{2}))$*, leading to an industry profit of* $\Pi_2 = t + \frac{\Delta^2}{9t}$.

5.1.3 Focal Firm's Investment Decision

We now derive the focal firm's investment decision given the outcome of the negotiation in period 1. When deciding whether to invest, Firm A anticipates the profits that it will generate in period 2 conditional on its investment decision.

Lemma 9. *In period 1, if Firm A buys the input from Firm S, it invests if and only if $c < \frac{\Delta}{6}$. If Firm A buys from Firm T, it invests if and only if $c < \frac{\Delta}{3}$.*

The condition for investing in the competitor's input ($c < \frac{\Delta}{6}$) is the same as in the main model. However, the range of cost values for which Firm A is willing to invest in the third party's input ($c < \frac{\Delta}{3}$) is not as large as in the main model. The difference is that Firm A now anticipates that the third party will capture some of the surplus generated by this investment. Note that investment still occurs for a larger range of cost values when buying from the third party than when buying from the competitor. One reason for this result is Firm A anticipates that investing in the input of Firm T will compel Firm S to make a more attractive contract offer in the second period. Thus, although Firm T captures some of the profits, this investment also strengthens the outside option for Firm A.

5.1.4 Supply Contract in Period 1

Next we derive the negotiation outcome in period 1. Product values are low in this period ($v_{A,1} = v_{S,1} = 1$), so industry profits in period 1 are $1 - \frac{t}{2}$ if Firm A contracts with Firm S, and t if Firm A contracts with Firm T. When firms engage in bilateral negotiation in period 1, they account for the impact of the period 1 negotiation on the profits they earn in period 2. The winner of the negotiation in period 1 is the supplier that leads to higher total industry profit across the two periods.

We show that the parameter ranges for supplier choice and investment decisions in this model extension are the same as in the main model. Intuitively, the multiparty negotiation model still results in the supplier choice that maximizes industry profits. As shown in Lemma 9, the parameter range for which the focal firm is willing to invest in the competitor's input is the same as in the main model. Furthermore, the condition for choosing the third-party supplier and investing in its input in the main model implies $c < \frac{\Delta}{3}$, which guarantees the focal firm is willing to invest in the third party's input in this model extension.[9]

[9]The inequality $c < \frac{\Delta}{3}$ holds because $\frac{\Delta^2 - 18t + 27t^2}{9t} < \frac{\Delta}{3}$ given that $\Delta < 3t$ and $t < \frac{2}{3}$.

Proposition 3. *In the multiparty negotiation model extension, the supplier choice in each period and the focal firm's investment decision, as a function of the model parameters, are the same as those stated for the main model in Proposition 1.*

Thus, allowing for multiparty negotiation results in the third party generating positive profits if it is selected as the supplier, but this model extension and the main model lead to the same parameter ranges in which the focal firm chooses each given supplier and decides whether to invest.

5.2 Investment by the Competitive Supplier

In the main model, Firm A decides whether to invest in the input of its supplier. In this extension, we also allow Firm S to invest in its own input.

After the first period, Firm A and Firm S simultaneously decide whether to invest, respectively, c_A and c_S to improve the value of the input. Firm A's decision and its impact on product values remain the same as in the main model. Firm S also decides whether to invest c_S in its own input, which increases the value of products using this input in period two.[10] Thus, if Firm S invests c_S, its own product value will increase by Δ, and Firm A's product value also increases by Δ if it buys the input from Firm S in period 2. If both firms invest in the Firm S input, the value of products using this input increases by 2Δ. All other aspects of the model remain the same as in our main model.

Throughout the following analysis, we focus on the range of parameters for which the market is covered and both firms have positive equilibrium demand. The following proposition derives the equilibrium.

Proposition 4. *Firm A contracts with Firm T in both periods and invests if* $\frac{\Delta}{6} < c_A < \frac{\Delta^2+27t^2-18t}{9t}$ *and* $c_S > \frac{5\Delta}{6}$. *Otherwise, Firm A contracts with Firm S in both periods. In that*

[10]Lemma 2 implies, if Firm A buys from Firm S, industry profits are higher if both firms use the improved input rather than just one firm using the improved input. Therefore, under Nash bargaining, both firms use the improved input, and these firms would never reach an agreement in which Firm S uses the improved input for its own product but sells the unimproved input to Firm A.

case,

- *Both firms invest if* $c_A < \frac{\Delta}{6}$ *and* $c_S < \frac{5\Delta}{6}$.

- *Only Firm S invests if* $c_A > \frac{\Delta}{6}$ *and* $c_S < \frac{5\Delta}{6}$.

- *Only Firm A invests if* $c_A < \frac{\Delta}{6}$ *and* $c_S > \frac{5\Delta}{6}$.

- *Neither firm invests if* $c_A > \max\{\frac{\Delta^2+27t^2-18t}{9t}, \frac{\Delta}{6}\}$ *and* $c_S > \frac{5\Delta}{6}$.

The following Corollary derives the equilibrium for $c_A = c_S = c$.

Corollary 1. *If Firm A and Firm S have equal investment costs ($c_A = c_S = c$), Firm A contracts with Firm S in both periods. Moreover, both firms invest if* $c < \frac{\Delta}{6}$*, only Firm S invests if* $\frac{\Delta}{6} < c < \frac{5\Delta}{6}$*, and neither firm invests if* $c > \frac{5\Delta}{6}$.

Proposition 4 shows that, if $c_S > \frac{5\Delta}{6}$, then Firm S never invests, and the outcomes are the same as in our main model. The corollary shows that, if Firm A and Firm S are equally efficient at improving the input (that is, $c_A = c_S = c$), then Firm A always contracts with Firm S in both periods. In our main model, one incentive for the focal firm to buy from the third party is to ensure investment occurs and to gain a product market advantage over its competitor. This latter incentive is absent if the competitive supplier can invest and improve its own product at relatively low cost. The corollary also shows that, in some cases, Firm S invests but Firm A does not. This result occurs because Firm S can strengthen its negotiating position by investing in its own input, whereas Firm A weakens its negotiating position if it invests in its competitor's input.

5.3 Incomplete Knowledge Spillover

In the main model, the increase in product values from improving the input is the same for all firms that use the input. In particular, if Firm A invests in the Firm S input and again chooses Firm S as its supplier, then the value of the products produced by both firms increases by Δ. In reality, there may be incomplete knowledge spillover (Palit et al. 2023), so investment by Firm A has a smaller effect on the Firm S product. For example, if Apple invests in superior phone screens, this input (the screen) may be optimized for Apple's iPhone and not for Samsung's smartphones. In this model extension, investment increases the value of the Firm S product by $k\Delta$, where $0 \le k \le 1$. The case $k = 1$ corresponds to our main model. In the extreme case $k = 0$, the competitor does not receive any value increase from input investment, that is, knowledge spillover is completely absent.

The following proposition states the equilibrium for the case $\Delta \max\{k, 1-k\} < 3t$ for the sake of parsimony. This condition guarantees positive equilibrium market shares for both firms. The proof in the appendix analyses this extension for any $0 \le k \le 1$.

Proposition 5. *(i) Firm A buys from Firm S in both periods and invests in Firm S's input if* $c < \frac{2(1-k)^2\Delta^2+3(3-k)\Delta t}{36t}$. *(ii) Firm A buys from Firm S in both periods without investing in the input if* $\max\{\frac{2(1-k)^2\Delta^2+3(3-k)\Delta t}{36t}, \frac{k^2\Delta^2-18t+27t^2}{9t}\} < c$. *(iii) Firm A buys from Firm T in both periods and invests in Firm T's input if* $\frac{2(1-k)^2\Delta^2+3(3-k)\Delta t}{36t} < c < \frac{k^2\Delta^2-18t+27t^2}{9t}$.

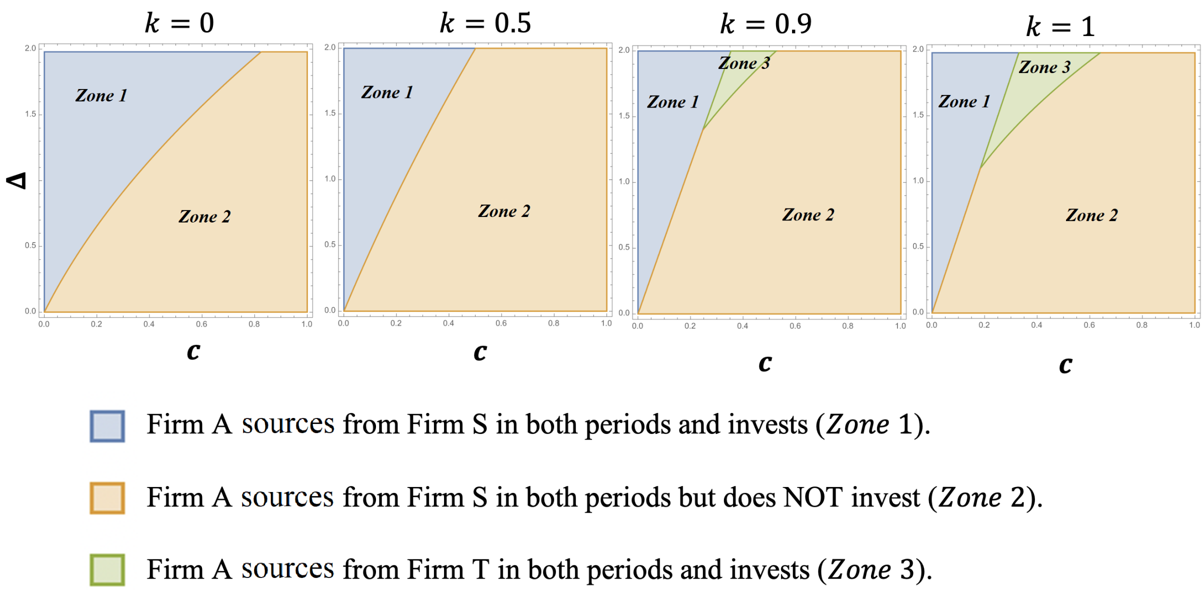
Corollary 2. *If the degree of knowledge spillover k is sufficiently small, or if the product differentiation t is sufficiently small, then the focal firm buys from the competitive supplier in both periods.*

Figure 4 illustrates the equilibrium outcome for different values of knowledge spillover k. As k decreases, investment in the competitor's input has a smaller effect on each firm's future negotiating position. Therefore, for small k, the focal firm is willing to buy from its competitor for a larger range of parameter values.

5.4 Contracts with no Fixed Transfers

In the main model, we allow the focal firm to make a fixed payment $F_{S,i}$ to Firm S that is negative relative to the fixed payment $F_{T,i}$ it would make to Firm T (with $F_{T,i}$ normalized to zero). For example, Firm S could agree to pay a larger share of the fixed costs of investment

Figure 4: Impact of Knowledge Spillover (k) on Firm A Supply Strategy ($t = 0.66$)



in production facilities dedicated to supplying Firm A. This fixed transfer allows for supply contracts that maximizes industry profits while transferring some of the profits generated by the contract to Firm A.

To illustrate the importance of this fixed transfer, we now restrict the fixed fees $F_{S,i}$ and $F_{T,i}$ to be zero, so the contracts involve only positive per-unit fees $w_{S,i}$ and $w_{T,i}$. Thus, it is not possible to transfer profits from Firm S to Firm A. All other aspects of the model remain the same as our main model. The following proposition states the equilibrium.

Proposition 6. *If the supply contracts cannot include fixed transfers, Firm A sources from Firm T in both periods and invests in Firm T's input if* $c < \frac{1}{18t}\Delta(\Delta + 6t)$*, and otherwise Firm A sources from Firm S in both periods without investing in the input.*

In this model extension, the focal firm never invests if it sources from the rival. If fixed transfers from Firm S to Firm A are not allowed, investment in the rival's input increases both product valuations but does not increase Firm A's equilibrium profits, as all of the additional profit generated goes to the competitive supplier.

5.5 One-period Models

Our two-period model implies the focal firm faces a trade-off between the short-term benefit (softer price competition) and long-term drawback (reduced investment in innovation) of buying from a competitor. Depending on the magnitude of these effects, in equilibrium, the firm may buy from the third party and invest, buy from its competitor and invest, or buy from its competitor without investing in innovation.

To illustrate the importance of having two periods of product market competition, the appendix explores one-period versions of our model and shows how the results differ. If the firm first decides whether to invest in a better input and can then transfer this knowledge to either supplier, we show the firm always chooses its competitor as its supplier to benefit from softer price competition. If the firm can commit to make an investment in the input of just a single supplier before it negotiates over the supply contract, it sometimes invests in the third party's input, but it never invests in the input of its rival, and it uses the outside option of buying an improved input from the third party to gain a stronger negotiating position with its rival. Thus, these one-period models do not produce the full range of possible outcomes that occur in our two-period model.

5.6 Contracting with Commitment not to Renegotiate

In our main model, firms cannot commit to a second-period supply contract during their first-period negotiation. Previous literature has noted legal and organizational reasons firms typically cannot commit to a contract that prevents renegotiation. Courts follow a longstanding legal principle that "those who make a contract may unmake it," which implies a contract can be renegotiated if both parties agree to do so (Jolls 1997). Furthermore, whereas two divisions in the same company may commit not to renegotiate if senior management enforces such an agreement, there is no general organizational mechanism that allows two separate firms to commit not to renegotiate (Che and Hausch 1999). To illustrate how such contract commitment would affect our results, the appendix includes a model in which firms initially negotiate a supply contract for both periods, and they commit not to renegotiate this contract. We show that this alternative set-up expands the range of parameter values for which the focal firm invests in the competitor's input because the competitor can no longer negotiate to extract the surplus created by investment. However, even for this alternative set-up with commitment not to renegotiate, there is still a range of parameters for which the firm buys from the third party and invests or buys from the competitor without investing in equilibrium.

6 Conclusion

This paper studies markets in which a firm can buy a production input from its product-market competitor. Although this practice leads to mitigated price competition, managers have expressed concern about the perils of knowledge spillover during the supply process. As a result, some firms switch to third-party suppliers that are not direct product market competitors. We study this problem using a framework in which a firm can buy an input either from a rival or from a third party. The firm also chooses whether to invest in the input in order to enhance the value of the product.

We find that, in some situations, the focal firm decides not to invest in innovation, or decides to contract with a third party instead of the competitor. Two key forces affect this supply decision. Buying from a rival mitigates price competition and improves industry profits. However, buying an input from a competitor and investing in the input strengthens the competitor's future negotiating position because the focal firm would then be forced to buy an inferior input from the third party if it did not reach an agreement with the competitive supplier in the next period. Anticipating this hold-up problem discourages the focal firm from buying from the rival and investing in innovation.

Our results imply, if there is little product differentiation, then managers should be willing to buy an input from a competitor to help avoid intense price competition. However, if there is greater product differentiation, managers may want to avoid buying from a competitor. In particular, if the value of innovation and the cost of investing in the input are both sufficiently large, managers should choose a third-party supplier, so that they are willing to invest in this supplier's input without concern about weakening their own negotiating position in the future.

We extend our main model to assess the robustness of our results. For a three-party negotiation model, in which the third party and the competitive supplier can both negotiate with the focal firm over the supply contract, we show that the sourcing outcomes are the same as in the main model. If the competitive supplier also can invest in the input, this supplier may have an even stronger incentive to invest in innovation than the focal firm. Furthermore, if the value of innovation is smaller for the competitive supplier than for the focal firm, the incentive to buy from a rival becomes stronger.

Future research could also extend our model in several ways. If there are capacity constraints and demand uncertainty, the focal firm may want to source from multiple suppliers to ensure sufficient supply. In addition, if firms interact repeatedly, they may form a relational contract that helps sustain investment in the input as the focal firm seeks to maintain its good relationship with its chosen supplier. Another possible extension would allow the third party to invest in input improvement, and firms would need to consider this supplier's investment incentives.

Future research could also explore implications of our model for consumer welfare and regulation. In our model, buying from a competitor leads to higher prices and less innovation, both of which could be harmful to consumers. These results suggest regulators may want to prevent firms from buying inputs from a competitor unless there is some other justification for doing so that benefits customers.

Funding and competing interests

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. The authors have no funding to report.

References

Amaldoss, W. and W. Shin (2015). Multitier store brands and channel profits. *Journal of Marketing Research 52*(6), 754–767.

Anand, K. S. and M. Goyal (2009). Strategic information management under leakage in a supply chain. *Management Science 55*(3), 438–452.

Arruñada, B. and X. H. Vázquez (2006). When your contract manufacturer becomes your competitor. *Harvard Business Review*.

Arya, A., B. Mittendorf, and D. E. Sappington (2008). The make-or-buy decision in the presence of a rival: Strategic outsourcing to a common supplier. *Management Science 54*(10), 1747–1758.

Bajari, P. and S. Tadelis (2001). Incentives versus transaction costs: A theory of procurement contracts. *The RAND Journal of Economics 32*(3), 387–407.

Baker, G., R. Gibbons, and K. J. Murphy (2002). Relational contracts and the theory of the firm. *The Quarterly Journal of Economics 117*(1), pp. 39–84.

Boyd, W. (2022). Hublot vs. Omega. *Exquisite Timepieces*. https://www.exquisitetimepieces.com/blog/hublot-vs-omega/.

Braithwaite, A. (2020). Canon drops HP bombshell. *OPI.net*. https://www.opi.net/news/region/001-north-america/canon-drops-hp-bombshell/.

Brandenburger, A. and B. Nalebuff (2021). The rules of co-opetition. *Harvard Business Review*.

Cachon, G. P. and M. Fisher (2000). Supply chain inventory management and the value of shared information. *Management Science 46*(8), 1032–1048.

Che, Y.-K. and D. B. Hausch (1999). Cooperative investments and the value of contracting. *The American Economic Review 89*(1), 125–147.

Chen, Y., P. Dubey, and D. Sen (2011). Outsourcing induced by strategic competition. *International Journal of Industrial Organization 29*(4), 484–492.

Coughlan, A. T. and B. Wernerfelt (1989). On credible delegation by oligopolists: A discussion of distribution channel management. *Management Science 35*(2), 226–239.

Demers, C. and A. Wiszniewska (2021). TV panel lottery. *RTINGS.com*. https://www.rtings.com/tv/learn/panel-lottery-samsung.

Desai, P., O. Koenigsberg, and D. Purohit (2004). Strategic decentralization and channel coordination. *Quantitative Marketing and Economics 2*(1), 5–22.

Dewatripont, M. (1988). Commitment through renegotiation-proof contracts with third parties. *The Review of Economic Studies 55*(3), 377–390.

Dukes, A. J., E. Gal-Or, and K. Srinivasan (2006). Channel bargaining with retailer asymmetry. *Journal of Marketing Research 43*(1), 84–97.

Epstein, Z. (2017). Apple is working on a revolutionary new iPhone, but it's worried Samsung will steal the design. *BGR*. https://bgr.com/tech/iphone-x-release-date-weeks-away-but-foldable-iphone-in-2020/.

Ghamat, S., H. Pun, and X. Yan (2018). Optimal outsourcing strategies when capacity is limited. *Decision Sciences 49*(5), 958–991.

Gibbons, R. (2005). Incentives between firms (and within). *Management Science 51*(1), pp. 2–17.

Grossman, S. and O. Hart (1986). The costs and benefits of ownership: A theory of vertical and lateral integration. *Journal of Political Economy 94*(4), 691–719.

Ha, A. Y. and S. Tong (2008). Contracting and information sharing under supply chain competition. *Management Science 54*(4), 701–715.

Hardwick, T. (2022). Apple developing thinner OLED panels potentially for foldable displays. *MacRumors*. https://www.macrumors.com/2022/05/10/apple-developing-thinner-oled-foldable-displays/.

Hart, O. and J. Moore (1988). Incomplete contracts and renegotiation. *Econometrica 56*(4), 755–785.

Heese, H. S., E. Kemahlıoğlu-Ziya, and O. Perdikaki (2021). Outsourcing under competition and scale economies: When to choose a competitor as a supplier. *Decision Sciences 52*(5), 1209–1241.

Ho, J. (2023). Hublot CEO Ricardo Guadalupe on the evolution of the brand and what's in store next. *AugustMan*. https://www.augustman.com/sg/watches/hublot-ceo-ricardo-guadalupe-on-the-evolution-of-the-brand-and-whats-in-store-next/ .

Iyer, G. (1998). Coordinating channels under price and nonprice competition. *Marketing Science 17*(4), 338–355.

Iyer, G. and J. M. Villas-Boas (2003). A bargaining theory of distribution channels. *Journal of Marketing Research 40*(1), 80–100.

Jeuland, A. P. and S. M. Shugan (1983). Managing channel profits. *Marketing Science 2*(3), pp. 239–272.

Jolls, C. (1997). Contracts as bilateral commitments: A new perspective on contract modification. *The Journal of Legal Studies 26*(1), 203–237.

Koltrowitz, S. (2020). Swatch Group free to supply watch movements, says Swiss watchdog. *Reuters*. https://www.reuters.com/article/us-swatch-ch-competition/swatch-group-free-to-supply-watch-movements-says-swiss-watchdog-idUSKCN24G19V .

Lawson, B., B. B. Tyler, and P. D. Cousins (2008). Antecedents and consequences of social capital on buyer performance improvement. *Journal of Operations Management 26*(3), 446–460.

Lee, H. L., K. C. So, and C. S. Tang (2000). The value of information sharing in a two-level supply chain. *Management Science 46*(5), 626–643.

Lee, H. L. and S. Whang (2000). Information sharing in a supply chain. *International Journal of Manufacturing Technology and Management 1*(1), 79–93.

Lessin, J., L. Luk, and J. Osawa (2013). Apple finds it difficult to divorce Samsung. *Wall Street Journal*. https://www.wsj.com/articles/SB10001424127887324682204578513882349940500.

Leuschner, R., D. S. Rogers, and F. F. Charvet (2013). A meta-analysis of supply chain integration and firm performance. *Journal of Supply Chain Management 49*(2), 34–57.

Levin, J. (2003). Relational incentive contracts. *The American Economic Review 93*(3), pp. 835–857.

Li, J. (2021). LG has officially stopped manufacturing smartphones. *Hypebeast*. https://hypebeast.com/2021/6/lg-officially-stopped-making-smartphones-announcement.

Li, L. (2002). Information sharing in a supply chain with horizontal competition. *Management Science 48*(9), 1196–1212.

Li, L. and H. Zhang (2008). Confidentiality and information sharing in supply chain coordination. *Management Science 54*(8), 1467–1481.

Liberatore, S. (2023). Your next iPhone could be foldable: Apple may release a smartphone that lets users interact with multiple screens - but will it crack like Samsung's Galaxy Z Fold 3? *Daily Mail UK*. https://www.dailymail.co.uk/sciencetech/article-11755591/Your-iPhone-FOLDABLE-Apple-release-smartphone-opens-larger-screen.html .

Lim, W. and S. Tan (2010). Outsourcing suppliers as downstream competitors: Biting the hand that feeds. *European Journal of Operational Research 203*(2), 360–369.

Longet, A. and M. Gabella (2023). Discussing how Hublot is shaping contemporary watchmaking with CEO Ricardo Guadalupe. *Watchonista*. https://www.watchonista.com/articles/interviews/watches-wonders-2023-discussing-how-hublot-shaping-contemporary-watchmaking-ceo-ricardo-guadalupe .

Maggio, E. (2017). Apple is reportedly investing $2.7 billion in LG Display to build OLED panels for future iPhones. *Business Insider*. https://www.businessinsider.com/apple-is-reportedly-investing-27-billion-in-lg-display-to-build-oled-panels-for-future-iphones-2017-7 .

McAfee, R. P. and M. Schwartz (1994). Opportunism in multilateral vertical contracting: Nondiscrimination, exclusivity, and uniformity. *The American Economic Review 84*(1), 210–230.

Moorthy, K. S. (1987). Managing channel profits: Comment. *Marketing Science 6*(4), 375–379.

Naas, R. (2019). Fate of watch brands hangs uncertain as Swatch Group's ETA faces production, distribution restrictions by COMCO. *Forbes*. https://www.forbes.com/sites/robertanaas/2020/12/30/fate-of-watch-brands-hangs-uncertain-as-swatch-groups-eta-faces-production-distribution-restrictions-by-comco/ .

Nistor, C. and M. Selove (2020). Pricing and quality provision in a supply relationship: A model of efficient relational contracts. *Marketing Science 39*(5), 939–955.

Palit, S., M. Hora, and S. Ghosh (2023). Innovation and knowledge accumulation in buyer-supplier relationships. Working paper.

Piccolo, S. and J. Miklós-Thal (2012). Colluding through suppliers. *The RAND Journal of Economics 43*(3), 492–513.

Plambeck, E. L. and T. A. Taylor (2007). Implications of renegotiation for optimal contract flexibility and investment. *Management Science 53*(12), 1872–1886.

Porter, J. (2021). Samsung reportedly inks deal to buy OLED TV panels from rival LG Display. *The Verge*. https://www.theverge.com/2021/4/9/22375179/samsung-electronics-lg-display-oled-tv-panels-quantum-dot-qd.

Pun, H. (2014). Supplier selection of a critical component when the production process can be improved. *International Journal of Production Economics 154*, 127–135.

Shaffer, G. and F. Zettelmeyer (2002). When good news about your rival is good for you: The effect of third-party information on the division of channel profits. *Marketing Science 21*(3), 273–293.

Stole, L. A. and J. Zwiebel (1996a). Intra-firm bargaining under non-binding contracts. *The Review of Economic Studies 63*(3), 375–410.

Stole, L. A. and J. Zwiebel (1996b). Organizational design and technology choice under intrafirm bargaining. *The American Economic Review 86*(1), 195–222.

Taylor, T. A. and E. L. Plambeck (2007). Supply chain relationships and contracts: The impact of repeated interaction on capacity investment and procurement. *Management Science 53*(10), pp. 1577–1593.

Venkatesh, R., P. Chintagunta, and V. Mahajan (2006). Research note: Sole entrant, co-optor, or component supplier: Optimal end-product strategies for manufacturers of proprietary component brands. *Management Science 52*(4), 613–622.

Wayland, M. and L. Kolodny (2021). GM and Ford take cues from Tesla's success, but try to avoid Musk's mistakes. *CNBC*. https://www.cnbc.com/2021/03/16/gm-and-ford-take-cues-from-tesla-but-try-to-avoid-musks-mistakes.html.

Williamson, O. (1993). Opportunism and its critics. *Managerial and Decision Economics 14*(2), 97–107.

Williamson, O. (2008). Transaction cost economics. *Handbook of New Institutional Economics*, 41–65.

Xu, Y., H. Gurnani, and R. Desiraju (2010). Strategic supply chain structure design for a proprietary component manufacturer. *Production and Operations Management 19*(4), 371–389.

Yang, Z., X. Hu, H. Gurnani, and H. Guan (2018). Multichannel distribution strategy: Selling to a competing buyer with limited supplier capacity. *Management Science 64*(5), 2199–2218.

Supplemental Appendices

Buying from a Competitor: A Model of Knowledge Spillover and Innovation

Appendix A presents formal proofs of results from the main body of the paper. Appendix B contains additional model extensions and variations.

A Appendix A: Proofs

A.1 Proof of Lemma 1

We consider two cases: $|v_A - v_S| < 3t$ (implying positive equilibrium market shares), and $|v_A - v_S| \geq 3t$ (implying one firm may serve the entire market). We drop the period subscript i for simpler exposition.

- **$|v_A - v_S| < 3t$:**

  If Firm A buys from Firm T, equilibrium prices and profits are as in the standard Hoteling model. If A and S both have positive demand, the indifferent customer on the Hoteling line is at location: $x = \frac{1}{2} - \frac{p_A - p_S + v_S - v_A}{2t}$. Profits for Firm A and S are: $\pi_A = p_A(\frac{1}{2} - \frac{p_A - p_S + v_S - v_A}{2t})$ and $\pi_S = p_S(\frac{1}{2} + \frac{p_A - p_S + v_S - v_A}{2t})$. Solving the first-order conditions, equilibrium prices are: $p_A = t + \frac{v_A - v_S}{3}$ and $p_S = t + \frac{v_S - v_A}{3}$. Equilibrium quantities are: $q_A = \frac{1}{2} - \frac{v_S - v_A}{6t}$ and $q_S = \frac{1}{2} + \frac{v_S - v_A}{6t}$. Equilibrium profits are: $\pi_A = \frac{1}{18t}(3t + v_A - v_S)^2$ and $\pi_S = \frac{1}{18t}(3t - v_A + v_S)^2$. Industry profits are: $\Pi = \pi_A + \pi_S = t + \frac{1}{9t}(v_S - v_A)^2$. Full market coverage requires that the indifferent customer x to have positive utility, so, $v_A - p_A - tx > 0$, that is, $v_A + v_S > p_A + p_S + t$. Inserting prices yields, $v_A + v_S > 3t$, which holds because $t < \frac{2}{3}$. Moreover, both firms should have positive demands, which results in the constraint $|v_A - v_S| < 3t$.

  If Firm A buys from Firm S, the profit functions become: $\pi_A = (p_A - w_S)(\frac{1}{2} - \frac{p_A - p_S + v_S - v_A}{2t}) - F_S$ and $\pi_S = p_S(\frac{1}{2} + \frac{p_A - p_S + v_S - v_A}{2t}) + w_S(\frac{1}{2} - \frac{p_A - p_S + v_S - v_A}{2t}) + F_S$. Then, $\frac{\partial \pi_A}{\partial p_A} = \frac{-2p_A + p_S + t - v_S + v_A + w_S}{2t}$ and $\frac{\partial \pi_S}{\partial p_S} = \frac{p_A - 2p_S + t + v_S - v_A + w_S}{2t}$. Thus, equilibrium prices become: $p_A = t + w_S + \frac{v_A - v_S}{3}$ and $p_S = t + w_S + \frac{v_S - v_A}{3}$. Equilibrium demands are: $q_A = \frac{1}{2} - \frac{v_S - v_A}{6t}$ and $q_S = \frac{1}{2} + \frac{v_S - v_A}{6t}$. Equilibrium profits are: $\pi_A = \frac{1}{18t}(3t + v_A - v_S)^2 - F_S$ and $\pi_S = \frac{1}{18t}(3t - v_A + v_S)^2 + w_S + F_S$. Industry profits are: $\Pi = t + \frac{1}{9t}(v_S - v_A)^2 + w_S$. The indifferent customer x should have a positive utility, thus, $v_A - p_A - tx > 0$, that is, $v_A + v_S > p_A + p_S + t$. Inserting equilibrium prices, $v_A + v_S > 2w_S + 3t > 3t$. Moreover, for both demands to be positive, we should have $|v_A - v_S| < 3t$.

- $|v_A - v_S| > 3t$**:**

  If Firm A buys from Firm T, then,

  If $v_A > v_S + 3t$, then Firm A serves the entire market. Firm A sets its price to make the $x = 1$ customer indifferent between buying from Firm A at p_A or from Firm S at $p_S = 0$. It follows $p_A = v_A - v_S - t$ and $p_S = 0$. Firm A and S profits are: $\pi_A = v_A - v_S - t$ and $\pi_S = 0$. Industry profits are: $\Pi = v_A - v_S - t$.

  If $v_S > v_A + 3t$, then, Firm S serves the entire market. We have $p_S = v_S - v_A - t$ and $p_A = 0$. Firm A and S profits are: $\pi_A = 0$ and $\pi_S = v_S - v_A - t$. Industry profits are: $\Pi = v_S - v_A - t$.

  If Firm A buys from Firm S, then,

  If $v_A > v_S + 3t$, Firm A serves the entire market. We have $p_A = v_A - v_S - t$ and $p_S = 0$. Profits are $\pi_A = v_A - v_S - t - w_S - F_S$ and $\pi_S = w_S + F_S$. Industry profits are: $\Pi = v_A - v_S - t$.

  If $v_S > v_A + 3t$, Firm S serves the entire market. We have $p_S = v_S - v_A - t$ and $p_A = 0$. Firm A and S profits are: $\pi_A = -F_S$ and $\pi_S = v_S - v_A - t + F_S$. Industry profits are: $\Pi = v_S - v_A - t$.

A.2 Proof of Lemma 2

Per Lemma 1, if $|v_A - v_S| < 3t$ and $2w_S < v_A + v_S - 3t$, the market is fully covered and the industry profits are: $\Pi = t + \frac{1}{9t}(v_S - v_A)^2 + w_S$, which is increasing in w_S. The maximum possible wholesale price would then be $w_S^{max} = \frac{1}{2}(v_A + v_S - 3t)$, which fully extracts the surplus of the indifferent customer. So the maximum possible industry profits are: $\Pi^{max} = \frac{1}{2}(v_A + v_S) + \frac{1}{9t}(v_S - v_A)^2 - \frac{1}{2}t$.

Now consider the case $2w_S > v_A + v_S - 3t$, so the market is not fully covered. In this case, each firm is a local monopolist. Profits are $\pi_A = (p_A - w_S)(\frac{v_A - p_A}{t}) - F_S$ and $\pi_S = p_S(\frac{v_S - p_S}{t}) + w_S(\frac{v_A - p_A}{t}) + F_S$. Thus, equilibrium prices are: $p_A = \frac{v_A + w_S}{2}$ and $p_S = \frac{v_S}{2}$.

Equilibrium demands are: $q_A = \frac{v_A - w_S}{2t}$ and $q_S = \frac{v_S}{2t}$. Equilibrium profits are: $\pi_A = \frac{1}{4t}(v_A - w_S)^2 - F_S$ and $\pi_S = \frac{1}{4t}(v_S)^2 + w_S(\frac{v_A - w_S}{2t}) + F_S$. Industry profits are: $\Pi = \frac{1}{4t}(v_A^2 + v_S^2 - w_S^2)$. Thus, industry profits decrease with w_S, implying that firms would not increase the wholesale price above $w_S^{max} = \frac{1}{2}(v_A + v_S - 3t)$.

If $|v_A - v_S| > 3t$, Lemma 1 shows that the industry profits are $|v_A - v_S| - t$, which is independent of the wholesale price.

A.3 Proof of Lemma 3

With $v_{A,2} = v_{S,2} = 1$, per Lemma 1, if Firm A buys from Firm T in period 2, we have $\pi_{A,2} = \pi_{S,2} = \frac{1}{2}t$ and so the industry profit becomes $\Pi_2^{AT} = t$. Per Lemma 1 and 2, if Firm A buys from Firm S, then $\pi_{A,2} = \frac{1}{2}t - F_{S,2}$, $\pi_{S,2} = \frac{1}{2}t + w_{S,2} + F_{S,2}$ and so the industry profit becomes $\Pi_2^{AS} = t + w_{S,2}$ where $w_{S,2} = \frac{1}{2}(2 - 3t)$. So, Firm A buys from Firm S because $\Pi_2^{AS} > \Pi_2^{AT}$.

To derive $F_{S,2}$, we need to take into account firms' outside options. If Firm A and S fail to reach an agreement, then Firm A buys from Firm T resulting in $\pi_{A,2}^O = \pi_{S,2}^O = \frac{t}{2}$. Then, the fixed payment is derived from $\pi_{A,2} - \pi_{A,2}^O = \pi_{S,2} - \pi_{S,2}^O$ (firms will have equal surplus over their outside options). Solving for $F_{S,2}$ yields $F_{S,2} = -\frac{1}{2}w_{S,2} = \frac{1}{4}(3t - 2)$. Inserting $w_{S,2}$ and $F_{S,2}$ back into firm profits, we have, $\pi_{A,2} = \pi_{S,2} = \frac{1}{4}(2 - t)$.

A.4 Proof of Lemma 4

We first consider the $\Delta < 3t$ case. If Firm A buys from Firm S in period 1 and invests c, then Firm A has 2 options: to continue with Firm S in period or to switch to Firm T.

If Firm A continues sourcing from Firm S in period 2, we have $v_{A,2} = v_{S,2} = 1 + \Delta$. Inserting these product values into Lemmas 1 and 2, in period 2 we have firm profits $\pi_{A,2} = \frac{t}{2} - F_{S,2}$ and $\pi_{S,2} = \frac{t}{2} + w_{S,2} + F_{S,2}$, the wholesale price $w_{S,2} = \Delta + 1 - \frac{3t}{2}$, and industry profits $\Pi_2 = 1 + \Delta - \frac{t}{2}$.

However, if in period 2 Firm A switches to Firm T, we have $v_{A,2} = 1$ and $v_{S,2} = 1 + \Delta$.

Inserting these values into Lemma 1, firm profits in period 2 are $\pi_{A,2} = \frac{1}{18t}(3t - \Delta)^2$ and $\pi_{S,2} = \frac{1}{18t}(3t + \Delta)^2$, leading to industry profits of $\Pi_2 = t + \frac{1}{9t}\Delta^2$.

We have, $t + \frac{1}{9t}\Delta^2 < 1 + \Delta - \frac{t}{2} \Leftrightarrow (\frac{3t}{2} - 1) + \Delta(\frac{\Delta}{9t} - 1) < 0$, given that $\frac{\Delta}{3} < t < \frac{2}{3}$. Thus, industry profits are always higher if Firm A continues sourcing from Firm S. Thus, Firm A continues sourcing from Firm S with the wholesale price $w_{S,2} = \Delta + 1 - \frac{3t}{2}$.

We now calculate the fixed payment $F_{S,2}$. The fixed payment is derived from $\pi_{A,2} - \pi^O_{A,2} = \pi_{S,2} - \pi^O_{S,2}$ where superscript O denotes outside options (when Firm A and S fail to agree and hence Firm A contracts with Firm T). Inserting $\pi^O_{A,2} = \frac{1}{18t}(3t - \Delta)^2$ and $\pi^O_{S,2} = \frac{1}{18t}(3t + \Delta)^2$ into the above equation yields $F_{S,2} = -(\frac{1+\Delta}{2} - \frac{3t}{4}) + \frac{\Delta}{3}$. Inserting $F_{S,2}$ back into the profit functions, we have: $\pi_{A,2} = \frac{1}{12}(2\Delta - 3t + 6)$ and $\pi_{S,2} = \frac{1}{12}(10\Delta - 3t + 6)$.

We now consider the case $\Delta > 3t$.

Suppose in period 2 Firm A switches to Firm T. We have $v_{A,2} = 1$ and $v_{S,2} = 1 + \Delta$ with $\Delta > 3t$. In this case, Firm S serves the entire market, leading to $\pi_{A,2} = 0$ and $\pi_{S,2} = \Delta - t$, and industry profits of $\Pi_2 = \Delta - t$, which is less than $1 + \Delta - \frac{t}{2}$. Thus, Firm A continues sourcing from Firm S with the wholesale price $w_{S,2} = \Delta + 1 - \frac{3t}{2}$.

We now calculate the fixed payment $F_{S,2}$ for the $\Delta > 3t$ case. The fixed payment is derived from $\pi_{A,2} - \pi^O_{A,2} = \pi_{S,2} - \pi^O_{S,2}$ where $\pi^O_{A,2} = 0$ and $\pi^O_{S,2} = \Delta - t$. Hence, $(\frac{t}{2} - F_{S,2}) - 0 = (\frac{t}{2} + \Delta + 1 - \frac{3t}{2} + F_{S,2}) - (\Delta - t)$, which results in: $F_{S,2} = -\frac{1}{2} + \frac{t}{4}$. Inserting F_S back into the profit functions, we have: $\pi_{A,2} = \frac{1}{2} + \frac{t}{4}$ and $\pi_{S,2} = \frac{1}{2} + \Delta - \frac{3t}{4}$.

A.5 Proof of Lemma 5

We first consider the case $\Delta < 3t$. If Firm A buys from Firm T in period 1 and invests c, then Firm A has 2 options: to continue with Firm T in period 2 or to switch to Firm S.

If Firm A continues sourcing from Firm T in period 2, we have $v_{A,2} = 1 + \Delta$ and $v_{S,2} = 1$. Inserting these product values in Lemma 1, in period 2 we have $\pi_{A,2} = \frac{1}{18t}(3t + \Delta)^2$ and $\pi_{S,2} = \frac{1}{18t}(3t - \Delta)^2$, leading to industry profits of $\Pi_2 = t + \frac{1}{9t}\Delta^2$.

However, if in period 2 Firm A switches to Firm S, we have $v_{A,2} = v_{S,2} = 1$. Inserting these values into Lemma 1, firm profits in period 2 are $\pi_{A,2} = \frac{t}{2} - F_{S,2}$ and $\pi_{S,2} = \frac{t}{2} + w_{S,2} + F_{S,2}$, the wholesale price is $w_{S,2} = 1 - \frac{3t}{2}$, and industry profits are $\Pi_2 = 1 - \frac{t}{2}$.

We have, $t + \frac{1}{9t}\Delta^2 > 1 - \frac{t}{2} \Leftrightarrow \frac{\Delta^2}{9t} > 1 - \frac{3t}{2}$. Thus, in period 2, if $\frac{\Delta^2}{9t} > 1 - \frac{3t}{2}$ Firm A buys the input from the third-party, and otherwise it buys the input from its competitor. In the latter case, $w_{S,2} = 1 - \frac{3t}{2}$. The fixed payment is derived from $\pi_{A,2} - \pi^O_{A,2} = \pi_{S,2} - \pi^O_{S,2}$. Inserting $\pi^O_{A,2} = \frac{1}{18t}(3t + \Delta)^2$ and $\pi^O_{S,2} = \frac{1}{18t}(3t - \Delta)^2$ into the above equation yields $F_{S,2} = -\frac{1}{2}w_{S,2} - \frac{1}{3}\Delta = -(\frac{1}{2} - \frac{3t}{4}) - \frac{\Delta}{3}$. This leads to firm profits $\pi_{A,2} = \frac{1}{2} - \frac{1}{4}t + \frac{1}{3}\Delta$ and $\pi_{S,2} = \frac{1}{2} - \frac{1}{4}t - \frac{1}{3}\Delta$.

We now consider the case $\Delta > 3t$. If Firm A buys from Firm T in period 1 and invests c, then Firm A has 2 options: to continue with Firm T in period 2 or to switch to Firm S.

If Firm A continues sourcing from Firm T in period 2, we have $v_{A,2} = 1 + \Delta$ and $v_{S,2} = 1$ where $\Delta > 3t$. Then we have $\pi_{A,2} = \Delta - t$ and $\pi_{S,2} = 0$, leading to industry profits of $\Delta - t$.

However, if in period 2 Firm A switches to Firm S, we have $v_{A,2} = v_{S,2} = 1$. Inserting these values in Lemma 1, firm profits in period 2 are $\pi_{A,2} = \frac{t}{2} - F_{S,2}$ and $\pi_{S,2} = \frac{t}{2} + w_{S,2} + F_{S,2}$, the wholesale price is $w_{S,2} = 1 - \frac{3t}{2}$, and industry profits are $\Pi_2 = 1 - \frac{t}{2}$.

We have, $\Delta - t > 1 - \frac{t}{2} \Leftrightarrow \Delta > 1 + \frac{t}{2}$. Thus, in period 2, if $\Delta > 1 + \frac{t}{2}$ Firm A buys the input from the third-party, and otherwise, it buys the input from its competitor. In the latter case, $w_{S,2} = 1 - \frac{3t}{2}$. The fixed payment is derived from $\pi_{A,2} - \pi^O_{A,2} = \pi_{S,2} - \pi^O_{S,2}$. Inserting $\pi^O_{A,2} = \Delta - t$ and $\pi^O_{S,2} = 0$ into the preceding equation yields $(\frac{t}{2} - F_{S,2}) - (\Delta - t) = (\Delta + 1 - t + F_{S,2}) - 0$, yielding, $F_{S,2} = -\frac{1}{2} + \frac{5t}{4} - \Delta$. This leads to firm profits $\pi_{A,2} = \frac{1}{2} - \frac{3}{4}t + \Delta$ and $\pi_{S,2} = \frac{1}{2} + \frac{1}{4}t$.

A.6 Proof of Lemma 6

First, we consider the case $\Delta < 3t$. If Firm A buys from Firm S in period 1, its profits in period 2 are $\frac{\Delta}{6} + \frac{1}{4}(2 - t)$ if it invests, and $\frac{1}{4}(2 - t)$ if it does not (see Lemmas 3 and 4). Therefore, Firm A will invest c if and only if $\frac{\Delta}{6} > c$.

If Firm A buys from Firm T in period 1, its profits in period 2 are equal to $\frac{1}{2}t + \frac{\Delta^2}{18t} + \frac{1}{3}\Delta$

if it invests and $\frac{\Delta^2}{9t} > 1 - \frac{3t}{2}$, equal to $\frac{1}{2} - \frac{1}{4}t + \frac{1}{3}\Delta$ if it invests and $\frac{\Delta^2}{9t} < 1 - \frac{3t}{2}$, and equal to $\frac{1}{2} - \frac{1}{4}t$ if it does not invest (see Lemmas 3 and 5).

Thus, Firm A invests if and only if $\frac{\Delta^2}{9t} > 1-\frac{3t}{2}$ and $c < \frac{1}{2}(\frac{\Delta^2}{9t} - (1-\frac{3t}{2})) + \frac{\Delta}{3}$, or $\frac{\Delta^2}{9t} < 1-\frac{3t}{2}$ and $c < \frac{\Delta}{3}$. These two conditions are combined together into $c < max\{\frac{2\Delta^2-18t+27t^2}{36t}, 0\} + \frac{\Delta}{3}$.

Next, we consider the case $\Delta > 3t$. If Firm A buys from Firm S in period 1, its profits in period 2 are $\frac{1}{4}(2+t)$ if it invests and $\frac{1}{4}(2-t)$ if it does not (see proofs of Lemma 3 and 4). Therefore, if $\Delta > 3t$, and Firm A buys from Firm S in period 1, Firm A will invest if $c < \frac{t}{2}$.

If Firm A buys from Firm T in period 1, its profit in period 2 are equal to $\Delta - t$ if it invests and $\Delta > 1 + \frac{t}{2}$, equal to $\frac{1}{2} - \frac{3}{4}t$ if it invests and $\Delta < 1 + \frac{t}{2}$, and equal to $\frac{1}{2} - \frac{1}{4}t$ if it does not invest (see proofs of Lemma 3 and 5). Thus, if Firm A buys from Firm T in period 1, it invests if and only if $\Delta > 1 + \frac{t}{2}$ and $\Delta - t - c > \frac{1}{2} - \frac{1}{4}t \Leftrightarrow c < \Delta - \frac{3t}{4} - \frac{1}{2}$.

A.7 Proof of Proposition 1

We first consider the case $\Delta < 3t$. Per Lemma 6, if the Period 1 supplier is Firm S, Firm A will invest c if and only if $c < \frac{\Delta}{6}$. On the other hand, if $c > \frac{\Delta}{6}$, we need to compare the following two industry profits: (i) If Firm A buys From S in both periods and does not invest in the input, total industry profits are $\Pi = 2 - t$ (see Lemma 3) (ii) If Firm A buys From T in both periods and invests, total industry profits are: $\Pi = 2t + \frac{1}{9t}\Delta^2 - c$ (see Lemma 5). The former is larger if and only if $c > \frac{\Delta^2-18t+27t^2}{9t}$. Thus, Firm A buys from Firm S in both periods and does not invest iff $c > \frac{\Delta^2-18t+27t^2}{9t}$ and $c > \frac{\Delta}{6}$ whereas Firm A buys from Firm T in both periods and invests in Firm T's input iff $c < \frac{\Delta^2-18t+27t^2}{9t}$ and $c > \frac{\Delta}{6}$.

Next, we derive the period 1 fixed payment when Firm A and Firm S contract, $F_{S,1}$. The fixed payment is derived from $\pi_A - \pi_A^O = \pi_S - \pi_S^O$, where π_A is focal firm's total profit across the two periods including any investment cost and π_S is Firm S's total profit across he two periods. The superscript O denotes outside options (when Firm A and Firm S fail to agree in period 1 and hence Firm A contracts with Firm T). As we showed above, there are three cases:

1. If $c < \frac{\Delta}{6}$, Firm A buys from Firm S in both periods and invests.

2. If $c > \frac{\Delta}{6}$ and $c > \frac{\Delta^2 - 18t + 27t^2}{9t}$, Firm A buys from Firm S in both periods and does not invest.

3. If $\frac{\Delta}{6} < c < \frac{\Delta^2 - 18t + 27t^2}{9t}$, Firm A buys from Firm T in both periods and invests.

We need to calculate the fixed payment in the first two cases in which Firm A and Firm S contract. Consider the first case, $c < \frac{\Delta}{6}$. In this case we have:

$$\pi_A = \underbrace{(\frac{t}{2} - F_{S,1})}_{Period\ 1} - \underbrace{c}_{investment\ cost} + \underbrace{\frac{1}{12}(2\Delta - 3t + 6)}_{Period\ 2},$$

$$\pi_S = \underbrace{(\frac{t}{2} + (1 - \frac{3t}{2}) + F_{S,1})}_{Period\ 1} + \underbrace{\frac{1}{12}(10\Delta - 3t + 6)}_{Period\ 2}$$

If Firm A and Firm S fail to agree in period 1, Firm A buys input from Firm T in period 1, and per Lemma 6, it will invest. Then, per Lemma 5, in period 2, if $\frac{\Delta^2}{9t} > 1 - \frac{3t}{2}$, Firm A buys the input from the third party, resulting in period 2 profits $\pi_{A,2} = \frac{t}{2} + \frac{\Delta}{3} + \frac{\Delta^2}{18t}$ and $\pi_{S,2} = \frac{t}{2} - \frac{\Delta}{3} + \frac{\Delta^2}{18t}$, and industry profits $\Pi_2 = t + \frac{\Delta^2}{9t}$. Otherwise, Firm A buys the input from its competitor, with input contract $w_{S,2} = 1 - \frac{3t}{2}$ and $F_{S,2} = -(\frac{1}{2} - \frac{3t}{4}) - \frac{\Delta}{3}$, which results in profits $\pi_{A,2} = \frac{1}{2} - \frac{t}{4} + \frac{\Delta}{3}$ and $\pi_{S,2} = \frac{1}{2} - \frac{t}{4} - \frac{\Delta}{3}$, and industry profits $\Pi_2 = 1 - \frac{t}{2}$.

Therefore, the disagreement payoffs, π_A^O and π_S^O, depend on whether or not $\frac{\Delta^2}{9t} > 1 - \frac{3t}{2}$. In particular, if $\frac{\Delta^2}{9t} > 1 - \frac{3t}{2}$, then

$$\pi_A^O = (\tfrac{t}{2}) - c + (\tfrac{t}{2} + \tfrac{\Delta}{3} + \tfrac{\Delta^2}{18t}),$$

$$\pi_S^O = (\tfrac{t}{2}) + (\tfrac{t}{2} - \tfrac{\Delta}{3} + \tfrac{\Delta^2}{18t})$$

Whereas if $\frac{\Delta^2}{9t} < 1 - \frac{3t}{2}$, then

$$\pi_A^O = (\tfrac{t}{2}) - c + (\tfrac{1}{2} - \tfrac{t}{4} + \tfrac{\Delta}{3}),$$

$$\pi_S^O = (\tfrac{t}{2}) + (\tfrac{1}{2} - \tfrac{t}{4} - \tfrac{\Delta}{3})$$

The fixed payment is derived from $\pi_A - \pi_A^O = \pi_S - \pi_S^O$. Regardless of whether $\frac{\Delta^2}{9t} > 1 - \frac{3t}{2}$ or not, we have $F_{S,1} = \frac{1}{12}(9t - 8\Delta - 6)$. Recall from Lemma 4, $F_{S,2} = \frac{1}{2}w_{S,2} + \frac{\Delta}{3} = \frac{1}{12}(9t - 2\Delta - 6)$. Thus, $F_{S,1} = F_{S,2} - \frac{\Delta}{2}$, implying $F_{S,1} < F_{S,2} < 0$.

Next we consider $c > \frac{\Delta}{6}$ and $c > \frac{\Delta^2-18t+27t^2}{9t}$, or, $c > \max\{\frac{\Delta}{6}, \frac{\Delta^2-18t+27t^2}{9t}\}$ and so Firm A buys from Firm S in both periods and does not invest. In this case we have:

$\pi_A = (\frac{t}{2} - F_{S,1}) + \frac{1}{4}(2-t)$,

$\pi_S = (\frac{t}{2} + (1 - \frac{3t}{2}) + F_{S,1}) + \frac{1}{4}(2-t)$

If Firm A and Firm S fail to agree in period 1, Firm A contracts with Firm T in period 1. Then, per Lemma 6, it invests only if $c < \max\{\frac{2\Delta^2-18t+27t^2}{36t}, 0\} + \frac{\Delta}{3} = \hat{c}$. Thus, if $\max\{\frac{\Delta}{6}, \frac{\Delta^2-18t+27t^2}{9t}\} < c < \hat{c}$, Firm A invests in cases of disagreement and hence the disagreement payoffs would be the same as $c < \frac{\Delta}{6}$ case. In particular, $\pi_A^O - \pi_S^O = \frac{2\Delta}{3} - c$. Moreover, $\pi_A - \pi_S = -2F_{S,1} - (1 - \frac{3t}{2})$. Thus, $F_{S,1} = \frac{c}{2} - \frac{\Delta}{3} - 1 + \frac{3t}{2}$.

On the other hand, if $c > \max\{\frac{\Delta}{6}, \frac{\Delta^2-18t+27t^2}{9t}, \hat{c}\}$, the investment would not occur in case of first-period disagreement. As a result, $\pi_A^O - \pi_S^O = 0$, because $\pi_A^O = \pi_S^O = (\frac{t}{2}) + (\frac{1}{4}(2-t))$. Thus, $F_{S,1} = -\frac{1}{2}(1 - \frac{3t}{2})$. Table 2 summarizes the outcomes (contract terms, firm profits, and industry profits) for $\Delta < 3t$.

Next, we consider the case $\Delta > 3t$. We will show that:

1. Firm A buys from Firm S in both periods and invests if $c < \frac{t}{2}$.

2. Firm A buys from Firm S in both periods and does not invest if $\max\{\frac{t}{2}, \Delta + t - 2\} < c$.

3. Firm A buys from Firm T in both periods and invests if $\frac{t}{2} < c < \Delta + t - 2$.

1. If $c < \frac{t}{2}$, then if the Period 1 supplier is Firm S, Firm A will invest (see proof of Lemma 6); thus, $\Pi = (1 - \frac{t}{2}) - c + (1 - \frac{t}{2} + \Delta) = \Delta - t + 2 - c$. However, if the Period 1 supplier is Firm T, the total industry profits are $(t) - c + (\Delta - t) = \Delta - c$ if Firm A invests ($T \rightarrow invest \rightarrow T$), and are $(t) + (1 - \frac{t}{2}) = 1 + \frac{t}{2}$ if it does not invest ($T \rightarrow Not\ invest \rightarrow S$). Since $\Delta - t + 2 - c$ is larger than both $\Delta - c$ and $1 + \frac{t}{2}$, Firm A buys from Firm S in both periods and invests.

2. If $\max\{\frac{t}{2}, \Delta + t - 2\} < c$, if the Period 1 supplier is Firm S, Firm A will not invest, resulting in $\Pi = (1 - \frac{t}{2}) + (1 - \frac{t}{2}) = 2 - t$. However, if the Period 1 supplier is Firm T and Firm A invests, the total industry profits are $\Pi = (t) - c + (\Delta - t) = \Delta - c$. The

Table 2: Equilibrium outcomes of the main model ($\Delta < 3t$).

Equilibrium Outcomes		**Condition**		
		$c < \frac{\Delta}{6}$	$\max\{\frac{\Delta}{6}, \frac{\Delta^2-18t+27t^2}{9t}\} < c$	$\frac{\Delta}{6} < c < \frac{\Delta^2-18t+27t^2}{9t}$
Firm A Sources from ...		Firm S (both periods)	Firm S (both periods)	Firm T (both periods)
Period 1	$w_{S,1}$	$1 - \frac{3t}{2}$	$1 - \frac{3t}{2}$	–
Period 1	$F_{S,1}$	$\frac{1}{12}(9t - 8\Delta - 6)$	$\frac{1}{6}(9t - 2\Delta - 6 + 3c)$ if $c < \hat{c}$ $\frac{1}{4}(3t-2)$ if $c > \hat{c}$	–
Period 1	$\pi_{A,1}$	$\frac{1}{12}(-3t + 8\Delta + 6)$	$\frac{1}{6}(-6t + 2\Delta + 6 - 3c)$ if $c < \hat{c}$ $\frac{1}{4}(-t+2)$ if $c > \hat{c}$	$\frac{t}{2}$
Period 1	$\pi_{S,1}$	$\frac{1}{12}(-3t - 8\Delta + 6)$	$\frac{1}{6}(3t - 2\Delta + 3c)$ if $c < \hat{c}$ $\frac{1}{4}(-t+2)$ if $c > \hat{c}$	$\frac{t}{2}$
Period 1	Π_1	$1 - \frac{t}{2}$	$1 - \frac{t}{2}$	t
Firm A invests?		Yes	No	Yes
Period 2	$w_{S,2}$	$\Delta + 1 - \frac{3t}{2}$	$1 - \frac{3t}{2}$	–
Period 2	$F_{S,2}$	$\frac{1}{12}(9t - 2\Delta - 6)$	$\frac{1}{4}(3t-2)$	–
Period 2	$\pi_{A,2}$	$\frac{1}{12}(-3t + 2\Delta + 6)$	$\frac{1}{4}(-t+2)$	$\frac{1}{18t}(3t+\Delta)^2$
Period 2	$\pi_{S,2}$	$\frac{1}{12}(-3t + 10\Delta + 6)$	$\frac{1}{4}(-t+2)$	$\frac{1}{18t}(3t-\Delta)^2$
Period 2	Π_2	$\Delta + 1 - \frac{t}{2}$	$1 - \frac{t}{2}$	$t + \frac{\Delta^2}{9t}$
Across Periods	π_A	$\frac{1}{6}(-3t + 5\Delta + 6) - c$	$\frac{1}{12}(-15t + 4\Delta + 18 - 6c)$ if $c < \hat{c}$ $\frac{1}{2}(-t+2)$ if $c > \hat{c}$	$t + \frac{\Delta^2}{18t} + \frac{\Delta}{3} - c$
Across Periods	π_S	$\frac{1}{6}(-3t + \Delta + 6)$	$\frac{1}{12}(3t - 4\Delta + 6 + 6c)$ if $c < \hat{c}$ $\frac{1}{2}(-t+2)$ if $c > \hat{c}$	$t + \frac{\Delta^2}{18t} - \frac{\Delta}{3}$
Across Periods	Π	$\Delta + 2 - t - c$	$2 - t$	$2t + \frac{\Delta^2}{9t} - c$

latter is smaller because $c > \Delta + t - 2$. If the Period 1 supplier is Firm T and Firm A does not invest, total industry profits are $\Pi = (t) + (1 - \frac{t}{2}) = 1 + \frac{t}{2}$, which is again smaller than $2 - t$. Consequently, Firm A buys from Firm S in both periods and does not invest if $\max\{\frac{t}{2}, \Delta + t - 2\} < c$.

3. Finally, if $\frac{t}{2} < c < \Delta + t - 2$, it implies $c < \Delta - \frac{3t}{4} - \frac{1}{2}$ and $1 + \frac{t}{2} < \Delta$. If the Period 1 supplier is Firm S, per Lemma 6's proof, Firm A will not invest, resulting in $\Pi = (1 - \frac{t}{2}) + (1 - \frac{t}{2}) = 2 - t$. However, it invests if the Period 1 supplier is Firm T, yielding a

total industry profit of $\Pi = (t) - c + (\Delta - t) = \Delta - c$. The latter is larger because $c < \Delta + t - 2$. Hence, Firm A buys from Firm T in both periods and invests if $\frac{t}{2} < c < \Delta + t - 2$.

We now calculate the fixed payment. Consider $c < \frac{t}{2}$. Then,

$$\pi_A = \underbrace{(\frac{t}{2} - F_{S,1})}_{Period\ 1} - \underbrace{c}_{investment\ cost} + \underbrace{\frac{1}{2} + \frac{t}{4}}_{Period\ 2},$$

$$\pi_S = \underbrace{(\frac{t}{2} + (1 - \frac{3t}{2}) + F_{S,1})}_{Period\ 1} + \underbrace{\Delta + \frac{1}{2} - \frac{3t}{4}}_{Period\ 2}$$

$$\pi_S - \pi_A = 2F_{S,1} + c + \Delta - \tfrac{5t}{2} + 1$$

If Firm A and Firm S fail to agree in period 1, Firm A contracts with Firm T in period 1. Then, per Lemma 6, it invests if and only if $\Delta > 1 + \frac{t}{2} = \hat{\Delta}$ and $c < \Delta - \frac{3t}{4} - \frac{1}{2}$. Therefore, the disagreement payoffs, π_A^O and π_S^O, depend on whether or not $\Delta > \hat{\Delta}$. In particular, if $\Delta > \hat{\Delta}$, then $c < \frac{t}{2}$ implies $c < \Delta - \frac{3t}{4} - \frac{1}{2}$. Therefore,

$$\pi_A^O = (\tfrac{t}{2}) - c + (\Delta - t),$$

$$\pi_S^O = (\tfrac{t}{2}) + (0)$$

$$\pi_S^O - \pi_A^O = c + t - \Delta$$

Whereas if $\Delta < \hat{\Delta}$, investment does not occur:

$$\pi_A^O = (\tfrac{t}{2}) + (\tfrac{1}{2} - \tfrac{t}{4}),$$

$$\pi_S^O = (\tfrac{t}{2}) + (\tfrac{1}{2} - \tfrac{t}{4})$$

$$\pi_S^O - \pi_A^O = 0$$

The fixed payment is derived from $\pi_S - \pi_A = \pi_S^O - \pi_A^O$. Hence, $F_{S,1} = -\Delta - \frac{1}{2} + \frac{7t}{4}$ if $\Delta > 1 + \frac{t}{2}$ and $F_{S,1} = -\frac{\Delta}{2} - \frac{1}{2} + \frac{5t}{4} - \frac{c}{2}$, otherwise.

Consider $\max\{\frac{t}{2}, \Delta + t - 2\} < c$. Then,

$$\pi_A = \underbrace{(\frac{t}{2} - F_{S,1})}_{Period\ 1} + \underbrace{\frac{1}{4}(-t + 2)}_{Period\ 2},$$

$$\pi_S = \underbrace{(\frac{t}{2} + (1 - \frac{3t}{2}) + F_{S,1})}_{Period\ 1} + \underbrace{\frac{1}{4}(-t + 2)}_{Period\ 2}$$

$$\pi_S - \pi_A = 2F_{S,1} + 1 - \tfrac{3t}{2}$$

If Firm A and Firm S fail to agree in period 1, Firm A contracts with Firm T in period 1. Then, per Lemma 6, it invests if and only if $\Delta > 1 + \frac{t}{2} = \hat{\Delta}$ and $c < \Delta - \frac{3t}{4} - \frac{1}{2}$. Therefore, if $\Delta > \hat{\Delta}$ and $c < \Delta - \frac{3t}{4} - \frac{1}{2}$, or, $\Delta > \max\{\hat{\Delta}, c + \frac{3t}{4} + \frac{1}{2}\} = \bar{\Delta}$,

$\pi_A^O = (\frac{t}{2}) - c + (\Delta - t)$,

$\pi_S^O = (\frac{t}{2}) + (0)$

$\pi_S^O - \pi_A^O = c + t - \Delta$

Otherwise, if $\Delta < \bar{\Delta}$, investment does not occur, and:

$\pi_A^O = (\frac{t}{2}) + (\frac{1}{2} - \frac{t}{4})$,

$\pi_S^O = (\frac{t}{2}) + (\frac{1}{2} - \frac{t}{4})$

$\pi_S^O - \pi_A^O = 0$

The fixed payment is derived from $\pi_S - \pi_A = \pi_S^O - \pi_A^O$. Hence, $F_{S,1} = \frac{1}{4}(5t - 2\Delta - 2 + 2c)$ if $\Delta > \bar{\Delta}$ and $F_{S,1} = -\frac{1}{2} + \frac{3t}{4}$, otherwise. Table 3 summarizes the game outcomes for the case of $\Delta > 3t$.

A.8 Proof of Proposition 2

The condition for the focal firm to source from the third party based on Proposition 1 is $\frac{\Delta}{6} < c < \frac{\Delta^2 - 18t + 27t^2}{9t}$, which can hold only if $\frac{\Delta}{6} < \frac{\Delta^2 - 18t + 27t^2}{9t}$. After rearranging terms, the latter condition is equivalent to: $2\Delta^2 - 3t\Delta - 36t + 54t^2 > 0$. Applying the quadratic equation and given $t < \frac{2}{3}$, we find that this inequality holds if and only if $\Delta > [3t + \sqrt{9t^2 + 4(72t - 108t^2)}]/4$, which is equivalent to $\Delta > \frac{3}{4}(t + \sqrt{32t - 47t^2})$. For $\Delta < 3t$, this inequality can hold only if $\frac{3}{4}(t + \sqrt{32t - 47t^2}) < 3t$, which is equivalent to $32t - 47t^2 < 9t^2$ and to $t > \frac{4}{7}$. Furthermore, we have $\frac{\partial}{\partial t}[\frac{\Delta^2 - 18t + 27t^2}{9t}] = 3 - \frac{\Delta^2}{9t^2}$, which is strictly positive for $\Delta < 3t$. Therefore, as t increases, the region of sourcing from the third party expands.

A.9 Proof of Lemma 7

In the model extension, the joint profits for Firms A and T if they reach an agreement are the same as the profits for Firm A in the main version of the model when it buys from Firm

Table 3: Equilibrium outcomes of the main model ($\Delta > 3t$).

Equilibrium Outcomes		**Condition:** $c < \frac{t}{2}$	**Condition:** $\max\{\frac{t}{2}, \Delta + t - 2\} < c$	**Condition:** $\frac{t}{2} < c < \Delta + t - 2$
Firm A Sources from ...		Firm S (both periods)	Firm S (both periods)	Firm T (both periods)
Period 1	$w_{S,1}$	$1 - \frac{3t}{2}$	$1 - \frac{3t}{2}$	–
Period 1	$F_{S,1}$	$\frac{1}{4}(7t - 4\Delta - 2)$ if $\Delta > \hat{\Delta}$ $\frac{1}{4}(5t - 2\Delta - 2 - 2c)$ if $\Delta < \hat{\Delta}$	$\frac{1}{4}(5t - 2\Delta - 2 + 2c)$ if $\Delta > \bar{\Delta}$ $\frac{1}{4}(3t - 2)$ if $\Delta < \bar{\Delta}$	–
Period 1	$\pi_{A,1}$	$\frac{1}{4}(-5t + 4\Delta + 2)$ if $\Delta > \hat{\Delta}$ $\frac{1}{4}(-3t + 2\Delta + 2 + 2c)$ if $\Delta < \hat{\Delta}$	$\frac{1}{4}(-3t + 2\Delta + 2 - 2c)$ if $\Delta > \bar{\Delta}$ $\frac{1}{4}(-t + 2)$ if $\Delta < \bar{\Delta}$	$\frac{t}{2}$
Period 1	$\pi_{S,1}$	$\frac{1}{4}(3t - 4\Delta + 2)$ if $\Delta > \hat{\Delta}$ $\frac{1}{4}(t - 2\Delta + 2 - 2c)$ if $\Delta < \hat{\Delta}$	$\frac{1}{4}(t - 2\Delta + 2 + 2c)$ if $\Delta > \bar{\Delta}$ $\frac{1}{4}(-t + 2)$ if $\Delta < \bar{\Delta}$	$\frac{t}{2}$
Period 1	Π_1	$1 - \frac{t}{2}$	$1 - \frac{t}{2}$	t
Firm A invests?		Yes	No	Yes
Period 2	$w_{S,2}$	$\Delta + 1 - \frac{3t}{2}$	$1 - \frac{3t}{2}$	–
Period 2	$F_{S,2}$	$\frac{1}{4}(t - 2)$	$\frac{1}{4}(3t - 2)$	–
Period 2	$\pi_{A,2}$	$\frac{1}{2} + \frac{t}{4}$	$\frac{1}{4}(-t + 2)$	$\Delta - t$
Period 2	$\pi_{S,2}$	$\Delta + \frac{1}{2} - \frac{3t}{4}$	$\frac{1}{4}(-t + 2)$	0
Period 2	Π_2	$\Delta + 1 - \frac{t}{2}$	$1 - \frac{t}{2}$	$\Delta - t$
Across Periods	π_A	$-t + \Delta + 1 - c$ if $\Delta > \hat{\Delta}$ $\frac{1}{2}(-t + \Delta + 2 - c)$ if $\Delta < \hat{\Delta}$	$\frac{1}{4}(-4t + 2\Delta + 4 - 2c)$ if $\Delta > \bar{\Delta}$ $\frac{1}{2}(-t + 2)$ if $\Delta < \bar{\Delta}$	$\Delta - \frac{t}{2} - c$
Across Periods	π_S	1 if $\Delta > \hat{\Delta}$ $\frac{1}{2}(-t + \Delta + 2 - c)$ if $\Delta < \hat{\Delta}$	$\frac{1}{4}(-2\Delta + 4 + 2c)$ if $\Delta > \bar{\Delta}$ $\frac{1}{2}(-t + 2)$ if $\Delta < \bar{\Delta}$	$\frac{t}{2}$
Across Periods	Π	$\Delta + 2 - t - c$	$2 - t$	$\Delta - c$

T. Conditional on any given product price for Firm S, these joint profits of Firms A and T are maximized when Firm A chooses a product price to set its first-order condition equal to zero given a wholesale input price of $w_{T,i} = 0$ (see the proof of Lemma 1). Any higher value of $w_{T,i}$ results in Firm A setting a product price higher than the level that maximizes these joint profits.

A.10 Proof of Lemma 8

Similar to the main model (see Lemma 5), Firm A can continue with Firm T or switch to Firm S. Period 2 industry profits if it continues with Firm T are $\Pi_2 = t + \frac{\Delta^2}{9t}$. Period 2 industry profits if it switches to Firm S are $\Pi_2 = 1 - \frac{t}{2}$. We have, $t + \frac{\Delta^2}{9t} > 1 - \frac{t}{2} \Leftrightarrow \frac{\Delta^2}{9t} > 1 - \frac{3t}{2}$.

We now derive the fixed payment when Firm A contracts with Firm T (when $\frac{\Delta^2}{9t} > 1 - \frac{3t}{2}$). We derive the disagreement payoffs. If Firm A contracts with Firm T, then Firm S makes $\pi_{S,2} = \frac{1}{18t}(3t - \Delta)^2$, so this is the lowest profit Firm S would accept. Therefore, if Firm A and T contract, Firm A's disagreement payoff is $\pi^O_{A,2} = 1 - \frac{t}{2} - \frac{1}{18t}(3t - \Delta)^2$. Firm T's disagreement payoff is zero.

We have: $\pi_{A,2} - \pi^O_{A,2} = \pi_{T,2} - \pi^O_{T,2} \Rightarrow (\frac{1}{18t}(3t+\Delta)^2 - F_{T,2}) - (1 - \frac{t}{2} - \frac{1}{18t}(3t-\Delta)^2) = (F_{T,2}) - 0$. Thus, $F_{T,2} = \frac{1}{2}(\frac{\Delta^2}{9t} - (1 - \frac{3t}{2}))$. Inserting the fixed fee back into Firm A and Firm T profits results in the expressions in the Lemma.

A.11 Proof of Lemma 9

If Firm A buys from Firm S in period 1, its profits in period 2 are $\pi_{A,2} = \frac{1}{12}(2\Delta - 3t + 6)$ if it invests (see Lemma 4) and $\pi_{A,2} = \frac{1}{4}(2 - t)$ if it does not invest (see Lemma 3). Therefore, Firm A will invest c if and only if the difference between these two is larger than investment cost c, that is, $c < \frac{\Delta}{6}$.

If Firm A buys from Firm T in period 1, its profits in period 2 are $\pi_{A,2} = \frac{1}{4}(2-t) + \frac{1}{3}\Delta$ if it invests (see Lemma 8) and $\pi_{A,2} = \frac{1}{4}(2 - t)$ if it does not invest (see Lemma 3). Therefore, Firm A will invest c if and only if $c < \frac{\Delta}{3}$.

A.12 Proof of Proposition 3

If $c < \frac{\Delta}{6}$, Firm A will invest if it contracts with Firm S (see Lemma 9). Therefore, Firm A buys from Firm S in both periods and invests.

If $c > \frac{\Delta}{3}$, Firm A never invests (see Lemma 9). Thus, Firm A buys from Firm S in both periods.

If $\frac{\Delta}{6} < c < \frac{\Delta}{3}$, Firm A invests only if the period 1 supplier is Firm T. In this case, industry profits across two periods are:

$$\Pi^{AT \to I \to AT} = t + t + \frac{\Delta^2}{9t} - c$$

However, if Firm A contracts with Firm S in both periods and does not invest:

$\Pi^{AS\to N\to AS} = 1 - \frac{t}{2} + 1 - \frac{t}{2}$

The former is larger if and only if $c < \frac{\Delta^2-18t+27t^2}{9t}$. Thus, Firm A buys from Firm T in both periods and invests in Firm T's input if $\frac{\Delta}{6} < c < \min\{\frac{\Delta}{3}, \frac{\Delta^2-18t+27t^2}{9t}\} = \frac{\Delta^2-18t+27t^2}{9t}$. Otherwise, if $\max\{\frac{\Delta}{6}, \frac{\Delta^2-18t+27t^2}{9t}\} < c$, Firm A buys from Firm S in both periods without investing in the input. The regions are the same as those in Proposition 1.

B Appendix B: Model Extensions and Variations

B.1 Multiparty Negotiation with $w_{T,i} > 0$

In the multiparty negotiation model in the body of the paper, we require the input contract with the third party to be renegotiation-proof, which implies $w_{T,i} = 0$. To illustrate the importance of renegotiation-proof contracts, this appendix presents a model of multiparty negotiation that allows $w_{T,i} > 0$ and shows how the equilibrium regions for different supplier choices and investment decisions change under this alternative set-up. In this case, Firm A may agree to a high per-unit input price with Firm T in order to compel Firm S to set a higher product price.

We follow the same backwards induction process as in the main model. We drive the equilibrium prices. We then derive the period 2 supply contract. After that, we derive the innovation investment. Finally, we derive the period 1 supply contract, leading to equilibrium of the entire game.

B.1.1 Pricing

If Firm A buys Firm S, outcomes are the same as in main model (Lemma 1). However, if Firm A contracts with Firm T, it buys each unit of the input at $w_{T,i}$, and this per-unit fee may be strictly positive. We drop the subscript i in the following lemma for clarity of exposition.

Lemma 10. *(i) If Firm A buys from Firms S, product prices are:* $p_A = t + \frac{v_A - v_S}{3} + w_S$ *and* $p_S = t + \frac{v_S - v_A}{3} + w_S$*, profits are:* $\pi_A = \frac{1}{18t}(3t + v_A - v_S)^2 - F_S$ *and* $\pi_S = \frac{1}{18t}(3t - v_A + v_S)^2 + (w_S + F_S)$*, and industry profits are:* $\Pi_i = t + \frac{1}{9t}(v_A - v_S)^2 + w_S$ *for all* $w_S \in [0, \frac{1}{2}(v_A + v_S - 3t)]$*.*

(ii) If Firm A buys from Firm T, prices are: $p_A = t + \frac{v_A - v_S}{3} + \frac{2}{3}w_T$ *and* $p_S = t + \frac{v_S - v_A}{3} + \frac{1}{3}w_T$*, profits are:* $\pi_A = \frac{1}{18t}(3t - w_T + v_A - v_S)^2 - F_T$*,* $\pi_S = \frac{1}{18t}(3t + w_T - v_A + v_S)^2$*, and* $\pi_T = \frac{1}{6t}w_T(3t - w_T + v_A - v_S) + F_T$ *and industry profits are:* $\Pi_i = t + \frac{1}{9t}(v_A - v_S - w_T)^2 + \frac{1}{6t}w_T(3t - w_T + v_A - v_S)$ *for all* $w_T \in [0, (v_A + v_S - 3t)]$*.*

Proof: The first part is the same as Lemma 1. The second part is the standard Hotelling model with Firm A's marginal cost w_T. In particular, the indifferent customer is at location $x = \frac{1}{2} - \frac{p_A - p_S + v_S - v_A}{2t}$. Firm A and S profits are: $\pi_A = (p_A - w_T)(\frac{1}{2} - \frac{p_A - p_S + v_S - v_A}{2t})$ and $\pi_S = p_S(\frac{1}{2} + \frac{p_A - p_S + v_S - v_A}{2t})$. Solving the first-order conditions, equilibrium prices are: $p_A = t + \frac{v_A - v_S}{3} + \frac{2}{3}w_T$ and $p_S = t + \frac{v_S - v_A}{3} + \frac{1}{3}w_T$. Equilibrium quantities are: $q_A = \frac{1}{2} - \frac{v_S - v_A}{6t} - \frac{1}{6t}w_T$ and $q_S = \frac{1}{2} + \frac{v_S - v_A}{6t} + \frac{1}{6t}w_T$. Hence, for positive market shares we require $-3t + v_A - v_S < w_T < 3t + v_A - v_S$. Equilibrium profits are: $\pi_A = \frac{1}{18t}(3t - w_T + v_A - v_S)^2$ and $\pi_S = \frac{1}{18t}(3t + w_T - v_A + v_S)^2$. Full market coverage requires that the indifferent customer x to have positive utility, so, $v_A - p_A - tx > 0$, that is, $v_A + v_S - 3t > w_T$. We note that although prices are increasing in w_T, buying from the rival mitigates price competition to a larger extent because both prices increase by w_S.

Next, similar to Lemma 2, we derive the wholesale price that maximizes total profits of the negotiating firms. We drop the subscript i in the following lemma.

Lemma 11. *(i) If Firm A purchases the input from Firm S in period* i*, total Firm A and Firm S profits are maximized by setting wholesale input price* $w_S = \frac{1}{2}(v_A + v_S - 3t)$*, resulting in* $\pi_A = \frac{1}{18t}(3t + v_A - v_S)^2 - F_S$*,* $\pi_S = \frac{1}{18t}(3t - v_A + v_S)^2 + \frac{1}{2}(v_A + v_S - 3t + F_S)$*,* $\pi_T = 0$*, and total industry profits* $\Pi_i = \frac{1}{2}(v_A + v_S) + \frac{1}{9t}(v_S - v_A)^2 - \frac{1}{2}t$*.*

(ii) If Firm A purchases the input from Firm T in period i*, total Firm A and Firm T profits are maximized by setting wholesale input price* $w_T = \frac{1}{4}(v_A - v_S + 3t)$*, resulting in* $\pi_A = \frac{1}{32t}(3t + v_A - v_S)^2 - F_T$*,* $\pi_S = \frac{1}{32t}(5t - v_A + v_S)^2$*, and* $\pi_T = \frac{1}{32t}(3t + v_A - v_S)^2 + F_T$ *and*

the total industry profits $\Pi_i = \frac{1}{32t}(43t^2 + 2t(v_A - v_S) + 3(v_S - v_A)^2)$.

Proof. The first part of lemma is the same as Lemma 2. For the second part, we derive the first order condition:

$$\frac{d}{dw_T}(\pi_A + \pi_T) = \frac{d}{dw_T}(\frac{1}{18t}(3t - w_T + v_A - v_S)^2 + \frac{1}{6t}w_T(3t - w_T + v_A - v_S)) = 0,$$

yielding $w_T = \frac{1}{4}(v_A - v_S + 3t)$. To make sure market is fully covered we require $w_T = \frac{1}{4}(v_A - v_S + 3t) \in [0, (v_A + v_S - 3t)]$. Thus, $15t < 3v_A + 5v_S$. The valuations are equal or greater than one. Thus, a sufficient condition that guarantees interior solution would be $15t < 3+5$, or $t < \frac{8}{15}$, a stricter requirement than the condition $t < \frac{2}{3}$ from our main model.

B.1.2 Supply Contract in period 2

Similar to our base model, there are three sub-games: No investment in period 1, investment in the Firm S input, and investment in the Firm T input. The following three lemmas characterize the equilibrium for these three sub-games.

Lemma 12. *If Firm A did not invest in innovation in period 1, in period 2 it buys the input from the competitor, with contract* $w_{S,2} = 1 - \frac{3t}{2}$ *and* $F_{S,2} = \frac{55}{64}t - \frac{1}{2}$*, which results in profits* $\pi_{A,2} = \frac{1}{64}(32 - 23t)$*,* $\pi_{S,2} = \frac{1}{64}(32 - 9t)$*, and industry profit* $\Pi_2 = 1 - \frac{t}{2}$.

Proof. Thus, similar to main model, Firm A contracts with Firm S in period 2 if there was no investment in period 1. To prove this, we show that total industry profits are higher with this A-S contract. Using Lemma 11 with $v_{A,2} = v_{S,2} = 1$, the A-S contract results in $\Pi_2 = 1 - \frac{1}{2}t$ whereas the A-T contract results in $\Pi_2 = \frac{43}{32}t$. The former is higher because $t < \frac{8}{15} < \frac{32}{59}$. Thus, without period 1 investment, Firm A contracts with Firm S.

We now derive the the fixed payment ($F_{S,2}$). We first need to determine disagreement payoffs. Firm A's disagreement payoff ($\pi^O_{A,2}$) is the total maximum Firm A and Firm T combined profits at the maximizing wholesale price $w_{T,2} = \frac{1}{4}(v_{A,2} - v_{S,2} + 3t) = \frac{3t}{4}$. Inserting this wholesale price into Firm A and Firm T profits in Lemma 11 yields:

$$\pi^O_{A,2} = (\pi_{A,2} + \pi_{T,2}) \text{ at } \{w_{T,2} = \tfrac{3t}{4}\} = \tfrac{9t}{32} + \tfrac{9t}{32} = \tfrac{18t}{32}.$$

Moreover, at this level of wholesale price ($w_{T,2} = \frac{3t}{4}$), Firm S would make $\frac{25}{32}t$, which would be its disagreement payoff ($\pi^O_{S,2} = \frac{25}{32}t$). The fixed payment is derived from:

$$\pi_{A,2} - \pi^O_{A,2} = \pi_{S,2} - \pi^O_{S,2} \Rightarrow (\tfrac{t}{2} - F_{S,2}) - (\tfrac{18}{32}t) = (1 - t + F_{S,2}) - (\tfrac{25}{32}t) \Rightarrow F_{S,2} = \tfrac{55}{64}t - \tfrac{1}{2}.$$

Inserting this fixed payment into each firm's profits results in the expressions in Lemma 12. Next, we solve the second sub-game.

Lemma 13. *If Firm A buys input from the competitor in period 1 and invests in innovation, then in period 2 it again buys the input from the competitor with contract* $w_{S,2} = 1 + \Delta - \frac{3t}{2}$ *and* $F_{S,2} = \frac{1}{192t}(-3\Delta^2 - 96t - 46\Delta t + 165t^2)$*, leading to period 2 profits* $\pi_{A,2} = \frac{1}{64t}(\Delta^2 + 32t + 10\Delta t - 23t^2)$ *and* $\pi_{S,2} = \frac{1}{64t}(-\Delta^2 + 32t + 54\Delta t - 9t^2)$*, and industry profits* $\Pi_2 = 1 + \Delta - \frac{t}{2}$.

Proof. Thus, similar to the main model, Firm A continues with Firm S in period 2. To prove this, we show that total industry profit is higher with the A-S contract. Per Lemma 11 with $v_{A,2} = v_{S,2} = 1 + \Delta$, the A-S contract would result in $\Pi_2 = 1 - \frac{1}{2}t + \Delta$ whereas the A-T contract results in $\Pi_2 = \frac{1}{32t}(43t^2 - 2t\Delta + 3\Delta^2)$. The former is larger since $t < \frac{8}{15}$. Thus, Firm A continues with Firm S in period 2.

We now derive the the fixed payment ($F_{S,2}$). Firm A's disagreement payoff ($\pi^O_{A,2}$) is: $\pi^O_{A,2} = (\pi_{A,2} + \pi_{T,2})$ *at* $\{w_{T,2} = \frac{1}{4}(3t - \Delta)\} = \frac{1}{16t}(3t - \Delta)^2$ (see Lemma 11). Moreover, Firm S's disagreement payoff is $\pi^O_{S,2} = \frac{1}{32t}(5t + \Delta)^2$. The fixed payment is derived from: $\pi_{A,2} - \pi^O_{A,2} = \pi_{S,2} - \pi^O_{S,2}$, leading to $F_{S,2} = \frac{1}{192t}(-3\Delta^2 - 96t - 46\Delta t + 165t^2)$, and period 2 profits $\pi_{A,2} = \frac{1}{64t}(\Delta^2 + 32t + 10\Delta t - 23t^2)$ and $\pi_{S,2} = \frac{1}{64t}(-\Delta^2 + 32t + 54\Delta t - 9t^2)$.

Lemma 14. *Suppose in period 1 Firm A buys input from Firm T and invests in improving its input. In period 2,*

(i) if $59t^2 + 2t\Delta + 3\Delta^2 > 32t$*, Firm A buys the input from the third party with supply arrangement* $w_{T,2} = \frac{1}{4}(3t + \Delta)$ *and* $F_{T,2} = \frac{1}{64t}(\Delta^2 - 10\Delta t - 32t + 41t^2)$*. Firms make* $\pi_{A,2} = \frac{1}{64t}(\Delta^2 + 32t + 22t\Delta - 23t^2)$ *and* $\pi_{S,2} = \frac{1}{32t}(5t - \Delta)^2$*, and* $\pi_{T,2} = \frac{1}{64t}(3\Delta^2 - 32t + 2t\Delta + 59t^2)$*, leading to industry profits of* $\Pi_2 = \frac{1}{32t}(3\Delta^2 + 2t\Delta + 43t^2)$.

(ii) if $59t^2 + 2t\Delta + 3\Delta^2 < 32t$*, Firm A buys the input from its competitor, with input contract* $w_{S,2} = 1 - \frac{3t}{2}$ *and* $F_{S,2} = \frac{1}{64t}(\Delta^2 - 22\Delta t - 32t + 55t^2)$*. Firm profits are* $\pi_{A,2} =$

$\frac{1}{64t}(\Delta^2+32t+22t\Delta-23t^2)$, $\pi_{S,2}=\frac{1}{64t}(-\Delta^2+32t-22t\Delta-9t^2)$, *and* $\pi_{T,2}=0$, *with industry profits* $\Pi_2=1-\frac{t}{2}$.

Proof: Thus, similar to the main model (see Lemma 5), Firm A might continue with Firm T or switch to Firm S. Total period 2 industry profits if it continues with Firm T are $\Pi_2=\frac{1}{32t}(43t^2+2t\Delta+3\Delta^2)$ (we insert $v_{A,2}=1+\Delta, v_{S,2}=1$ into Lemma 11). The total period 2 industry profits if it switches to Firm S are $\Pi_2=1-\frac{t}{2}$. Then, $\frac{1}{32t}(43t^2+2t\Delta+3\Delta^2)>1-\frac{t}{2}\Leftrightarrow 59t^2+2t\Delta+3\Delta^2>32t$. The derivation of fixed payments and equilibrium profits are similar to the previous two lemmas.

B.1.3 Focal Firm's Investment Decision

We derive the focal firm's investment decision given the outcome of the negotiation in period 1.

Lemma 15. *In period 1, if Firm A buys the input from Firm S, it invests if and only if* $c<\frac{\Delta(\Delta+10t)}{64t}$. *If Firm A buys from Firm T, it invests if and only if* $c<\frac{(\Delta+22t)}{64t}$.

Proof: If Firm A buys from Firm S in period 1, its profits in period 2 are $\pi_{A,2}=\frac{1}{64t}(\Delta^2+10t\Delta+32t-23t^2)$ if it invests (see Lemma 13) and $\pi_{A,2}=\frac{1}{64}(32-23t)$ if it does not invest (see Lemma 12). Therefore, Firm A will invest c if and only if the difference between these two profits is larger than investment cost c, that is, $c<\frac{\Delta(\Delta+10t)}{64t}$.

If Firm A buys from Firm T in period 1, its profit in period 2 are $\pi_{A,2}=\frac{1}{64t}(\Delta^2+22t\Delta+32t-23t^2)$ if it invests (see Lemma 14) and $\pi_{A,2}=\frac{1}{64}(32-23t)$ if it does not invest (see Lemma 12). Therefore, Firm A will invest c if and only if $c<\frac{\Delta(\Delta+22t)}{64t}$.

B.1.4 Supply Contract in period 1

Next we derive the negotiation outcome in period 1. Product values are low in this period ($v_{A,1}=v_{S,1}=1$). Therefore, industry profits in period 1 are $1-\frac{t}{2}$ if Firm A contracts with Firm S, and $\frac{43t}{32}$ if Firm A contracts with Firm T. Note that when firms engage in bilateral negotiation in period 1, they account for the impact of the period 1 negotiation on the profits they earn in period 2. The winner of the negotiation in period 1 is the supplier that leads to higher total industry profits across the two periods.

Proposition 7. *(i) Firm A buys from Firm S in both periods and invests in Firm S's input if* $c < \frac{\Delta(\Delta+10t)}{64t}$*. (ii) Firm A buys from Firm S in both periods without investing in the input if* $\max\{\frac{\Delta(\Delta+10t)}{64t}, \frac{3\Delta^2-64t+2\Delta t+118t^2}{32t}\} < c$*. (iii) Firm A buys from Firm T in both periods and invests in Firm T's input if* $\frac{\Delta(\Delta+10t)}{64t} < c < \frac{3\Delta^2-64t+2\Delta t+118t^2}{32t}$*.*

Proof: If $c < \frac{\Delta(\Delta+10t)}{64t}$, Firm A will invest if it contracts with Firm S in period 1 (see Lemma 15). Therefore, Firm A buys from Firm S in both periods and invests.

If $c > \frac{\Delta(\Delta+22t)}{64t}$, Firm A never invests (see Lemma 15). Thus, Firm A buys from Firm S in both periods.

When $\frac{\Delta(\Delta+10t)}{64t} < c < \frac{\Delta(\Delta+22t)}{64t}$, Firm A invests only if the period 1 supplier is Firm T. If so, industry profits across the two periods are:

$\Pi^{AT\to I\to AT} = \frac{43t}{32} + \frac{1}{32t}(3\Delta^2 + 2t\Delta + 43t^2) - c$

However, if Firm A contracts with Firm S in both periods and does not invest:

$\Pi^{AS\to N\to AS} = 1 - \frac{t}{2} + 1 - \frac{t}{2}$

The former is larger if and only if $c < \frac{3\Delta^2-64t+2\Delta t+118t^2}{32t}$. Thus, Firm A buys from Firm T in both periods and invests in Firm T's input if $\frac{\Delta(\Delta+10t)}{64t} < c < Min\{\frac{3\Delta^2-64t+2\Delta t+118t^2}{32t}, \frac{\Delta(\Delta+22t)}{64t}\} = \frac{3\Delta^2-64t+2\Delta t+118t^2}{32t}$. This condition requires $t > \frac{128}{263}$, which is a wider condition compared to the main model $t > \frac{4}{7}$ (see Proposition 2). Thus, Firm T's bargaining power over the supply arrangement and ability to commit to a positive per-unit input price expands the region of parameters in which Firm A contracts with the third-party across the two periods.

B.2 Proof of Proposition 4 (Investment by the Competitive Supplier)

We follow the same backward induction process as in the main model. We first derive the equilibrium prices. Then we derive the period 2 supply contract. Next we derive the investment decisions by Firm A and Firm S. Finally, we derive the period 1 supply contract.

B.2.1 Pricing

Pricing remains the same as in the main model. Lemma 1 and Lemma 2 continue to hold.

B.2.2 Supply Contract in period 2

We now derive the equilibrium contract in the second period (corresponding to Lemmas 3, 4, and 5 in the main text). There are eight sub-games depending on the period 1 supplier and whether Firm A and Firm S decide to invest ($2 \times 2 \times 2$). When neither firm invests, the outcomes derived in Lemma 3 continue to hold. If only Firm S invests in innovation, then in period 2 Firm A buys the input from the competitor, and the outcomes are the same as in Lemma 4. Similarly, if in period 1 Firm A buys the input from Firm S and invests in improving its input, but Firm S does not invest, then in period 2, Firm A buys the input from the competitor, and the outcomes are the same as Lemma 4. Moreover, suppose in period 1 Firm A buys the input from Firm T and invests in improving its input, and Firm S does not invest in its input. In this case, the period 2 contract is the same as in Lemma 5.

There are two additional sub-games that we need to examine, described in the following two lemmas.

Lemma 16. *Suppose in period 1, Firm A buys the input from Firm S and invests in improving its input, and Firm S also invests in its input. In period 2, Firm A buys the input from the competitor with contract* $w_{S,2} = 1 + 2\Delta - \frac{3t}{2}$ *and* $F_{S,2} = -\frac{1}{2}w_{S,2} + \frac{2\Delta}{3}$*, leading to period 2 profits* $\pi_{A,2} = \frac{1}{12}(4\Delta - 3t + 6)$ *and* $\pi_{S,2} = \frac{1}{12}(20\Delta - 3t + 6)$*, and industry profits*

$\Pi_2 = 1 - \frac{t}{2} + 2\Delta$.

Proof. We replace Δ by 2Δ in the main text's Lemma 4. Firm A prefers to continue sourcing from Firm S because, if it switches to Firm T, it loses all input improvement while Firm S uses the improved input.

Lemma 17. *Suppose in period 1 Firm A buys the input from Firm T and invests in its input, and Firm S also invests in its own input. In period 2, Firm A will switch to Firm S, with input contract* $w_{S,2} = 1 + \Delta - \frac{3t}{2}$ *and* $F_{S,2} = -\frac{1}{2}(1 + \Delta - \frac{3t}{2})$*, leading to profits,* $\pi_{A,2} = \pi_{S,2} = \frac{1}{2} - \frac{t}{4} + \frac{\Delta}{2}$*, and industry profits* $\Pi_2 = 1 - \frac{t}{2} + \Delta$.

Proof. If Firm A sources from Firm T in period 1 and invests c_A, and Firm S also invest c_S, then Firm A has 2 options: to continue with Firm T in period 2 or to switch to Firm S.

If Firm A continues sourcing from Firm T in period 2, we will have $v_{A,2} = 1 + \Delta$ and $v_{S,2} = 1 + \Delta$. Inserting these product values into Lemma 1, in period 2 we have $\pi_{A,2} = \frac{t}{2}$ and $\pi_{S,2} = \frac{t}{2}$, leading to an industry profits of $\Pi_2 = t$.

However, if in period 2 Firm A switches to Firm S, we have $v_{A,2} = v_{S,2} = 1 + \Delta$. Inserting these values into Lemma 1, industry profits are $\Pi_2 = 1 + \Delta - \frac{t}{2}$.

Given that $t < \frac{2}{3}$, we have $1 + \Delta - \frac{t}{2} > t$, so in period 2 Firm A will switch to Firm S. In this case, $w_{S,2} = 1 + \Delta - \frac{3t}{2}$. The fixed payment is derived from $\pi_{A,2} - \pi^O_{A,2} = \pi_{S,2} - \pi^O_{S,2}$. Inserting $\pi^O_{A,2} = \frac{t}{2}$ and $\pi^O_{S,2} = \frac{t}{2}$ yields: $\pi_{A,2} = \frac{t}{2} - F_{S,2} = \pi_{S,2} = \frac{t}{2} + w_{S,2} + F_{S,2}$. Thus, $F_{S,2} = -\frac{1}{2}w_{S,2} = -\frac{1}{2}(1 + \Delta - \frac{3t}{2})$. This leads to firm profits $\pi_{A,2} = \pi_{S,2} = \frac{t}{2} - F_{S,2} = \frac{t}{2} + \frac{1}{2}(1 + \Delta - \frac{3t}{2}) = \frac{1}{2} + \frac{\Delta}{2} - \frac{t}{4}$.

B.2.3 Firms' Investment Decisions

Having solved the equilibrium supply contract in period 2, we derive firms' investment decisions given the period 1 supplier. We first summarize the period 2 profits (derived above) net of investment cost in a 2×2 game payoff matrix. In the these tables, let $X = \frac{1}{2} - \frac{t}{4}$.

Table 4: When Period 1 supplier is Firm S

	Firm S invests = Yes	Firm S invests = No
Firm A invests = Yes	$(X+\frac{\Delta}{3}-c_A\ ,\ X+\frac{5\Delta}{3}-c_S)$	$(X+\frac{\Delta}{6}-c_A\ ,\ X+\frac{5\Delta}{6})$
Firm A invests = No	$(X+\frac{\Delta}{6}\ ,\ X+\frac{5\Delta}{6}-c_S)$	$(X\ ,\ X)$

Table 5: When Period 1 Supplier is Firm T ($\frac{\Delta^2}{9t}<1-\frac{3t}{2}$).

	Firm S invests = Yes	Firm S invests = No
Firm A invests = Yes	$(X+\frac{\Delta}{2}-c_A\ ,\ X+\frac{\Delta}{2}-c_S)$	$(X+\frac{\Delta}{3}-c_A\ ,\ X-\frac{\Delta}{3})$
Firm A invests = No	$(X+\frac{\Delta}{6}\ ,\ X+\frac{5\Delta}{6}-c_S)$	$(X\ ,\ X)$

Table 6: When Period 1 Supplier is Firm T ($\frac{\Delta^2}{9t}>1-\frac{3t}{2}$).

	Firm S invests = Yes	Firm S invests = No
Firm A invests = Yes	$(X+\frac{\Delta}{2}-c_A\ ,\ X+\frac{\Delta}{2}-c_S)$	$(\frac{t}{2}+\frac{\Delta}{3}+\frac{\Delta^2}{18t}-c_A\ ,\ \frac{t}{2}-\frac{\Delta}{3}+\frac{\Delta^2}{18t})$
Firm A invests = No	$(X+\frac{\Delta}{6}\ ,\ X+\frac{5\Delta}{6}-c_S)$	$(X\ ,\ X)$

The following three lemmas derive the Firm A and Firm S investment strategies.

Lemma 18. *If Firm A buys the input from Firm S in period 1, Firm A invests if and only if $c_A<\frac{\Delta}{6}$ whereas Firm S invests if and only if $c_S<\frac{5\Delta}{6}$.*

Proof. See Table 4.

Lemma 19. *If Firm A buys the input from Firm T in period 1 and $\frac{\Delta^2}{9t}<1-\frac{3t}{2}$, Firm A invests if and only if $c_A<\frac{\Delta}{3}$ whereas Firm S invests if and only if $c_S<\frac{5\Delta}{6}$.*

Proof. See Table 5.

Lemma 20. *If Firm A buys the input from Firm T in period 1 and $\frac{\Delta^2}{9t}>1-\frac{3t}{2}$, investment strategies are as shown in Table 7.*

Table 7: Firm A and Firm S Investment strategies when Period 1 Supplier is Firm T and $A = \frac{\Delta^2}{9t} - (1 - \frac{3t}{2}) > 0$.

c_A and c_S	$c_S < \frac{5\Delta}{6} - \frac{A}{2}$	$\frac{5\Delta}{6} - \frac{A}{2} < c_S < \frac{5\Delta}{6}$	$c_S > \frac{5\Delta}{6}$
$c_A < \frac{\Delta}{3}$	Both invest	Only A invests	Only A invests
$\frac{\Delta}{3} < c_A < \frac{\Delta}{3} + \frac{A}{2}$	Only S invests	Only A invests or Only S invests	Only A invests
$c_A > \frac{\Delta}{3} + \frac{A}{2}$	Only S invests	Only S invests	Neither invests

Proof. Using Table 6, if Firm S does not invest, Firm A invests if $\frac{t}{2} + \frac{\Delta}{3} + \frac{\Delta^2}{18t} - c_A > \frac{1}{2} - \frac{t}{4}$, or, $c_A < \frac{1}{2}(\frac{\Delta^2}{9t} - (1 - \frac{3t}{2})) + \frac{\Delta}{3}$. If Firm S invests, Firm A invests if $c_A < \frac{\Delta}{3}$.

If Firm A does not invest, Firm S invests if $c_S < \frac{5\Delta}{6}$. If Firm A invests, Firm S also invests if $\frac{1}{2} - \frac{t}{4} + \frac{\Delta}{2} - c_S > \frac{t}{2} - \frac{\Delta}{3} + \frac{\Delta^2}{18t}$, or, $c_S < \frac{5\Delta}{6} - \frac{1}{2}(\frac{\Delta^2}{9t} - (1 - \frac{3t}{2}))$.

Thus, letting $A = \frac{\Delta^2}{9t} - (1 - \frac{3t}{2})$, there are two cut-offs for c_A ($\frac{\Delta}{3}$ and $\frac{\Delta}{3} + \frac{A}{2}$), and two cut-offs for c_S ($\frac{5\Delta}{6} - \frac{A}{2}$ and $\frac{5\Delta}{6}$). The equilibrium investment strategies are then summarized in Table 7. We note that when $\frac{\Delta}{3} < c_A < \frac{\Delta}{3} + \frac{A}{2}$ and $\frac{5\Delta}{6} - \frac{A}{2} < c_S < \frac{5\Delta}{6}$ there are two equilibria: Only Firm A invests or only Firm S invests.

B.2.4 Supply Contract in period 1

In this section, we derive the equilibrium supply contracts in period 1. We consider two cases separately: When $A = \frac{\Delta^2}{9t} - (1 - \frac{3t}{2}) < 0$, and when $A > 0$.

$A < 0$**:** In this case, per Lemmas 18 and 19, Firm S invests if and only if $c_S < \frac{5\Delta}{6}$. Firm A's investment decision depends on the period 1 supplier. If the period 1 supplier is Firm S, Firm A invests if $c_A < \frac{\Delta}{6}$. If the period 1 supplier is Firm T, Firm A invests if $c_A < \frac{\Delta}{3}$. Table 8 summarizes total industry profits for different Firm A and Firm S costs.

Proposition 8. *If* $\frac{\Delta^2}{9t} - (1 - \frac{3t}{2}) < 0$*, Firm A contracts with Firm S in both periods. Firm*

Table 8: Industry profit (Π) across two periods ($A < 0$).

Costs		Period 1 Supplier	
c_A	c_S	Firm S	Firm T
$c_A < \frac{\Delta}{6}$	$c_S < \frac{5\Delta}{6}$	$(1-\frac{t}{2})+(1-\frac{t}{2}+2\Delta)-c_A-c_S$	$(t)+(1-\frac{t}{2}+\Delta)-c_A-c_S$
$c_A < \frac{\Delta}{6}$	$c_S > \frac{5\Delta}{6}$	$(1-\frac{t}{2})+(1-\frac{t}{2}+\Delta)-c_A-0$	$(t)+(1-\frac{t}{2})-c_A-0$
$\frac{\Delta}{6} < c_A < \frac{\Delta}{3}$	$c_S < \frac{5\Delta}{6}$	$(1-\frac{t}{2})+(1-\frac{t}{2}+\Delta)-0-c_S$	$(t)+(1-\frac{t}{2}+\Delta)-c_A-c_S$
$\frac{\Delta}{6} < c_A < \frac{\Delta}{3}$	$c_S > \frac{5\Delta}{6}$	$(1-\frac{t}{2})+(1-\frac{t}{2})-0-0$	$(t)+(1-\frac{t}{2})-c_A-0$
$c_A > \frac{\Delta}{3}$	$c_S < \frac{5\Delta}{6}$	$(1-\frac{t}{2})+(1-\frac{t}{2}+\Delta)-0-c_S$	$(t)+(1-\frac{t}{2}+\Delta)-0-c_S$
$c_A > \frac{\Delta}{3}$	$c_S > \frac{5\Delta}{6}$	$(1-\frac{t}{2})+(1-\frac{t}{2})-0-0$	$(t)+(1-\frac{t}{2})-0-0$

A invests if and only if $c_A < \frac{\Delta}{6}$, and Firm S invests if and only if $c_S < \frac{5\Delta}{6}$.

Proof. The proof follows directly from the comparison of industry profits in each case in Table 8.

$A > 0$**:** Per Lemmas 18 and 20, there are 12 cases to be considered, depending on the cut-offs for c_A or c_S. Table 9 summarizes these 12 cases and the total industry profits in each case. By comparing industry profits in each case, we derive the following proposition.

Proposition 9. *If $\frac{\Delta^2}{9t} - (1 - \frac{3t}{2}) > 0$, Firm A contracts with Firm T in both periods if and only if $\frac{\Delta}{6} < c_A < \frac{\Delta^2+27t^2-18t}{9t}$ and $c_S > \frac{5\Delta}{6}$. Otherwise, Firm A contracts with Firm S in both periods.*

Proof. Consider Table 9. The column between Firm A and Firm S indicates that in all cases except Case 6, sourcing from Firm S produces higher industry profits. Case 6 ($\frac{\Delta}{6} < c_A < \frac{\Delta}{3}$ and $c_S > \frac{5\Delta}{6}$) is similar to our base model; Firm A buys from Firm S in period

Table 9: Industry profit (Π) across two periods ($A > 0$).

	Costs		Period 1 Supplier		
	c_A	c_S	Firm S		Firm T
1	$c_A < \frac{\Delta}{6}$	$c_S < \frac{5\Delta}{6} - \frac{A}{2}$	$(1-\frac{t}{2}) + (1-\frac{t}{2}+2\Delta) - c_A - c_S$	$>$	$(t) + (1-\frac{t}{2}+\Delta) - c_A - c_S$
2	$c_A < \frac{\Delta}{6}$	$\frac{5\Delta}{6} - \frac{A}{2} < c_S < \frac{5\Delta}{6}$	$(1-\frac{t}{2}) + (1-\frac{t}{2}+2\Delta) - c_A - c_S$	$>$	$(t) + (t+\frac{\Delta^2}{9t}) - c_A - 0$
3	$c_A < \frac{\Delta}{6}$	$c_S > \frac{5\Delta}{6}$	$(1-\frac{t}{2}) + (1-\frac{t}{2}+\Delta) - c_A - 0$	$>$	$(t) + (t+\frac{\Delta^2}{9t}) - c_A - 0$
4	$\frac{\Delta}{6} < c_A < \frac{\Delta}{3}$	$c_S < \frac{5\Delta}{6} - \frac{A}{2}$	$(1-\frac{t}{2}) + (1-\frac{t}{2}+\Delta) - 0 - c_S$	$>$	$(t) + (1-\frac{t}{2}+\Delta) - c_A - c_S$
5	$\frac{\Delta}{6} < c_A < \frac{\Delta}{3}$	$\frac{5\Delta}{6} - \frac{A}{2} < c_S < \frac{5\Delta}{6}$	$(1-\frac{t}{2}) + (1-\frac{t}{2}+\Delta) - 0 - c_S$	$>$	$(t) + (t+\frac{\Delta^2}{9t}) - c_A - 0$
6	$\frac{\Delta}{6} < c_A < \frac{\Delta}{3}$	$c_S > \frac{5\Delta}{6}$	$(1-\frac{t}{2}) + (1-\frac{t}{2}) - 0 - 0$	$<>$	$(t) + (t+\frac{\Delta^2}{9t}) - c_A - 0$
7	$\frac{\Delta}{3} < c_A < \frac{\Delta}{3} + \frac{A}{2}$	$c_S < \frac{5\Delta}{6} - \frac{A}{2}$	$(1-\frac{t}{2}) + (1-\frac{t}{2}+\Delta) - 0 - c_S$	$>$	$(t) + (1-\frac{t}{2}+\Delta) - 0 - c_S$
8	$\frac{\Delta}{3} < c_A < \frac{\Delta}{3} + \frac{A}{2}$	$\frac{5\Delta}{6} - \frac{A}{2} < c_S < \frac{5\Delta}{6}$	$(1-\frac{t}{2}) + (1-\frac{t}{2}+\Delta) - 0 - c_S$	$>$ or $>$	$(t) + (t+\frac{\Delta^2}{9t}) - c_A$ or $(t) + (1-\frac{t}{2}+\Delta) - c_S$
9	$\frac{\Delta}{3} < c_A < \frac{\Delta}{3} + \frac{A}{2}$	$c_S > \frac{5\Delta}{6}$	$(1-\frac{t}{2}) + (1-\frac{t}{2}) - 0 - 0$	$>$	$(t) + (t+\frac{\Delta^2}{9t}) - c_A - 0$
10	$c_A > \frac{\Delta}{3} + \frac{A}{2}$	$c_S < \frac{5\Delta}{6} - \frac{A}{2}$	$(1-\frac{t}{2}) + (1-\frac{t}{2}+\Delta) - 0 - c_S$	$>$	$(t) + (1-\frac{t}{2}+\Delta) - 0 - c_S$
11	$c_A > \frac{\Delta}{3} + \frac{A}{2}$	$\frac{5\Delta}{6} - \frac{A}{2} < c_S < \frac{5\Delta}{6}$	$(1-\frac{t}{2}) + (1-\frac{t}{2}+\Delta) - 0 - c_S$	$>$	$(t) + (1-\frac{t}{2}+\Delta) - 0 - c_S$
12	$c_A > \frac{\Delta}{3} + \frac{A}{2}$	$c_S > \frac{5\Delta}{6}$	$(1-\frac{t}{2}) + (1-\frac{t}{2}) - 0 - 0$	$>$	$(t) + (1-\frac{t}{2}) - 0 - 0$

1 if $2 - t > 2t + \frac{\Delta^2}{9t} - c_A$, or, $c_A > 3t - 2 + \frac{\Delta^2}{9t} = \frac{\Delta^2+27t^2-18t}{9t}$. Otherwise, it buys from Firm T in period 1 and invests. Also note in Case 6, $\min\{\frac{\Delta}{3}, \frac{\Delta^2+27t^2-18t}{9t}\} = \frac{\Delta^2+27t^2-18t}{9t}$. This completes the proof.

Finally, combining propositions 8 and 9 yields proposition 4 in the main text.

B.3 Proof of Proposition 5 (Incomplete Knowledge Spillover)

B.3.1 Pricing

The pricing (Lemma 1 and 2) remains unchanged.

B.3.2 Supply Contract in period 2

Lemma 3 (when Firm A does not invest) and Lemma 5 (when the period 1 supplier is Firm T and the focal firm invests) remain unchanged.

Lemma 4 changes as follows. If Firm A buys from Firm S in period 1 and invests c, then Firm A has 2 options: to continue with Firm S or to switch to Firm T.

If Firm A continues sourcing from Firm S in period 2, we have $v_{A,2} = 1+\Delta, v_{S,2} = 1+k\Delta$. The difference between valuations is $(1-k)\Delta$. If $(1-k)\Delta < 3t$, then, in period 2, both firms have positive market shares with firm profits $\pi_{A,2} = \frac{1}{18t}(3t + (1-k)\Delta)^2 - F_{S,2}$ and $\pi_{S,2} = \frac{1}{18t}(3t-(1-k)\Delta)^2 + w_{S,2} + F_{S,2}$, the wholesale price $w_{S,2} = \frac{1+k}{2}\Delta + 1 - \frac{3t}{2}$, and industry profits are $\Pi_2 = 1 + \frac{1+k}{2}\Delta + \frac{(1-k)^2}{9t}\Delta^2 - \frac{t}{2}$.

However, if $(1-k)\Delta > 3t$, then Firm A serves the entire market in period 2, and we have firm profits $\pi_{A,2} = (1-k)\Delta - t - w_{S,2} - F_{S,2}$ and $\pi_{S,2} = w_{S,2} + F_{S,2}$, and industry profits are $\Pi_2 = (1-k)\Delta$. Note that industry profits do not depend on the wholesale price $w_{S,2}$.

If in period 2, Firm A switches to Firm T, we have $v_{A,2} = 1$ and $v_{S,2} = 1 + k\Delta$. The difference between valuations is $k\Delta$. If $k\Delta < 3t$, then firm profits in period 2 are $\pi_{A,2} = \frac{1}{18t}(3t - k\Delta)^2$ and $\pi_{S,2} = \frac{1}{18t}(3t + k\Delta)^2$, leading to industry profits $\Pi_2 = t + \frac{k^2}{9t}\Delta^2$. However, if $k\Delta > 3t$, then Firm S serves the entire market, and we have: $\pi_{A,2} = 0$ and $\pi_{S,2} = k\Delta - t$, leading to industry profits of $\Pi_2 = k\Delta - t$.

Hence, we need to consider 4 different cases: (1) $k\Delta < 3t$ and $(1-k)\Delta < 3t$, (2) $k\Delta > 3t$ and $(1-k)\Delta > 3t$, (3) $k\Delta < 3t$ and $(1-k)\Delta > 3t$, and (4) $k\Delta > 3t$ and $(1-k)\Delta < 3t$.

Consider case 1: $k\Delta < 3t$ and $(1-k)\Delta < 3t$. Then industry profits are higher sourcing from Firm S if and only if $1 + \frac{1+k}{2}\Delta + \frac{(1-k)^2}{9t}\Delta^2 - \frac{t}{2} > t + \frac{k^2}{9t}\Delta^2$. This condition is always true. Thus, industry profits are always higher if Firm A continues sourcing from Firm S (similar to our main model). Thus, Firm A continues sourcing from Firm S with wholesale price $w_{S,2} = \frac{1+k}{2}\Delta + 1 - \frac{3t}{2}$. We now calculate the fixed payment $F_{S,2}$. The fixed payment is derived from $\pi_{A,2} - \pi^O_{A,2} = \pi_{S,2} - \pi^O_{S,2}$. Inserting $\pi^O_{A,2} = \frac{1}{18t}(3t - k\Delta)^2$ and $\pi^O_{S,2} = \frac{1}{18t}(3t + k\Delta)^2$ yields $F_{S,2} = -\frac{1}{2} + \frac{3t}{4} - \frac{3k-1}{12}\Delta$. Inserting F_S back into profits, we have: $\pi_{A,2} = \frac{1}{12}(\frac{2(1-k)^2}{3t}\Delta^2 +$

$(3-k)\Delta - 3t + 6)$ and $\pi_{S,2} = \frac{1}{12}(\frac{2(1-k)^2}{3t}\Delta^2 + (7k+3)\Delta - 3t + 6)$.

Consider case 2: $k\Delta > 3t$ and $(1-k)\Delta > 3t$. Then industry profits are higher sourcing from Firm S if and only if $(1-k)\Delta > k\Delta - t$. Both sourcing outcomes are possible here.

Consider case 3: $k\Delta < 3t$ and $(1-k)\Delta > 3t$. Then industry profits are higher sourcing from Firm S if and only if $(1-k)\Delta > t + \frac{k^2}{9t}\Delta^2$. This condition is always true because LHS is larger than $3t$ and RHS is smaller than $2t$.

Consider case 4: $k\Delta > 3t$ and $(1-k)\Delta < 3t$. Then industry profits are higher sourcing from Firm S if and only if $1 + \frac{1+k}{2}\Delta + \frac{(1-k)^2}{9t}\Delta^2 - \frac{t}{2} > k\Delta - t$. This condition is always true because $1 + \frac{1-k}{2}\Delta + \frac{(1-k)^2}{9t}\Delta^2 + \frac{t}{2} > 0$.

B.3.3 Focal Firm's Investment Decision

We consider the case $k\Delta < 3t$ and $(1-k)\Delta < 3t$. If Firm A buys from Firm S in period 1, its profits in period 2 are $\frac{1}{12}(\frac{2(1-k)^2}{3t}\Delta^2 + (3-k)\Delta - 3t + 6)$ if it invests and $\frac{1}{4}(2-t)$ if it does not invest. Therefore, Firm A will invest c if and only if $c < \frac{\Delta}{12}(\frac{2(1-k)^2}{3t}\Delta + (3-k))$.

If Firm A buys from Firm T in period 1, Firm A invests if and only if $c < max\{\frac{2\Delta^2 - 18t + 27t^2}{36t}, 0\} + \frac{\Delta}{3}$ (see proof of Lemma 6).

B.3.4 Supply Contract in period 1

We consider the case $k\Delta < 3t$ and $(1-k)\Delta < 3t$. In this case, suppose $c < \frac{\Delta}{12}(\frac{2(1-k)^2}{3t}\Delta + (3-k))$. If Firm A buys from Firm S in period 1, it will invest and continue sourcing from Firm S. Therefore, total industry profits are $\Pi = (1 - \frac{t}{2}) - c + (1 + \frac{1+k}{2}\Delta + \frac{(1-k)^2}{9t}\Delta^2 - \frac{t}{2})$. These profits are higher than the total industry profits if Firm A sources from Firm T in period 1.

On the other hand, if $c > \frac{\Delta}{12}(\frac{2(1-k)^2}{3t}\Delta + (3-k))$, then if Firm A buys from Firm S without investment, industry profits are $2-t$ whereas if it buys from Firm T and invests, industry profits are $t - c + (t + \frac{k^2}{9t}\Delta^2)$. The latter is larger if and only if $c < 3t + \frac{k^2}{9t}\Delta^2 - 2 = \frac{k^2\Delta^2 - 18t + 27t^2}{9t}$. Thus, Firm A buys from Firm S in both periods and invests in Firm S's input if $c < \frac{2(1-k)^2\Delta^2+3(3-k)\Delta t}{36t}$. Firm A buys from Firm S in both periods without investing in the input if $\max\{\frac{2(1-k)^2\Delta^2+3(3-k)\Delta t}{36t}, \frac{k^2\Delta^2-18t+27t^2}{9t}\} < c$. Finally, Firm A buys from Firm T in both periods and invests in Firm T's input if $\frac{2(1-k)^2\Delta^2+3(3-k)\Delta t}{36t} < c < \frac{k^2\Delta^2-18t+27t^2}{9t}$. This completes the proof of Proposition 5.

To prove Corollary 2, note that when k is small enough, $c < \frac{k^2\Delta^2-18t+27t^2}{9t}$ cannot hold because $-18t + 27t^2 < 0$ (given $t < \frac{2}{3}$). Therefore, if k is small enough, Firm A never buys from Firm T. Moreover, $\frac{2(1-k)^2\Delta^2+3(3-k)\Delta t}{36t} < c < \frac{k^2\Delta^2-18t+27t^2}{9t}$, implies $2(1-k)^2\Delta^2 + 3(3-k)\Delta t < 4(k^2\Delta^2 - 18t + 27t^2)$. This inequality, together with $k\Delta < 3t$ and $(1-k)\Delta < 3t$, implies $t > \frac{8k^2}{15k^2+k-2}$. Note that with $k = 1$, we have $t > \frac{4}{7}$, which was previously derived in Proposition 2. Thus, t and k must both be sufficiently large for Firm A to contract with Firm T.

B.4 Proof of Proposition 6 (Contracts with no Fixed Transfers)

In the main model, we allow the contract to be a two-part tariff. In this variation, we require fixed fees to be zero. Moreover, the third party's input can be purchased by Firm A at $w_T \geq 0$ per unit. All other aspects of the model remain the same as our main model.

B.4.1 Pricing

Given that the third party charges w_T for the input, the following lemma, corresponding to Lemma 1 in the manuscript, characterizes equilibrium prices.

Lemma 21. *Equilibrium goods prices are:* $p_{A,i} = t + \frac{v_{A,i}-v_{S,i}}{3} + I_i w_{S,i} + (1-I_i)\frac{2w_T}{3}$ *and* $p_{S,i} = t + \frac{v_{S,i}-v_{A,i}}{3} + I_i w_{S,i} + (1-I_i)\frac{w_T}{3}$. *Equilibrium profits are:* $\pi_{A,i} = \frac{1}{18t}(3t + v_{A,i} - v_{S,i} - (1-I_i)w_T)^2$ *and* $\pi_{S,i} = \frac{1}{18t}(3t - v_{A,i} + v_{S,i} + (1-I_i)w_T)^2 + I_i w_{S_i}$, *leading to industry profit* $\Pi_i = t + \frac{1}{9t}(v_{A,i} - v_{S,i} - (1-I_i)w_T)^2 + I_i w_{S,i}$ *for all* $w_{S,i} \in [0, \frac{1}{2}(v_{A,i} + v_{S,i} - 3t)]$, *where* $I_i = 1$ *if Firm A buys the input from its competitor in period* i *and* $I_i = 0$ *otherwise.*

Proof: The proof is the same as Lemma 1 with two differences: (1) we let $F = 0$, and (2) when Firm A contracts with the third party (i.e., $I = 0$), Firm A pays w_T (in the main model we set $w_T = 0$). Hence, the w_T appears in the price and profits. Note that Firm A's profits do not depend on w_S because a small increase of size ϵ in this per-unit input fee causes both equilibrium goods prices to increase by ϵ while also causing firm A's per-unit cost to increase by ϵ, thus leaving Firm A profits unchanged. If Firm A purchases the input from Firm S, then w_S is set to the maximum level for which the market is fully covered, and all of the additional profits from increased goods prices go to Firm S.

Lemma 22. *If Firm A purchases the input from Firm S in period* i*, equilibrium industry profit for the period* (Π_i) *is maximized by setting wholesale input price* $w_{S,i} = \frac{1}{2}(v_{A,i}+v_{S,i}-3t)$*, resulting in* $\Pi_i = \frac{1}{2}(v_{A,i} + v_{S,i}) + \frac{1}{9t}(v_{S,i} - v_{A,i})^2 - \frac{1}{2}t$.

B.4.2 Supply Contract in period 2

We now derive the equilibrium contract in the second period (corresponding to Lemmas 3, 4, and 5 in the main text).

Lemma 23. *If Firm A did not invest in innovation in period 1, then in period 2, it buys from Firm S with contract* $w_{S,2} = 1 - \frac{3t}{2}$*, leading to period 2 profits* $\pi_{A,2} = \frac{t}{2}$ *and* $\pi_{S,2} = 1 - t$*, and industry profit* $\Pi_2 = 1 - \frac{t}{2}$.

Proof. If Firm A buys from T, it earns $\pi_{A,2} = \frac{1}{18t}(3t - w_T)^2$, which is less than $t/2$ for any $w_T > 0$. Thus, it buys from Firm S.

Lemma 24. *If Firm A buys the input from the competitor in period 1 and invests in innovation, then in period 2 it again buys from the competitor with contract* $w_{S,2} = 1+\Delta-\frac{3t}{2}$*, leading to period 2 profits* $\pi_{A,2} = \frac{t}{2}$ *and* $\pi_{S,2} = 1-t+\Delta$*, and industry profits* $\Pi_2 = 1-\frac{t}{2}+\Delta$.

Proof. In this case, there is no reason not to continue with Firm S. Switching to Firm T not only leads to a loss of improved value but also imposes input cost w_T.

Lemma 25. *Suppose in period 1 Firm A buys the input from Firm T and invests in improving its input. In period 2, if* $w_T < \Delta$ *Firm A buys the input from the third-party, and otherwise, it buys the input from its competitor, with input contract* $w_{S,2} = 1 - \frac{3t}{2}$.

Proof. If Firm A sources from Firm T in period 1 and invests c, then Firm A has 2 options: to continue with Firm T in period 2 or to switch to Firm S.

If Firm A continues sourcing from Firm T in period 2, we have $v_{A,2} = 1+\Delta$ and $v_{S,2} = 1$. Then, we have $\pi_{A,2} = \frac{1}{18t}(3t + \Delta - w_T)^2$ and $\pi_{S,2} = \frac{1}{18t}(3t - \Delta + w_T)^2$, leading to industry profits of $\Pi_2 = t + \frac{1}{9t}(\Delta - w_T)^2$.

However, if in period 2 Firm A switches to Firm S, we have $v_{A,2} = v_{S,2} = 1$. Firm profits in period 2 would be $\pi_{A,2} = \frac{t}{2}$ and $\pi_{S,2} = \frac{t}{2} + w_{S,2}$. Thus, Firm A contracts with Firm T if $w_T < \Delta$.

B.4.3 Focal Firm's Investment Decision

Having solved the equilibrium supply contract in period 2, we derive the focal firm's investment decision given its period 1 supplier. The following lemma summarizes the result.

Lemma 26. *If Firm A buys the input from Firm S in period 1, it does not invest in innovation. If Firm A buys the input from Firm T in period 1, it invests in innovation if and only if* $w_T < \Delta$ *and* $c < \frac{1}{18t}(\Delta - w_T)(6t + \Delta - w_T)$.

Proof. If Firm A sources from Firm S in period 1, its profit in period 2 are $\frac{t}{2}$ if it invests and also $\frac{t}{2}$ if it does not invest. Therefore, Firm A will not invest c.

If Firm A sources from Firm T in period 1, its profits in period 2 are equal to $\frac{1}{18t}(3t + \Delta - w_T)^2$ if it invests and $w_T < \Delta$, equal to $\frac{t}{2}$ if it invests and $w_T > \Delta$, and equal to $\frac{t}{2}$ if it does not invest.

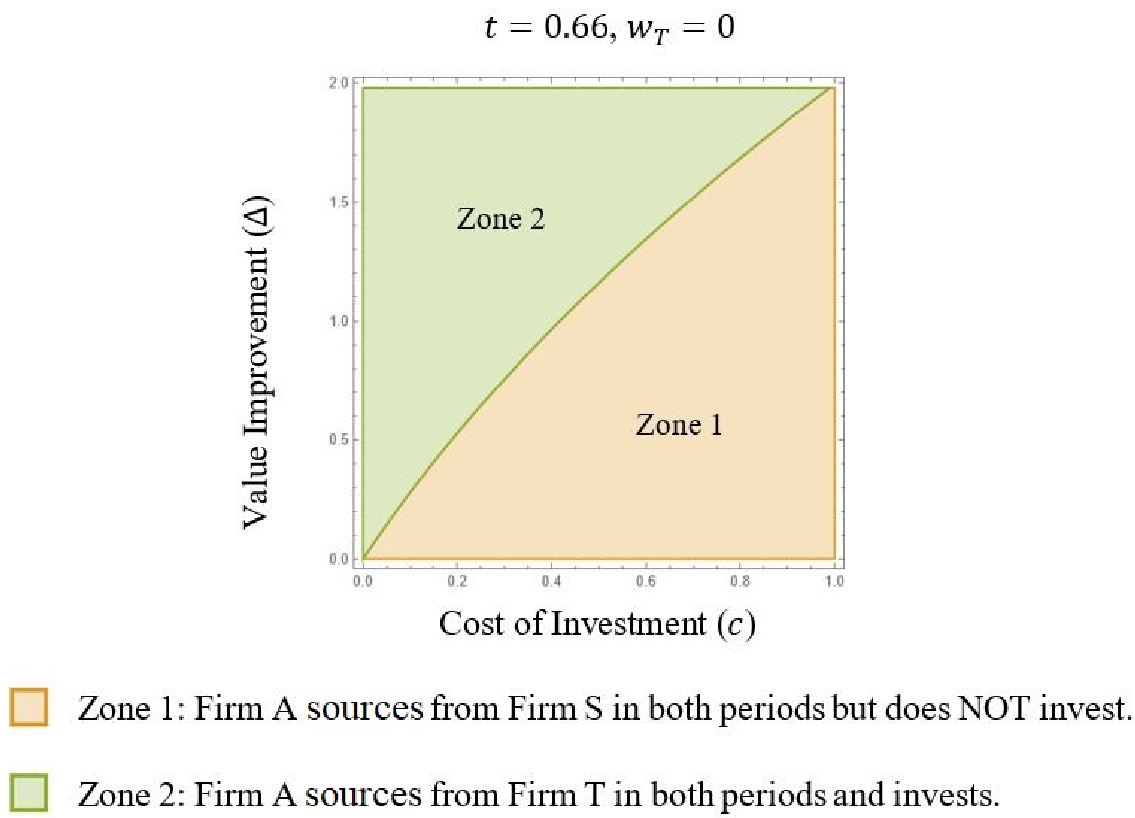
Thus, Firm A invests if and only if $w_T < \Delta$ and $c < \frac{1}{18t}(3t + \Delta - w_T)^2 - \frac{t}{2} = \frac{1}{18t}(\Delta - w_T)(6t + \Delta - w_T)$.

B.4.4 Supply Contract in period 1

In this section, we derive the equilibrium supply contracts in period 1.

Proposition 10. *Firm A sources from Firm T in both periods and invests in Firm T's input*

Figure 5: Equilibrium Regions for Firm A Supply Strategy (No Fixed Transfers).



if $w_T < \Delta$ *and* $c < \frac{1}{18t}(2w_T^2 + \Delta^2 - 2\Delta w_T + 6t\Delta - 12tw_T)$*. Otherwise, Firm A sources from Firm S in both periods without investing in the input.*

Proof. As shown in the preceding lemma, if the Period 1 supplier is Firm S, Firm A will not invest. Therefore, if Firm A selects Firm S in Period 1, its total profit across the two periods are $\Pi_A = t$. However, if it buys from Firm T in period 1, its total profit across the two periods are $\Pi_A = \frac{1}{18t}(3t - w_T)^2 - c + \frac{1}{18t}(3t + \Delta - w_T)^2$ if $\Delta > w_T$ and $c < \frac{1}{18t}(\Delta - w_T)(6t + \Delta - w_T)$ and $\Pi_A = \frac{1}{18t}(3t - w_T)^2 + \frac{t}{2}$ otherwise. The latter strategy is always dominated for any $w_T > 0$ because it is more profitable to buy from Firm S in the first period and not invest rather than to buy from Firm T and not invest. Thus, the only two possible outcomes are buying from Firm S in both periods and not investing or buying from Firm T in both periods and investing. The latter strategy occurs in equilibrium if

$t < \frac{1}{18t}(3t - w_T)^2 - c + \frac{1}{18t}(3t + \Delta - w_T)^2$, which is equivalent to $c < \frac{1}{18t}(2w_T^2 + \Delta^2 - 2\Delta w_T + 6t\Delta - 12tw_T)$. Note that letting $w_T = 0$ yields $c < \frac{1}{18t}(\Delta^2 + 6t\Delta)$, which is the condition in Proposition 6.

B.5 One-Period Models

In this section we analyze one-period models to demonstrate they cannot fully capture the dynamics and outcomes of our two-period model.

Model 1

Consider a one-period model with the following timing.

(1) Firm A decides whether to invest (and the resulting knowledge can be transferred to either supplier).

(2) Firms A and S negotiate over the supply contract.

(3) Firms A and S set product prices. Note that in Stage 1, Firm A's investment decision is not specific to a particular supplier; that is, Firm A commits to investing regardless of the identity of the supplier, which may occur because there is no history or relationship with any supplier. However, Firm A would rationally expect the equilibrium supplier choice when making the investment decision. If the supplier is going to be Firm T, the investment boosts Firm A's value only. However, if the supplier is going to be Firm S, the investment boosts both Firm A's and Firm S's product values.

As before, lemma 1 characterizes the pricing strategies. Suppose in Stage 1, Firm A decides not to invest. Then, in Stage 2, the supplier will be the competitive supplier. If the focal firm commits to invest, buying from Firm S yields an industry profit of $1 - \frac{t}{2} + \Delta$ whereas buying from Firm T yields an industry profit of $t + \frac{\Delta^2}{9t}$. The latter is always smaller. Thus, regardless of the commitment to the investment in Stage 1, the focal firm will buy from Firm S.

We now calculate the contract fixed payment F_S. The fixed payment is derived from

$\pi_A - \pi_A^O = \pi_S - \pi_S^O$. Inserting $\pi_A^O = \frac{1}{18t}(3t+\Delta)^2$ and $\pi_S^O = \frac{1}{18t}(3t-\Delta)^2$ into the above equation yields $F_S = -\frac{1}{2}w_S - \frac{2}{3}\Delta = -\frac{1}{2}(\Delta + 1 - \frac{3t}{2}) - \frac{2}{3}\Delta = -\frac{1}{2} + \frac{3t}{4} - \frac{7}{6}\Delta$. Inserting F_S back in profits, we get: $\pi_{A,2} = \frac{1}{2} - \frac{t}{4} + \frac{7}{6}\Delta$ and $\pi_{S,2} = \frac{1}{2} - \frac{t}{4} - \frac{1}{6}\Delta$.

Hence, in Stage 1, the focal firm invests if and only if $c < (\frac{1}{2} - \frac{t}{4} + \frac{7}{6}\Delta) - \frac{1}{2}(1 - \frac{t}{2}) = \frac{7}{6}\Delta$. To summarize, in Model 1, the focal firm will always buy from Firm S, and invests if $c < \frac{7}{6}\Delta$.

Model 2

Consider the following timing and strategies:

(1) Firm A decides whether to invest in the input of Firm S, or invest in the input of Firm T, or invest in neither input.

(2) Firms A and S negotiate over the supply contract.

(3) Firms A and S set product prices.

Please note that the Model 2 timing is similar to the Model 1 timing with one difference: Firm A commits to investing in a specific supplier in advance. The solution to Stage 2 is similar to our main model. In particular, Lemmas 3, 4, and 5 characterize the negotiation outcome in Stage 2.

In Stage 1, Firm A compares its profit across three different strategies it has. If it does not invest, its profit is $\frac{1}{2} - \frac{t}{4}$. If it invests in Firm S, its profit is $\frac{1}{2} - \frac{t}{4} + \frac{\Delta}{6} - c$. Finally, if it invests in Firm T:

-If $\frac{\Delta^2}{9t} > 1 - \frac{3t}{2}$, it contracts with the third party, resulting in profit $\frac{t}{2} + \frac{\Delta}{3} + \frac{\Delta^2}{18t} - c$.

-Otherwise, it buys from its competitor, which results in profits $\frac{1}{2} - \frac{t}{4} + \frac{\Delta}{3} - c$.

Therefore, investing in Firm S in Stage 1 is always dominated: if $c > \frac{\Delta}{6}$, it is better not to invest. If $c < \frac{\Delta}{6}$ and $\frac{\Delta^2}{9t} > 1 - \frac{3t}{2}$, it is better to invest in Firm T and buy from it because $c < \frac{1}{2}(\frac{\Delta^2}{9t} - 1 + \frac{3t}{2}) + \frac{\Delta}{6}$. If $c < \frac{\Delta}{6}$ and $\frac{\Delta^2}{9t} < 1 - \frac{3t}{2}$, it is better to invest in Firm T but then buy from the competitor to get a profit increase of $\frac{\Delta}{3}$ instead of $\frac{\Delta}{6}$.

To summarize, if $\frac{\Delta^2}{9t} > 1 - \frac{3t}{2}$ and $c < \frac{1}{2}(\frac{\Delta^2}{9t} - 1 + \frac{3t}{2}) + \frac{\Delta}{3}$ then Firm A invests in Firm T and buys from it. If $\frac{\Delta^2}{9t} < 1 - \frac{3t}{2}$ and $c < \frac{\Delta}{3}$, then Firm A invests in Firm T but buys from Firm S. Otherwise, Firm A does not invest and buys from the competitor.

B.6 Commitment not to Renegotiate

In this section, we allow Firm A and Firm S to agree on an input contract for both periods, and they commit not to renegotiate the supply contract. In particular, the two parties engage in negotiation only once, at the beginning of period 1. If they reach an agreement, they honor the contract and follow it in periods 1 and 2. If they fail to reach an agreement, the do not negotiate again in period 2, and the focal firm buys from the third party in both periods. Moreover, if the firms reach an agreement, they can commit to wholesale prices for both periods. In other words, at the beginning of period 1, they set period-1 wholesale price w_1 and period-2 wholesale price w_2 to maximize the industry profits across the two periods. Alternatively, we could restrict them to set a single wholesale price for both periods. The analysis of this alternative model, while more complicated, leads to qualitatively similar results.

Suppose Firm A and Firm S fail to reach an agreement in period 1. Firm A then buys again from Firm T in both periods regardless of its investment decision. If the focal firm invests in Firm T, its second-period profits will be $\pi_A = \frac{1}{18t}(3t + \Delta)^2$ (see Lemma 1 in the manuscript). Otherwise, its second-period profits will be $\frac{t}{2}$. Thus, Firm A will invest in Firm T if and only if $c < \frac{1}{18t}(3t + \Delta)^2 - \frac{t}{2} = \frac{\Delta}{18t}(\Delta + 6t)$.

Suppose Firm A and Firm S reach an agreement in period 1, with contract terms w_1, w_2 and F. Note that firms commit to the fixed fees, which implies distinguishing between F_1 and F_2 is unnecessary. The firms are then committed to honor this contract in period 2 and not renegotiate it. Thus, in period 2, Firm A buys from Firm S, paying w_2 per unit. Note that because the period-1 supplier is Firm S, the period-2 valuations for the product are equal. That is, both valuations are $1 + \Delta$ with investment and 1 without investment. We derive equilibrium goods prices and profits when Firm A buys input from Firm S at wholesale price w, where we drop the period index for w and the fixed fee F for parsimony.

As in our main model (Lemma 1), if w is low ($w < v - \frac{3t}{2}$), firms price at $p = t + w$, split the market equally, and Firm A and Firm S profits are $\frac{t}{2}$ and $\frac{t}{2} + w$, respectively, leading to industry profit of $t + w$.

Second, at a higher wholesale price ($v - \frac{3t}{2} < w < v - t$), in equilibrium both firms charge price $p = v - \frac{t}{2}$, with each selling to half of the market. In this parameter range, equilibrium prices are independent of w. We then have $\pi_A = \frac{1}{2}(v - \frac{t}{2} - w)$, $\pi_S = \frac{1}{2}(v - \frac{t}{2} + w)$ and industry profits are $(v - \frac{t}{2})$. In this case, industry profits do not depend on wholesale price, while Firm A profits decrease and Firm S profits increase with the wholesale price.

Finally, when wholesale price increases further to $w > v - t$, Firm A has an incentive to deviate from the above equilibrium and charge its local monopoly price, $p_A = \frac{v+w}{2}$ and sells to $q_A = \frac{v-w}{2t}$ customers. Firm S will then set its price to fully cover the market, that is, $v - p_S - t(1 - q_A) = 0$, or, $p_S = \frac{1}{2}(3v - 2t - w)$. In this case, profits are $\pi_A = \frac{(v-w)^2}{4t}$, $\pi_S = 2v - t - w - \frac{3(v-w)^2}{4t}$, leading to industry profits $\Pi = 2v - t - w - \frac{(v-w)^2}{2t}$. This completes the characterization of prices and profits for any $w < v$. The following lemma summarizes these results.

Lemma 27. *Suppose Firm A buys an input from Firm S at wholesale price w.*

(i) If $w < v - \frac{3t}{2}$ then prices are $p_A = p_S = t + w$ and profits are $\pi_A = \frac{t}{2}$ and $\pi_S = \frac{t}{2} + w$.

(ii) If $v - \frac{3t}{2} < w < v - t$ then prices are $p_A = p_S = v - \frac{t}{2}$ and profits are $\pi_A = \frac{1}{2}(v - \frac{t}{2} - w)$ and $\pi_S = \frac{1}{2}(v - \frac{t}{2} + w)$.

(iii) If $w > v - t$, then prices are $p_A = \frac{v+w}{2}$ and $p_S = \frac{1}{2}(3v - 2t - w)$, and profit are $\pi_A = \frac{(v-w)^2}{4t}$ and $\pi_S = 2v - t - w - \frac{3(v-w)^2}{4t}$.

We now consider Firm A's investment decision. This decision depends on the wholesale price w_2 that Firm A will face in period 2. If the second-period wholesale price w_2 is sufficiently low ($w_2 < 1 - \frac{3t}{2} < 1 + \Delta - \frac{3t}{2}$), then Firm A's profits with or without investment are $\frac{t}{2}$. Thus, Firm A will not invest.

Consider now a higher wholesale price $1 - \frac{3t}{2} < w_2 < 1 + \Delta - \frac{3t}{2}$. As we showed above, Firm A's profits are lower than $\frac{t}{2}$ if it does not invest. In particular, without investment, Firm A's profits are $\frac{1}{2}(1 - \frac{t}{2} - w_2)$ if $w_2 < 1 - t$ and $\frac{(1-w_2)^2}{4t}$ if $w_2 > 1 - t$ (see the Lemma above). Firm A invests if its incremental benefit of investment, which is $\frac{t}{2} - \frac{1}{2}(1 - \frac{t}{2} - w_2)$ if $w_2 < 1-t$ and $\frac{t}{2} - \frac{(1-w_2)^2}{4t}$ if $w_2 > 1-t$, is higher than c. Note that these incremental benefits become larger as w_2 becomes larger until it reaches $w_2 = 1+\Delta-\frac{3t}{2}$. Raising wholesale prices above this level cannot increase Firm A's incentives to invest because it will start to decrease Firm A's profit with investment.

Consequently, the second-period wholesale price w_2 should be set at $w_2 = 1 + \Delta - \frac{3t}{2}$ whenever this price leads Firm A to invest; otherwise, $w_2 = 1 - \frac{3t}{2}$. In particular, with $w_2 = 1 + \Delta - \frac{3t}{2}$, the benefit of investment for Firm A is $\frac{t}{2} - \frac{1}{2}(1 - \frac{t}{2} - 1 - \Delta + \frac{3t}{2})$ if $\Delta < \frac{t}{2}$, $\frac{t}{2} - \frac{(1-1-\Delta+\frac{3t}{2})^2}{4t}$ if $\frac{t}{2} < \Delta < \frac{3t}{2}$, and $\frac{t}{2}$ if $\Delta > \frac{3t}{2}$. In the last case, Firm A loses the entire market to Firm S if it does not invest. Thus, the wholesale price w_2 should be set at $w_2 = 1 + \Delta - \frac{3t}{2}$ if $c < \frac{\Delta}{2}$ and $\Delta < \frac{t}{2}$, or if $c < \frac{8t^2-(3t-2\Delta)^2}{16t}$ and $\frac{t}{2} < \Delta < \frac{3t}{2}$, or if $c < \frac{t}{2}$ and $\Delta > \frac{3t}{2}$. Otherwise, the wholesale price w_2 should be set at $w_2 = 1 - \frac{3t}{2}$ and investment will not occur. We proved the following lemma.

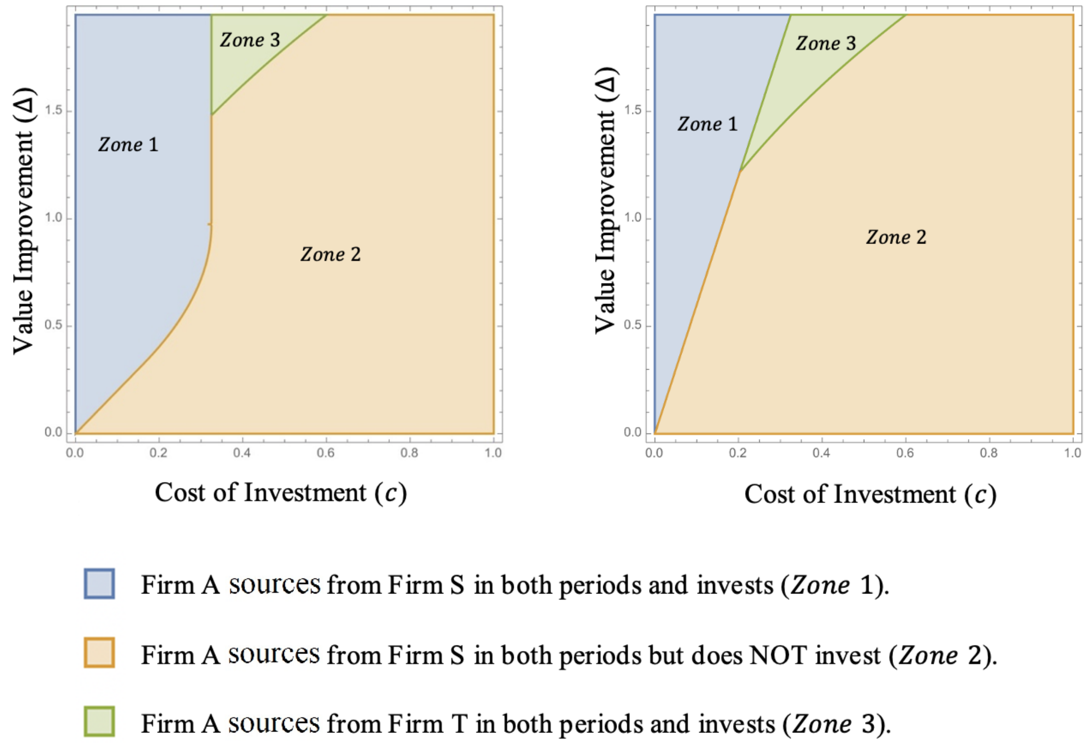
Lemma 28. *If Firm A and Firm S agree on a supply contract in Period 1 and commit not to renegotiate it, they set $w_1 = 1 - \frac{3t}{2}$, and a higher period-2 wholesale price $w_2 = 1+\Delta-\frac{3t}{2}$ only if $\Delta < \frac{t}{2}$ and $c < \frac{\Delta}{2}$, or if $\frac{t}{2} < \Delta < \frac{3t}{2}$ and $c < \frac{8t^2-(3t-2\Delta)^2}{16t}$, or if $\Delta > \frac{3t}{2}$ and $c < \frac{t}{2}$.*

We are now ready to derive the equilibrium of the game with commitment not to renegotiate. If Firm A buys from Firm T, industry profits across two periods are $2t + \frac{\Delta^2}{9t} - c$ if $c < \frac{\Delta}{18t}(\Delta + 6t)$ and $2t$, otherwise. On the other hand, if Firm A buys from Firm S, industry profits across the two periods are $(1 - \frac{t}{2}) + (1 + \Delta - \frac{t}{2} - c)$ if $\Delta < \frac{t}{2}$ and $c < \frac{\Delta}{2}$, or if $\frac{t}{2} < \Delta < \frac{3t}{2}$ and $c < \frac{8t^2-(3t-2\Delta)^2}{16t}$, or if $\Delta > \frac{3t}{2}$ and $c < \frac{t}{2}$. Otherwise, the investment will not occur, and industry profits across two periods are $(1 - \frac{t}{2}) + (1 - \frac{t}{2})$.

Comparing industry profits across these two sub-games (when Firm A buys from Firm S or Firm T) leads to the following proposition.

Proposition 11. *Firm A buys from Firm T and invests if $\frac{t}{2} < c < \frac{\Delta^2-18t+27t^2}{9t}$. Firm A buys from Firm S and invests if $\Delta < \frac{t}{2}$ and $c < \frac{\Delta}{2}$, or $\frac{t}{2} < \Delta < \frac{3t}{2}$ and $c < \frac{8t^2-(3t-2\Delta)^2}{16t}$, or if $\Delta > \frac{3t}{2}$ and $c < \frac{t}{2}$. Otherwise, Firm A buys from Firm S and does not invest.*

Figure 6: Equilibrium Regions for Firm A Supply Strategy ($t = 0.65$). Left panel: with commitment not to renegotiate. Right panel: Base model.



The above figure illustrates the proposition (outcomes of the game with a commitment not to renegotiate) side-by-side with those of our main model. We restrict our attention to the more interesting case of $\Delta < 3t$. Even when firms can commit not to renegotiate the contract in period 2, Firm A still may buy the input from the third party when Δ is large and c is in an intermediate range. Even though the firms commit to a supply contact, Firm A cannot commit to investment. Competition between Firm A and Firm S in the product market can lead to a relatively low benefit of investment for Firm A, which leads to the firm buying from the third party as a possible equilibrium outcome. Nonetheless, committing not to renegotiate expands the region of parameters in which Firm A buys from Firm S and invests while shrinking the region in which Firm A buys from the third party. Thus, although the commitment can improve channel outcomes and decrease the under-investment and hold-up issues, it does not fully eliminate them.

B.7 Uncertain Innovation Outcome

Suppose in our main model, if Firm A invests in its supplier, the product value increases by Δ only with probability q. If Firm A decides to invest, the value of the product (whether it is increased to v_H or not) is revealed after the investment occurs but before Period 2 negotiations. Our main model is obtained by letting $q = 1$.

Lemmas 1-2 do not change. In Lemmas 3-5, the statement "if Firm A invests,..." changes to "if Firm A invests and it is successful,...". In Lemma 6 (Investment decision), we replace c by $\frac{c}{q}$ because the investment occurs if the expected benefit of investments outweighs the cost, c. The benefit of a successful investment is the same as in the main model, whereas the benefit of an unsuccessful investment is zero.

Period 1 Equilibrium

There are three cases. If $\frac{c}{q} < \frac{\Delta}{6}$, similar to the main model, Firm A contracts with Firm S in both Periods and invests (which may or may not succeed).

On the other hand, if $\frac{c}{q} > max\{\frac{2\Delta^2-18t+27t^2}{36t}, 0\} + \frac{\Delta}{3}$, the investment would not occur (regardless of the Period 1 supplier). Thus, the Period 1 supplier is Firm S for the price softening benefit.

Finally, consider $\frac{\Delta}{6} < \frac{c}{q} < max\{\frac{2\Delta^2-18t+27t^2}{36t}, 0\} + \frac{\Delta}{3}$. Per Lemma 6, the investment decision depends on who the Period 1 supplier is. In particular,

- If the Period 1 supplier is Firm S, the investment does not happen, and industry profits across the two periods are $\Pi = 2 - t$
- If the Period 1 supplier is Firm T, the investment does occur, and the expected industry profit across the two periods is $E\Pi = t - c + q(t + \frac{1}{9t}\Delta^2) + (1-q)(1-\frac{t}{2})$

The first term is larger (Firm contracts Firm S) if and only if $c > 2t - 2 + q(t + \frac{1}{9t}\Delta^2) + (1-q)(1-\frac{t}{2})$. Otherwise, the Firm contracts with Firm T and invests. It is possible Firm

A contacts with Firm T and invests, but the investment fails. In this situation, Firm A switches to buying from Firm S in period 2.

To summarize:

- Firm A buys from Firm S in both periods and invests if $\frac{c}{q} < \frac{\Delta}{6}$

- Firm A buys from Firm S in both periods without investing if $\frac{c}{q} > max\{\frac{2\Delta^2-18t+27t^2}{36t}, 0\} + \frac{\Delta}{3}$, or $\frac{\Delta}{6} < \frac{c}{q} < max\{\frac{2\Delta^2-18t+27t^2}{36t}, 0\} + \frac{\Delta}{3}$ and $c > 2t - 2 + q(t + \frac{1}{9t}\Delta^2) + (1-q)(1-\frac{t}{2})$.

- Firm A buys from Firm T in Period one and invests if $\frac{\Delta}{6} < \frac{c}{q} < max\{\frac{2\Delta^2-18t+27t^2}{36t}, 0\} + \frac{\Delta}{3}$ and $c < 2t - 2 + q(t + \frac{1}{9t}\Delta^2) + (1-q)(1-\frac{t}{2})$.

As the probability of successful investment (q) decreases from one, Firm A's incentive to work with the third party shrinks because working with Firm T is beneficial only if it is followed by a successful investment in innovation.

Figure 7: Equilibrium Regions with Uncertain Innovation Outcome