Outsourcing and the Trade-Off between Economies of Scale and Specialization*

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Abstract

This paper studies the make-or-buy decisions of firms that require a common input but have different ideal input characteristics. Firms can outsource input production either to one of the firms themselves or to a third party. We show that outsourcing to a third party can occur although this party does not add value to the industry. The rationale is that, if input contracts are incomplete, a third party balances the demands for specialization and the benefits from economies of scale in a better way than firms do. We further find that the payoff of the third party is non-monotonic in its bargaining power. We also characterize under which conditions make-or-buy decisions are distorted from the efficient ones.

1 Introduction

Outsourcing of input production and services is a common practice in many industries. As explained by e.g. Feng and Lu (2013) and Jungbauer et al. (2023), manufacturing firms in the electronic or healthcare industry source important and

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valuable components for production, such as concept design and drug development, from outside companies. A similar structure can be observed in several other industries—e.g., the automotive, construction, and mechanical engineering industries (Atalay et al., 2014; Claussen et al., 2015; Bernard and Mitraille, 2023).

However, firms pursue different strategies with respect to production and outsourcing. While some firms focus on their downstream activities and source from third parties that are pure input providers—i.e., not active in the downstream market—others are active both in the downstream market and the outsourcing business. A prominent example of the latter strategy in the electronic industry is Samsung (Heese et al., 2021). Samsung manufactures several inputs in-house but also sells some of them to other firms only active in the downstream sector. Therefore, Samsung follows a make-and-sell strategy with respect to inputs, despite being active also in the output market, whereas other output-producing firms buy their inputs either from third parties or from Samsung.

The advantages and disadvantages of outsourcing versus in-house production have been extensively studied in the literature and are by now well understood.[1] However, the decision to *which* firm to outsource, that is, to a firm that uses the input also by itself or to a third party that is a pure input provider, has surprisingly received little attention so far.[2] This question is nevertheless at the core of a firm's decision as it needs to identify the supplier that best fulfills its specific input demand.

In this paper, we provide a model that explicitly considers not only firms' decisions on whether to outsource but also to which type of supplier. In general, outsourcing has the advantage that the respective supplier can benefit from economies of scale as it produces the input for multiple firms. At the same time, however, firms differ in their ideal input characteristics, which implies that the input supplier cannot produce the optimal input for all firms. In addition, as is well established by now, contracts for inputs are usually incomplete (Grossman and Hart, 1986; Hart and Moore, 1990; Hart, 1995). We show that, although this incompleteness holds for the contractual relationship to both a third-party supplier and a supplier that is also active downstream, its effect on those firms is different. Specifically, the third-party supplier balances their specific ideal input characteristics in a better way than the firms can do. Our theory therefore provides a rationale for why firms outsource to third parties, even if there is neither a technological reason

[1] See, e.g., the survey article by Aghion and Holdon (2011) or the book by Besanko et al. (2013).
[2] We provide a literature review in the next section.

for it—i.e., the third party is not more capable of producing the input or enjoys higher benefits from economies of scale—nor because downstream firms compete and do not want to outsource to a competitor.[3]

To bring out our effect in a simple way, we study a market consisting of two independent (non-competing) downstream firms that require a horizontally differentiated input for producing their final product. Each firm can produce its input in-house or buy it from another firm. This supplying firm can either be the other downstream firm or a third party, which is not active in the downstream market. Production of the input requires an investment into a production technology, where the cost of doing so is the same for each firm. Therefore, no firm has an advantage in the production of the input. Each downstream firm has its ideal input. In case a downstream firm produces with a less-than-ideal input, it incurs adjustment costs. If a downstream firm does not produce the input itself, it negotiates with a firm that is able to produce the input about the respective price. Firms are, however, not able to contract on the type of input.

Overall, our model captures, in a simple way, the trade-off between specialization and economies of scale. On the one hand, each firm's ideal input is different, which implies that investments in two input production technologies are necessary for fulfilling the specialized demands of each firm in an optimal way. On the other hand, investment in only one production technology saves on investment costs while still allowing each downstream firm to produce—i.e., economies of scale arise—but implies that one or both of the inputs are not ideal. We show that, in this context, the incompleteness of contracts opens the door for the third party to become active in the market (even in the absence of cost savings or strategic considerations).

In this framework, we first demonstrate that three potential investment configurations can emerge in equilibrium. First, if investing in the production technology is relatively cheap, both downstream firms invest, and each one produces its ideal input. In that case, the benefits from specialization outweigh economies of scale. Second, if the investment costs are relatively high, only one of the three firms will invest. Consider first the situation in which one of the downstream firms invests. As the firm can then sell its input to the other downstream firm, it needs to choose the type of input it produces—i.e., because downstream firms have different ideal input characteristics, the investing firm can decide whether to produce

[3]Of course, there are several other reasons why producers outsource to a common supplier, such as second sourcing or specialization. Our theory is complementary to these explanations.

a specialized input that is close to one of the two ideal ones or a more general input that leads to similar adjustment costs for both firms. However, the fact that the investing firm obtains only a part of the other firm's downstream profit in the negotiation creates an incentive to produce an input that is closer to its own ideal characteristics. In this respect, the input is distorted from the one that yields the lowest total adjustment costs.

If the input is produced by the third party—who then becomes a common input supplier—this party also needs to decide about the type it offers. However, since it is not active in the product market, it chooses an input that optimally balances the ideal characteristics of the downstream firms. This allows the third party to become active in the market, even though it has no technological advantage relative to the downstream firms. In particular, we show that in the (profit-dominant) equilibrium the third party is the common input supplier if its bargaining power is in an intermediate range. If its bargaining power is too low, it will not be able to recoup its investment costs in the negotiations with the downstream firms. Instead, if the third party's bargaining power is too large, the downstream firms will obtain too little of the industry surplus and are therefore better off when one or both of them invest. However, for intermediate values, outsourcing to a common input supplier occurs. What also follows is that the profit of this supplier is non-monotonic in its bargaining power.

We also determine whether the equilibrium investment configuration is efficient. We demonstrate that, if outsourcing to the third party occurs, this is always efficient. However, the same unambiguous conclusion does not hold for the configuration in which both firms produce the input in-house. In particular, from a welfare perspective, in-house production by both firms occurs too often. The intuition is that a non-investing firm can only reap part of the profit from selling its product, which implies that the private incentives to realize economies of scale are lower than the social incentives. Finally, if one of the downstream firms invests in equilibrium, the decision to avoid a duplication of investment costs is always efficient, but the input distortion that the investing firm creates still leads to a welfare loss.

Overall, our paper shows that the mere fact that input contracts are incomplete can provide a rationale for common input supply. From an incomplete-contracts perspective, an investing downstream firm choosing a less-than-ideal input for itself undertakes an (asset-specific) investment, as it chooses an input that is closer to the one of the other downstream firm. However, in the negotiation, it cannot reap the full benefit, which creates an incentive to deviate from the efficient input characteristic. By contrast, the revenues that a third party obtains from selling the input are the same for both downstream firms, which implies that offering an input that strikes an optimal balance between the firms' ideal input characteristics is in its best interest. The incompleteness of the contract hence becomes irrelevant.[4]

The rest of the paper is organized as follows: Section 2 relates our paper to existing literature. Section 3 sets out the model and Section 4 derives the different equilibrium configurations. Section 5 compares the equilibrium outcome with the efficient one. Finally, Section 6 concludes.

2 Literature

Our paper contributes to existing literature in several dimensions. First, we add to the extensive supply chain literature dealing with firms' outsourcing decisions.[5] At the heart of this literature is the question of why a firm decides to source an input from an external supplier even though it is capable of producing it in-house. The major justification shown in different forms is that the supplier benefits from cost efficiencies relative to a downstream firm (e.g., Lewis and Sappington, 1989; van Mieghem, 1999; Anderson and Parker 2002; Cachon and Harker, 2002; Shy and Stenbacka, 2003; Sappington, 2005). Another reason pertains to strategic considerations, which primarily apply to competing firms that outsource to common input suppliers (e.g., Cachon and Harker, 2002; Gilbert et al., 2006; Arya et al. 2008; Feng and Lu, 2012, 2013; Grahovac et al., 2015; Milliou, 2020). The predominant rationale in those papers is that outsourcing raises the rival's costs and/or softens competition in the downstream market.

Within this stream of literature, some papers focus on the decision to outsource to a downstream rival. For instance, Spiegel (1993) shows that a firm in quantity competition may outsource to a competitor if the latter can produce at lower costs.[6] Instead, Chen et al. (2011) show that outsourcing to a rival puts a firm at a strategic

[4]If the downstream firms were able to write an enforceable contract about the type of the input in advance, the resulting input specification would be efficient, and the market would not provide room for a third party that does not exhibit cost advantages.

[5]For an overview of existing research on outsourcing in supply chains, see Tsay et al. (2018).

[6]Sappington (2005) also shows that downstream firms will buy from the most efficient supplier, regardless of whether this firm is a competitor or not.

disadvantage because it transforms a simultaneous game into a sequential game.[7]

Another strand of literature analyzes why firms may outsource to producers that do not benefit from efficiencies. For instance, Colombo and Scrimitore (2018) find that outsourcing can co-exist with more efficient in-house production because it allows firms to exploit the competitive benefits of strategic delegation. In an incumbent-entrant model, Hu et al. (2022) show that the entrant may horizontally outsource to the incumbent who is less efficient than an alternative supplier to soften downstream competition, given that the entrant can commit to sole sourcing.

In contrast to all of those papers, we do not consider a setting in which potential suppliers have different production technologies nor do we consider strategic considerations between downstream firms. We show that, even in this case, outsourcing to an equally efficient third party can be optimal because of the incompleteness of input contracts.

We further enrich the literature by accounting for the trade-off between economies of scale and the degree of specialization in a firm's input production decision. The only study we are aware of that integrates considerations about input specialization into their analysis of firms' outsourcing decisions is Feng and Lu (2010). In their model, scope economies may lead a supplier to decrease horizontal differentiation between the products she designs for competing downstream firms. However, their set-up and research question is very different from ours, as they, e.g., do not consider contract incompleteness, but focus on competition in the downstream market.

Finally, we borrow from the literature on incomplete contracts, pioneered by Grossman and Hart (1986), Hart and Moore (1990), and Hart (1995), that firms cannot contract on the specificity of an input. This literature has made a lot of progress in explaining the vertical and lateral boundaries of the firm and potential solutions for the hold-up problem. Our focus, in contrast, is on how third parties can overcome problems arising from incomplete contracting.

[7] For studies in which firms may outsource to a common supplier, see Wang et al. (2013) and Milliou (2019).

3 The Model

We consider a model with two downstream firms, F_i, $i = 1, 2$, each of which produces and independently sells an output to consumers in its respective product market. Both firms receive a revenue of $R > 0$ from selling this output. To produce the output, each firm needs an input good. Input goods can be produced by F_i and by a third party (upstream firm) U that is not active in any of the final goods markets. Firms F_i differ in their ideal characteristic of the input good. To fix ideas, we suppose that the characteristic of the input is represented by a point on the interval $[0, 1]$. The ideal input of F_1 is 0, while the ideal input of F_2 is 1. If F_1 (resp. F_2) produces its output using an input with characteristic θ, it incurs costs of $t\theta^2$ (resp. $t(1-\theta)^2$). These costs represent, for instance, adjustment costs in the firm's production process to produce the final output.

An input good θ can be produced by investing in a production technology. Such an investment leads to costs of k. Investment costs are independent of the input characteristic, which is a natural assumption since differentiation in input goods is horizontal rather than vertical, i.e., it is not related to quality. To make the problem interesting, we suppose that $R > k$. For simplicity, there are no further costs of production; that is, marginal costs of producing inputs and transforming inputs to outputs are assumed to be zero. Each firm can invest at most in one production technology and decides about the kind of input to produce; that is, it chooses θ. For ease of exposition, we also assume that $k > t/4$—i.e., the costs to invest in the production technology are large relative to the adjustment cost.[8]

To be able to produce an output, a firm F_i does not need to invest in a production technology but can also buy the input from another firm. For example, if only F_i invests, then firm F_{-i} can buy the input from F_i with the θ chosen by F_i. In that case, F_i and F_{-i} negotiate about the terms of trade—i.e., the fee that F_{-i} pays to F_i for the use of its input.[9] We assume that negotiations take place according to Nash (1950), resulting in the Nash bargaining solution. The bargaining power in a bilateral negotiation between F_i and F_{-i} is 1/2 while the bargaining power of firm U in a bilateral negotiation with one of the downstream firms is $\beta \in (0, 1)$.[10] If U

[8] This assumption does not affect our main results.

[9] Bargaining takes place over a fixed fee or surplus share instead of a wholesale price (following, e.g., van Mieghem (1999) and Plambeck and Taylor (2005)).

[10] All our results would be unchanged if bargaining occurred non-cooperatively following a take-it-or-leave-it structure in which the bargaining power represents the probability with which a firm makes the offer.

and F_i invest but not F_{-i}, then F_{-i} bargains alternatingly with the investing firms until an agreement with one supplier is reached, where the bargaining powers are again β and $1-\beta$ in the negotiation between U and F_{-i}, and 1/2 in the negotiation between F_i and F_{-i}. This is a natural structure since it implies that F_{-i}'s outside option in each bilateral negotiation is to switch to the other firm that has invested and reach agreement with it.[11] Similarly, if U is the only firm that invests, it bargains alternatingly with F_1 and then with F_2. We assume $R - t > 0$; that is, even if the distance to the optimal input of one of the downstream firms is maximal, a positive surplus can be generated.

If firm U does not invest, its outside option is normalized to 0. If a downstream firm does not invest and also decides not to buy the input from another firm, it has the possibility to invest at a later point in time. However, its profit is then discounted by $\delta \in (0, 1)$. This captures the idea that a downstream firm can always decide to produce the input good itself, even when originally planning to buy it from another firm, but the latter did not materialize. In such a case, the firm foregoes initial profit opportunities because it could not produce and sell for some time. Since the firm can then also not sell to another firm, it will invest in a production technology that produces its ideal input. Therefore, the outside option of F_i is given by $\delta(R - k) > 0$.

The game proceeds as follows: In the first stage, each firm decides whether to invest in a production technology and, if it does, it chooses the input characteristic θ. In the second stage, investing and non-investing firms negotiate with each other, where bargaining follows the structure described above. Finally, in the third stage, each downstream firm that has not assured input supply in the first two stages has the possibility to invest in a production technology to obtain a profit of $\delta(R - k)$.

Our solution concept is subgame-perfect Nash equilibrium, with the refinement that if multiple equilibria occur in the first stage, the equilibrium that yields the highest industry profit is selected. This is a natural selection criterion, as firms can coordinate on that equilibrium by allowing pre-play side payments.

Note that our assumptions imply that firms cannot contract on the input characteristic in advance. I.e., there is no pre-stage of the game in which firms can write a contract that specifies the θ that an investing firm needs to choose in the

[11] Specifically, F_{-i} first negotiates e.g. with U, where the outcome is determined by the Nash bargaining solution with F_{-i}'s outside option being the payoff it would get in the negotiation with F_i. If U and F_{-i} do not reach an agreement, then F_{-i} bargains with F_i, where F_{-i}'s outside option is the payoff it would get in the negotiation with U, and so on. This can be interpreted as alternating bargaining without discounting.

first stage of the game. As in the literature on incomplete contracts (e.g., Grossman and Hart, 1986; Hart and Moore, 1988; Hart, 1995; Aghion and Holdon, 2011), inputs are complex and their characteristics cannot be described in a contract that can later be verified in a court of law.

4 Equilibrium Investment Configurations

In this section, we solve for conditions under which different equilibrium investment configurations can prevail. In general, there exist five plausible equilibria: 1) all firms invest, 2) firms U and F_i invest and F_{-i} does not, 3) firms F_i and F_{-i} invest and U does not, 4) only firm F_i invests and firms U and F_{-i} do not, and 5) only firm U invests and F_i and F_{-i} do not. We will prove that only the latter three investment configurations may constitute an equilibrium and derive conditions for which each of these equilibria will occur. One of our central results will be that, even though U is not more efficient than the downstream firms and there is no downstream competition, U will be active in equilibrium if k is sufficiently high and its bargaining power is neither too high nor too low.

First, it can never be optimal for all three firms to invest in equilibrium. If this was the case, neither of the downstream firms F_1 and F_2 would buy from another firm, as they have invested themselves. Therefore, both downstream firms would produce their respective ideal input. Firm U can then not offer a higher profit to the firms, which implies that none of them buys from U; hence, U would make losses of k while it gets 0 when staying inactive.

Second, the scenario where F_i and U invest but not F_{-i} can also never constitute a subgame-perfect equilibrium. In that case, U can only sell to F_{-i} (as F_i has produced its own input) and therefore sets θ equal to the ideal input of F_{-i}. The maximal surplus that is generated in the relationship between U and F_{-i} equals $R-k$ and F_{-i} gets some fraction of it dependent on β and its outside option. However, if F_{-i} deviates in the first stage and invests on its own, it gets a profit of $R-k$ with certainty which is strictly larger than the profit from non-investing and buying from U.

In the following, we derive the parameter constellations where the remaining investment configurations constitute a subgame-perfect equilibrium (Lemmas 1-3). Afterward, we apply our equilibrium selection criterion to single out a unique equilibrium.

We start with the scenario in which both downstream firms invest.

Lemma 1: If F_1 and F_2 invest, they set $\theta = 0$ and $\theta = 1$, respectively, and U is inactive. This scenario is a subgame-perfect equilibrium if and only if

$$k \leq \frac{R(1-\delta)}{2-\delta} + \frac{t}{2-\delta} \equiv k_1. \tag{1}$$

Profits are $\Pi_U = 0$ and $\Pi_{F_1} = \Pi_{F_2} = R - k$.

Proof of Lemma 1: We will check if it can pay off for U or for one of the downstream firms to deviate. Clearly, it can never be profitable for U to invest. Since each F_i produces its ideal input, none of them would buy from U in the second stage. Since investing is costly, U would incur losses if it deviated.

Now suppose that F_i deviates and does not invest. If F_i buys the input from F_{-i} at stage 2, it has to incur costs of t, since F_{-i} produces the input at the largest distance to F_i. Because k is sunk, the surplus that can be split is $R - t$, leading to a deviation profit for F_i of

$$\frac{1}{2}\max\{R - t - \delta(R-k), 0\} + \delta(R-k). \tag{2}$$

The above expression shows that in the negotiation process with F_{-i}, F_i always receives at least its outside option $\delta(R-k)$ (second term of (2)). Any remaining amount of the generated surplus is then split according to the firms' bargaining power 1/2 (first term of (2)).

Suppose, first, that the remainder of the generated surplus, i.e., the first term of (2), is larger than zero. Comparing the deviation profit with $R - k$ yields that deviating does not pay off if (1) is fulfilled. If, instead, the first term of (2) equals zero, then a deviation never pays off since $\delta(R-k) < R - k$. Determining under which condition the first term of (2) is zero, we obtain that this is the case if $k \leq (-R(1-\delta)+t)/\delta$. It is easy to check that $(-R(1-\delta)+t)/\delta$ is smaller than the right-hand side of (1). It follows that the investment configuration of Lemma 1 is a subgame-perfect equilibrium if (1) holds. ■

The result of Lemma 1 is fairly intuitive. It states that, if k is below a critical value (denoted by k_1), it is optimal for both downstream firms to invest in the production technology. Although this implies that each firm incurs costs of k, they can use their respective optimal input and hence save on adjustment costs. As k is small, each firm is better off investing instead of buying the input from the other downstream firm.

The threshold k_1 is increasing in t and R and decreasing in δ. The intuitions are the following: First, if t increases, procuring a non-ideal input becomes more costly. Hence, each firm has a higher incentive to produce its input in-house. This highlights the trade-off between saving own investment costs and benefiting from a more specialized input. Second, if R increases, investing becomes more attractive because, in this case, an investing firm does not have to share its higher downstream profit with another firm. Finally, a decrease in δ implies that a non-investing firm has a lower outside option and therefore gets a lower share in the negotiation with an outside input supplier.

We next turn to the scenario in which only one of the downstream firms invests.

Lemma 2: If only F_i invests, it sets θ at a distance of $1/3$ to its ideal input. F_{-i} then buys the input from F_i, and U is inactive. This scenario is a subgame-perfect equilibrium if and only if

$$k \geq \begin{cases} \frac{R(1-\delta)}{2-\delta} + \frac{4t}{9(2-\delta)} \equiv k_2' & \text{for} \quad \delta \leq \frac{9R-6t}{9R-5t} \\ \frac{-R(1-\delta)}{\delta} + \frac{2t}{3\delta} \equiv k_2'' & \text{for} \quad \delta \geq \frac{9R-6t}{9R-5t} \end{cases} \tag{3}$$

In this case, profits are $\Pi_U = 0$,

$$\Pi_{F_i} = R - k - \frac{1}{9}t + \frac{1}{2}\left(R - \frac{4}{9}t - \delta(R-k)\right) \tag{4}$$

and

$$\Pi_{F_{-i}} = \frac{1}{2}\left(R - \frac{4}{9}t - \delta(R-k)\right) + \delta(R-k). \tag{5}$$

Proof of Lemma 2: Without loss of generality, we assume that F_1 is the investing firm while F_2 and U do not invest. We start with the maximization problem of F_1. It is given by

$$\max_{\theta} \Pi_{F_1} = R - k - t\theta^2 + \frac{1}{2}(R - t(1-\theta)^2 - \delta(R-k)).$$

The solution of this problem is $\theta = 1/3$. Inserting $\theta = 1/3$ into the profit function of F_1 and F_2 yields the profits stated in Lemma 2.

Now consider a deviation of F_2. If F_2 deviates and invests, it obtains a profit of $R - k$. If F_2 does not invest, its payoff in the negotiation with F_1 is

$$\Pi_{F_2} = \frac{1}{2}\max\left\{R - \frac{4}{9}t - \delta(R-k), 0\right\} + \delta(R-k). \tag{6}$$

If the first term of (6) is strictly larger than zero, a deviation for F_2 is not profitable if $k \geq k_2'$. If, instead, this term is zero, a deviation is profitable since F_2 would obtain only $\delta(R-k)$ in equilibrium. The first term of (6) is zero if $k < -R(1-\delta)/\delta + 4t/(9\delta)$. However, $-R(1-\delta)/\delta + 4t/(9\delta)$ is smaller than the second term of k_2'. This implies that the condition $k \geq k_2'$ ensures that a deviation is not profitable for F_2. The payoff of F_2 is then given by (5).

Now consider a deviation of U. If U deviates, it optimally chooses a θ that equals the optimal input of firm F_2 since it can only sell to F_2. Now suppose that F_2 bargains with U. Then, F_2's outside option is either to buy from F_1 or to build the input on its own in stage 3. Let us first look at the case in which the first option gives F_2 a larger surplus. Since F_1 chooses a θ that is at a distance of $2/3$ to F_2's preferred input, the total surplus to be shared in the bilateral negotiation between F_1 and F_2 is $R - 4t/9$. This is smaller than R, which is the total surplus to be split in the negotiation between F_2 and U. Therefore, F_1 cannot claim any surplus in the negotiation with F_2, which implies that F_2's outside option is equal to $R - 4/9t$. U's payoff in the negotiation with F_2 is then $\beta(R - (R - 4t/9)) = \beta t4/9$ and U's total payoff is $\beta t4/9 - k$. Therefore, U has no incentive to deviate if $k \geq \beta t4/9$. It is straightforward to check that for any $\delta \in (0,1)$, $\beta t4/9$ is smaller than k_2'. It follows that if $k \geq k_2'$ is fulfilled and, thus, F_2 has no incentive to deviate, U also has no incentive to deviate.

Next, we turn to the case in which the relevant outside option for F_2 when bargaining with U is to build the input on its own at stage 3 instead of buying from F_1. This implies that $\delta(R-k) > (R - 4t/9)$ or $k < -R(1-\delta)/\delta + 4t/(9\delta)$. However, we know from above that for $k < -R(1-\delta)/\delta + 4t/(9\delta)$ a deviation by F_2 is already profitable. Therefore, when combining the deviation incentives by F_2 and U, we obtain that both firms have no incentive to deviate if $k \geq k_2'$.

Finally, consider a deviation of F_1. Because $\theta = 1/3$ is the optimal input given that F_1 decides to sell it to F_2, the only plausible deviation strategy is to not sell to F_2 and, hence, set θ equal to its ideal product (i.e., $\theta = 0$). Comparing the resulting profit of $R - k$ with the profit given by (4), we obtain that a deviation does not pay off for F_1 if

$$k \geq \frac{-3R(1-\delta)+2t}{3\delta} \equiv k_2''.$$

Comparing k_2'' with k_2' we obtain that the first threshold is larger than the second if $\delta \geq (9R-6t)(9R-5t)$. Therefore, we obtain that the investment configuration of Lemma 2 is an equilibrium if and only if $k \geq k_2'$ given that $\delta \leq (9R-6t)(9R-5t)$ and $k \geq k_2''$ given that $\delta \geq (9R-6t)(9R-5t)$. ■

Lemma 2 shows that the scenario in which only one of the downstream firms invests occurs if investment costs are sufficiently high (i.e., k must be larger than a threshold). In this case, firms benefit from economies of scale, as the investing firm can provide sufficient inputs for both firms to produce. However, the disadvantage is that the input is less specialized as F_i chooses an input characteristic θ that is between the two ideal inputs of 0 and 1.

Interestingly, F_i chooses a θ that is closer to its own ideal input than to the one of F_{-i}. The reason for this is that F_i obtains only a share of the surplus from selling to F_{-i}. Hence, it benefits to a less than full extent if its choice of θ decreases F_{-i}'s adjustment costs while it benefits to the full extent if its own adjustment costs decrease. Thus, F_i optimally distorts the produced input in the direction of its own ideal input characteristics. As will be discussed in the next section in greater detail, the socially optimal balance would be achieved by choosing $\theta = 1/2$ as this trades off the ideal input characteristics of the downstream firms in a better way.

As for Lemma 1, we next explain how the parameters shape the threshold values for k. First, note that k_2' is obtained by considering the incentive of the non-investing firm F_{-i} to deviate and invest itself. Naturally, the trade-off for F_{-i} in the decision to invest itself or buy the input from another firm is very similar to the one in Lemma 1, which explains why the threshold is again increasing in t and R and decreasing in δ. Deviating and producing the input in-house becomes more attractive than sourcing it from the other firm the higher the adjustment costs, the higher the revenue that has to be shared with the other firm, and the lower the outside option in the negotiation process. However, this differs for k_2''. Even though this threshold still increases in t, it now falls in R and rises in δ. For the intuition, it is important to note that k_2'' is obtained by considering a deviation of the investing firm F_i, whose only plausible deviation strategy is to refrain from selling to F_{-i}. In this case, it will produce its ideal input and thus save on adjustment costs but forego additional profit from selling to the other downstream firm. An increase in t

clearly reinforces the former benefit. At the same time, the loss in additional profit is mitigated when the surplus to be shared in the negotiation decreases; hence, when t increases and F_{-i}'s revenues R decrease. Foregone profits also decrease when F_{-i}'s share of the surplus, and therefore δ, becomes higher.

The reason why the deviation incentives of U are not decisive is the following: In the current scenario, F_{-i} finds it beneficial not to invest but to buy a less-than-ideal input from the other downstream firm. This can only mean that F_{-i} currently earns more than $R-k$, which is the payoff it would obtain when investing. However, if U invests, the maximum surplus that is generated is $R-k$. As F_{-i} only gets a fraction of this surplus, it will never buy from U.

In sum, the equilibrium in which only one downstream firm invests is more likely the lower the adjustment costs t. In addition, the equilibrium is more likely to occur if both δ and R are in an intermediate range instead of being rather high or low.

Finally, we consider the scenario in which only U invests, and both downstream firms buy from U.

Lemma 3: If only U invests, it sets $\theta = 1/2$ and both F_i and F_{-i} buy the input from U. This scenario is a subgame-perfect equilibrium if and only if

$$\beta_3' \equiv \frac{2k}{4R(1-\delta)+4\delta k - t} \leq \beta \leq \frac{4k-t}{4R(1-\delta)+4\delta k - t} \equiv \beta_3''. \tag{7}$$

In this case, profits are

$$\Pi_U = 2\beta\left(R - \frac{t}{4} - \delta(R-k)\right) - k \tag{8}$$

and

$$\Pi_{F_1} = \Pi_{F_2} = (1-\beta)\left(R - \frac{t}{4}\right) + \beta\delta(R-k). \tag{9}$$

Proof of Lemma 3: If firm U invests and both downstream firms buy the input from it, the optimization problem of U can be written as $\beta(R - t\theta^2 - \delta(R-k)) + \beta(R - t(1-\theta)^2 - \delta(R-k)) - k$. The solution is $\theta = 1/2$. Determining the profit from the respective bargaining game then yields (8).

We now analyze the firms' deviation incentives. For firm U, investment is profitable if $\Pi_U \geq 0$. Rewriting this condition yields

$$\beta \geq \frac{2k}{4R(1-\delta)+4\delta k - t}.$$ [12]

Without loss of generality, we now consider a deviation by F_1. There are two possible deviation strategies. First, it can either invest in a production technology that produces its optimal input and does not sell to F_2. Second, it can try to sell to F_2 and choose an input between 0 and 1. We start with the first case. Comparing F_1's deviation profit of $R-k$ with the equilibrium profit of F_1 as given in (9), we obtain that a deviation is not profitable if

$$\beta \leq \frac{4k-t}{4R(1-\delta)+4\delta k - t}.$$

If F_1 plans to sell to F_2, it can only do so if its input characteristic is $\theta \in (1/2, 1]$ because, otherwise, F_2 obtains a larger surplus from buying from U. Determining the profit of F_1 when selling to F_2 yields $R - t\theta^2 - k + 1/2[R - t(1-\theta)^2 - R + t/4]$. It is easy to check that, for any $\theta \in (1/2, 1]$, this profit is smaller than $R-k$, which is F_1's profit when setting $\theta = 0$ and not selling to F_2. Thus, the latter is F_1's optimal deviation strategy and the relevant no-deviation condition is the one determined above. Taken together, we obtain that neither U nor F_1 has an incentive to deviate if and only if

$$\frac{2k}{4R(1-\delta)+4\delta k - t} \leq \beta \leq \frac{4k-t}{4R(1-\delta)+4\delta k - t},$$

which is the condition stated in Lemma 3. ■

Lemma 3 shows that the scenario where only U invests is an equilibrium if and only if its bargaining power is in an intermediate range. If β is very small, U does not receive a large enough profit in the bargaining stage to render investing in the first stage worthwhile. In contrast, if β is very large, downstream firms receive only a small share of the surplus in the bargaining stage. Thus, it pays off for them to deviate and invest on their own. Another implication of Lemma 3 is that $k \geq t/2$ is a necessary condition for the equilibrium to occur. Otherwise, $\beta_3' > \beta_3''$ and, hence, (7) can never be fulfilled. Thus, if investment costs are relatively small, downstream firms would have an incentive to deviate and produce the input on

[12]Since $k > t/4$, the denominator and thus the threshold is always positive.

their own.

In contrast to the case in which only F_i invests, U sets the input characteristic at 1/2, which achieves the optimal balance between the ideal input characteristics of the downstream firms. The reason is that U only obtains its revenue from selling the input to the downstream firm and does not need the input for itself. Hence, it has no incentive to treat one of them more favorably.

As above, we now briefly discuss the comparative statics of the two thresholds for β in (7). First, we observe that both β_3' and β_3'' increase in δ. In this case, the configuration where only U invests necessitates and also allows for a higher bargaining power of U. The intuition is that a higher outside option of F_i gives firm U a lower share of the surplus, reducing the attractiveness of being active in the market. This has to be counteracted via a higher bargaining power of U. At the same time, a higher outside option increases F_i's incentives to not invest but buy from U, implying that firm U's share of the surplus in the negotiation, and hence β, can be higher.

Second, both thresholds decrease in R, requiring and also allowing for a lower bargaining power of U for the current equilibrium to occur. On the one hand, a higher revenue for F_i renders it more beneficial to invest on its own as the higher surplus does not have to be split with another firm. To reduce this incentive, the share of the surplus for F_i when negotiating with U has to increase. Hence, β has to be lower. On the other hand, a higher R increases the surplus to be shared between the bargaining parties, increasing the profitability of U to invest and sell the input to the downstream firms. Its share of the total surplus can thus be lower.

Finally, β_3' increase in t while β_3'' decreases in t, which implies that condition (7) becomes harder to fulfil. The reason is that higher adjustment costs decrease the surplus to be shared between U and the downstream firms, rendering it less profitable for U to be active in the market and, at the same time, more profitable for the downstream firms to produce the input in-house.

We next determine how the regions for the different equilibria relate to each other. First, when considering the results of Lemma 1 and Lemma 2, we obtain that k_1 is strictly larger than k_2' and k_2''. This implies that there exists a region, i.e., if k is in between k_2' or k_2'' and k_1, for which both equilibrium configurations exist. Second, combining the results of Lemmas 1-3, it is easy to check that $t/2$, which is the threshold for the equilibrium in Lemma 3 to occur, is always smaller than k_1, k_2', and k_2''. This implies that there exists a region, i.e., if k is between $t/2$

and $max\{k_2', k_2''\}$, for which the equilibrium in Lemma 1 and Lemma 3 exist and also a region, i.e., if k is between $max\{k_2', k_2''\}$ and k_1, for which all equilibrium configurations exist. Figure 1 illustrates the parameter restrictions associated with the investment configurations of Lemmas 1-3.

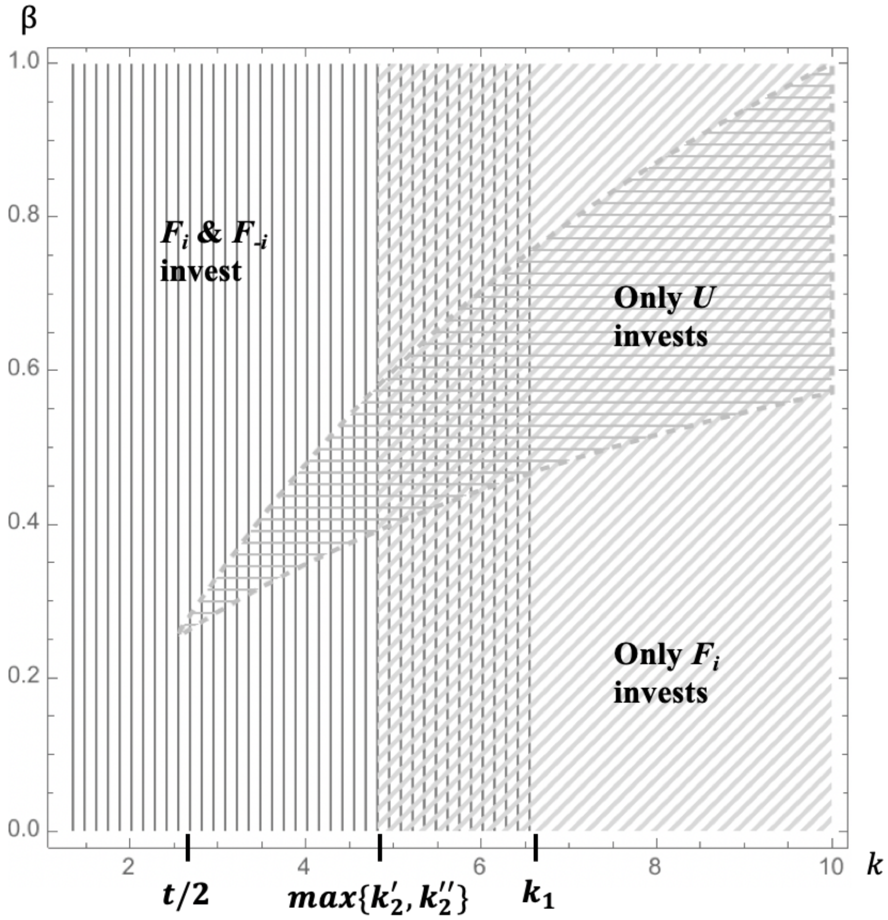

Figure 1: Parameter restrictions of the investment configurations as given in Lemmas 1-3 ($t = 5$, $R = 10$, $\delta = 0.5$).

As explained in Section 3, to single out a unique equilibrium for the parameter constellations in which multiple equilibria exist, we use profit-dominance as a selection criterion (i.e., we focus on the equilibrium that yields the highest aggregate profit). Applying this equilibrium refinement, we obtain the following result:

Proposition 1: Depending on the parameter constellation, the following investment configurations will occur as the unique profit-dominant equilibrium:

– If $k \leq t/2$, both downstream firms F_1 and F_2 invest and choose $\theta_1 = 0$ and $\theta_2 = 1$, respectively, while U is not active.

– If $k \geq t/2$ and $\beta \in [\beta_3', \beta_3'']$, only U invests, chooses $\theta = 1/2$, and sells to both downstream firms.

– Finally, if $k \geq t/2$ and $\beta \notin (\beta_3', \beta_3'')$, U is not active. If

$$k \geq \begin{cases} k_2' & \text{for} \quad \delta \leq \frac{9R-6t}{9R-5t} \\ k_2'' & \text{for} \quad \delta \geq \frac{9R-6t}{9R-5t}, \end{cases}$$

only F_i invests, chooses a θ at distance $1/3$ from its ideal input, and sells it to F_{-i}. Otherwise, both downstream firms F_1 and F_2 invest and choose $\theta_1 = 0$ and $\theta_2 = 1$, respectively.

If $k \leq t/2$, the selection criterion is not needed as the only subgame-perfect equilibrium in that case is the one in which both downstream firms invest. However, for $k > t/2$, there are parameter constellations with multiple equilibria. As Proposition 1 shows, if the equilibrium where only firm U invests exists (see Lemma 3), it always leads to higher industry profits than the other two scenarios. The reason for this is twofold:

First, compared to the equilibrium in which only one downstream invests, the input characteristic chosen by U is more efficient than that chosen by the investing downstream firm as it achieves a better balance between the ideal input characteristics of the downstream firms. As investment costs are only incurred once in both equilibria, the industry profit is higher in the equilibrium where U invests as compared to the equilibrium where F_i invests.

Second, compared to the equilibrium in which both firms invest, the equilibrium in which only U invests avoids a duplication of the investment costs but leads to less specialized inputs and thereby to an increase in adjustment costs. However, the former effect dominates from a joint profit perspective. The reason is that the individual incentive of a downstream firm to invest is relatively high as it can then keep all surplus for itself. Instead, when buying the input from U, it must partially share the surplus with U. Therefore, the individual incentives to invest are inefficiently strong, and joint profits are higher in case only U invests.

For the same reasons, if the equilibrium where only F_i invests exists, it always leads to higher industry profits than the scenario where both F_1 and F_2 invest.

Overall, the result shows that a profit-dominant equilibrium emerges in which U is active and sells its input to both downstream firms. This occurs despite the fact that U has *no advantage* in producing this input over and above what downstream firms can do themselves. The main reason is that an investing downstream firm has an interest in distorting the input toward its own ideal characteristics as it cannot fully appropriate the additional profit it obtains when positioning the input closer to the ideal input characteristics of the other downstream firm. Firm U, however lacks such a distortion incentive because it is not active in the downstream market and, therefore, does not have an inherent interest in producing a particular type of input. This opens the door for U to be active in the market even though it has no advantage in producing the input over the downstream firms.

From the above analysis, it follows that U can only be active if its bargaining power is in an intermediate range. Analyzing how U's profit depends on its bargaining power yields the following result.

Proposition 2: If $k \geq t/2$, the profit of U changes non-monotonically in its bargaining power. It is 0 for $\beta < \beta_3'$, increases continuously for $\beta \in [\beta_3', \beta_3'')$, jumps back to 0 at $\beta = \beta_3''$ and stays 0 for $\beta \in (\beta_3'', 1)$.

If $k \geq t/2$, U's profit is highly non-monotonic in its bargaining power. Below β_3', U is not active in equilibrium and hence does not earn any profit. From β_3' onward, its profits become positive and increase in β until $\beta = \beta_3'$, where profit are at their maximum of $k - t/2$. If β increases even further, it will again be inactive with zero profits.

Figure 2 illustrates those non-monotonicities for a parameter constellation where, depending on U's bargaining power, either both downstream firms or only U invest in equilibrium ($k \in [t/2, max\{k_2', k_2''\}]$). A graph for a parameter constellation where either only F_i or U invests in equilibrium ($k > max\{k_2', k_2''\}$) looks very similar.

5 Efficiency

A question that arises from our previous analyses is whether the equilibrium investment configurations given in Proposition 1 are efficient or whether firms' endogenous investment and sourcing decisions lead to a welfare loss. For this purpose, we first derive the socially optimal investment configurations, which are summarized in Proposition 3.

Proposition 3: If $k < \frac{t}{2} \equiv k_{eff}$, social welfare is maximized if two firms invest and produce the optimal inputs of F_1 and F_2, respectively. Instead, if $k > \frac{t}{2}$, social

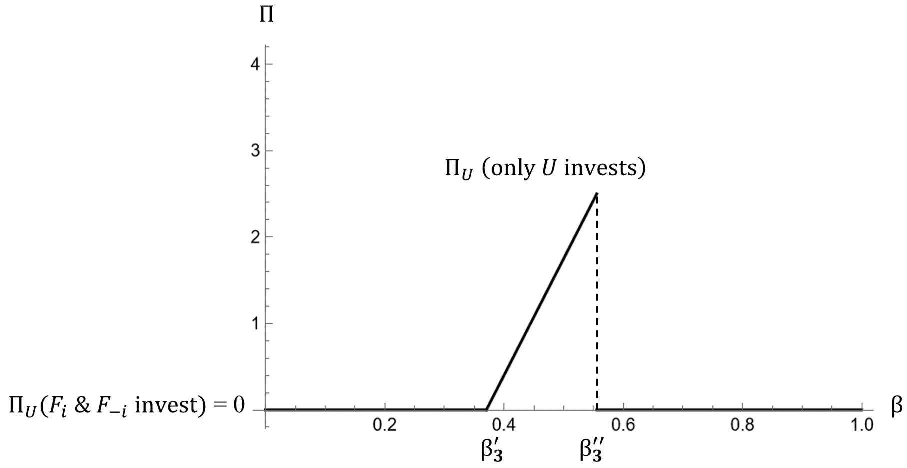

Figure 2: Profits of firm U for different levels of β, given $k \in [t/2, max\{k_2', k_2''\}]$ ($t = 5$, $k = 5$, $R = 11$, $\delta = 0.5$).

welfare is maximized if only one firm invests and sets $\theta = 1/2$.

Proof of Proposition 3: If there are two investments in production technologies, it is clearly optimal from a welfare point of view that they produce the ideal inputs of F_i, $i = 1, 2$. Social welfare in this case is given by $2(R - k)$. If, instead, only one firm invests, the optimal θ satisfies

$$\arg\max_{\theta} \quad 2R - k - t\theta^2 - t(1-\theta)^2.$$

Thus, $\theta^\star = 1/2$, which gives a social welfare of $2R - k - 1/2t$. Comparing the two scenarios yields that, from a social welfare point of view, two firms should invest if and only if $k < \frac{1}{2}t$.

An immediate result of Proposition 3 is that, if social welfare maximization requires that only one firm invests, the investment should be carried out by firm U rather than F_i. The reason is that, as explained after Lemma 2, F_i optimally distorts the input in its own direction, yielding a welfare loss.

We can now compare the equilibrium investment configurations of Proposition 1 to the efficient investment configurations of Proposition 3. This yields four scenarios that differ with respect to 1) whether both downstream firms produce the input themselves (*Make*) or at least one downstream firm buys the input from another firm (*Buy*) and 2) whether or not the investment constellation is efficient (*Efficient* vs. *Inefficient*). The following proposition summarizes the main results (see also Figure 3):

Proposition 4:

– Scenario 1: *Efficient Make* occurs if $k \leq \frac{t}{2}$.

– Scenario 2: *Efficient Buy* occurs if $k \geq \frac{t}{2}$ and $\beta \in [\beta_3', \beta_3'']$.

– Scenario 3: *Inefficient Make* occurs if $\beta \notin (\beta_3', \beta_3'')$ and

$$\frac{t}{2} \leq k \leq \begin{cases} k_2' & \text{for} \quad \delta \leq \frac{9R-6t}{9R-5t}, \\ k_2'' & \text{for} \quad \delta \geq \frac{9R-6t}{9R-5t}. \end{cases}$$

– Scenario 4: *Inefficient Buy* occurs if $\beta \notin (\beta_3', \beta_3'')$ and

$$k \geq \begin{cases} k_2' & \text{for} \quad \delta \leq \frac{9R-6t}{9R-5t}, \\ k_2'' & \text{for} \quad \delta \geq \frac{9R-6t}{9R-5t}. \end{cases}$$

What we observe in Figure 3 is that the equilibrium in which both F_1 and F_2 invest is efficient if and only if $k \leq \frac{t}{2}$. In the opposite case, the duplication of k weighs heavier than the adjustment cost firms would incur when sourcing the input from a common supplier. Moreover, the equilibrium in which only firm U invests is always efficient. This is because, as soon as k is sufficiently low such that efficiency calls for two instead of one firm to invest ($k < t/2$), both downstream firms have an incentive to produce the input in-house instead of buying it from firm U. If, instead, $k > t/2$, efficiency requires that only one firm invests and that $\theta = 1/2$, which is also what is in U's best interest. In contrast, the equilibrium in which only firm F_i invests is never efficient. The reason is that F_i always optimally distorts the input toward its own ideal characteristics.

6 Conclusion

This paper endogenously derives the equilibrium supply chain structure in a market involving two firms that are active in their respective downstream markets and require a common input but have different ideal input characteristics. Each firm can produce the input itself, can outsource the production to the other firm, or to a third party. Therefore, we explicitly investigate not only firms' make-or-buy decisions but, in case they choose to outsource, from which type of supplier to buy.

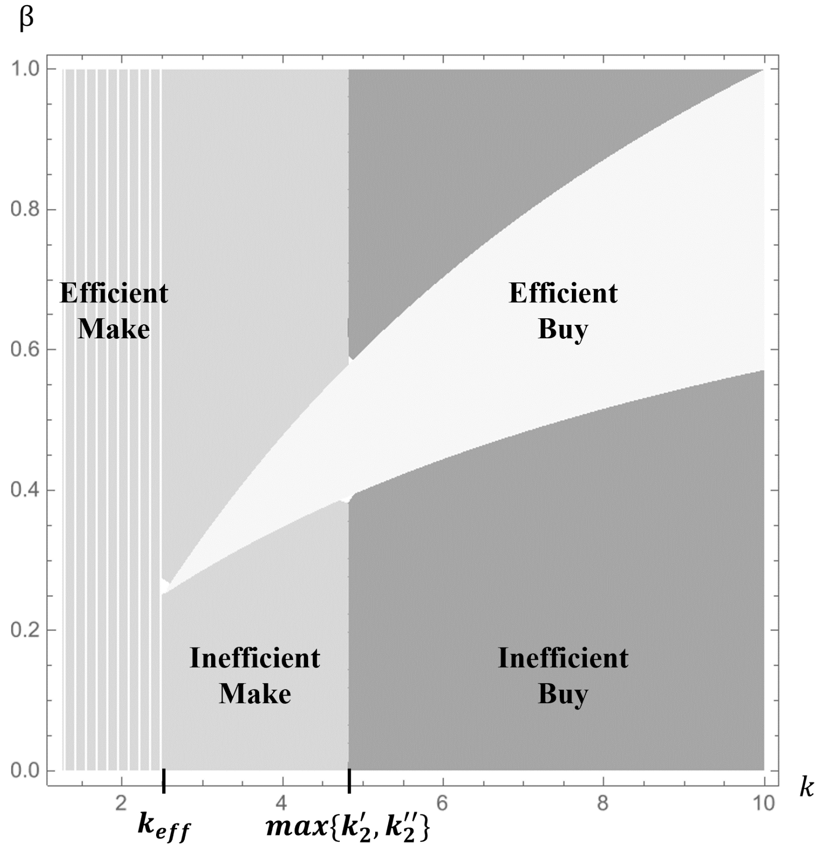

Figure 3: Parameter restrictions for which firms' make-or-buy decisions are (in)efficient ($t = 5$, $R = 10$, $\delta = 0.5$).

We show that, even though all firms are equally capable of producing and selling the input to another firm, the third party can become a common input supplier in equilibrium. The rationale for this outcome does not rely on technological or competitive advantages but on the incompleteness of input contracts. Specifically, if a downstream firm also becomes an input supplier to the other downstream firm, it has an incentive to distort the input toward its own ideal characteristics. The third party, in contrast, lacks such a distortion incentive. Hence, while both the investing downstream firm and the third party would realize the benefits from economies of scale, only the latter finds it in its best interest to produce an input that provides an optimal balance between the firms' ideal input characteristics, which opens the door for it to become active in the market.

From a welfare perspective, there exists an overly strong incentive to produce the input in-house and forego the benefits of economies of scale as outsourcing would require splitting the resulting surplus with another firm. However, if the equilibrium is characterized by the third party being the common input supplier, it is always efficient. In contrast, if one downstream firm acts as the input supplier to the other firm, the inherent distortion incentive always leads to a welfare loss.

Our model offers the potential to be extended in several directions. First, our current approach to incorporate economies of scale is relatively extreme as investment costs are always equal to k, irrespective of whether the investing firm supplies one or two firms. Further, our basic model restricts a firm to produce a single input. An alternative approach might be to allow one firm to produce two different inputs of types θ_1 and θ_2, which also allows for a more continuous treatment of economies of scale. The respective cost function might then be given by

$$C(\theta_1, \theta_2) = k\left(1 + \gamma(\theta_2 - \theta_1)^2\right),$$

with $\gamma \in (0, 1]$. Thus, when producing only one type of input, i.e., $\theta_1 = \theta_2$, a firm incurs costs of k, while if it chooses to produce two types of input, the costs are lower than $2k$ due to economies of scope. In particular, the costs function captures the realistic feature that these economies of scope are larger the more similar the two input types are.

Second, we so far assume that the type of input produced is not contractible. This fairly extreme assumption could be relaxed by considering an additional contracting stage at the beginning of the game, where the produced input can be contractually stipulated within a certain range, representing the degree to which the input is objectifiable.

Finally, our model abstracts from competition as the two downstream firms sell their product in two independent markets. Competing for customers might lead to additional insightful trade-offs guiding firms' investment and sourcing decisions.

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