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Strategic bi-sourcing

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Abstract: We provide a theoretical justification for bi-sourcing, which refers to the situation where a final goods producer buys an input from an outside supplier and also produces it in-house. Bi-sourcing occurs if the marginal cost of producing the input in-house is higher than the marginal cost of outside input supplier. In-house input production helps to reduce the input price charged by the outside supplier, and may make bi-sourcing as a profitable strategy. We show that bi-sourcing can be a profitable strategy under both monopoly and product market competition. The incentive for bi-sourcing depends on the product market and outside input market competition. Our result suggests that certain amount of input production with a relatively high-cost technology can make the consumers better off compared to the situation where the entire inputs are produced with a low-cost technology.

Key Words: Bi-sourcing; Competition; In-house input production

JEL Classifications: D21; D23; D43; L13; L23

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Strategic bi-sourcing

1. Introduction

Make-or-buy is often an important question faced by the organizations, and this has received significant attention in the literature. However, what is generally ignored in the literature is the case of *make-and-buy*, while evidence supports this strategy of modern organizations. For example, Nokia purchases a large proportion of key electronic components such as semiconductors and microprocessors from a global network of suppliers, and at the same time it produces these components in its own manufacturing plants (Nokia Annual Report, 2003). Freescale Semiconductor Inc., NXP Semiconductors and Analog Device Inc. behave as Integrated Device Manufacturers [1] and are also customers of Taiwan Semiconductor Manufacturing Company Ltd, which is a semiconductor dedicated foundry.

We provide a simple model to explain bi-sourcing, which refers to the situation where a final goods producer buys an input from an outside supplier and also produces it in-house. Bi-sourcing occurs if the marginal cost of in-house input production is higher than the marginal cost of the outside input supplier. In-house input production helps to reduce the input price charged by the outside supplier, and may make bi-sourcing as a profitable strategy. We show that bi-sourcing can be a profitable strategy under both monopoly and product market competition. The incentive for bi-sourcing depends on the product market and outside input market competition.

In a recent paper, Du et al. (2006) show that if a final goods producer uses complementary inputs, bi-sourcing helps to increase investments in inputs by mitigating

[1] An integrated device manufacturer is a semiconductor company which designs, manufactures, and sells integrated circuit products.

the hold-up problem. We provide a new reason for bi-sourcing. The reason for bi-sourcing in our analysis is attributable to the strategic effect of in-house input production on the outside input price.

There is a related literature which explains the reason for creating two sources for selling similar products (Kogut and Kulatilaka, 1994, Rob and Vettas, 2003, Choi and Davidson, 2004 and Mukherjee 2008). However, unlike that literature where the same final goods are sold in a particular market from two plants, we consider a problem where a final goods producer uses two sources for inputs, viz., the in-house production and buying from an outside supplier.

The remainder of the paper is organized as follows. Section 2 considers bi-sourcing by monopolist final goods producer. Section 3 shows the implications of competition in the product market. Section 4 concludes.

2. The case of monopolist final goods producer

Consider monopolist final goods producer, called firm 1, who can produce a critical input at the constant marginal cost of production c. We assume that the inputs can be transformed into the final goods at a constant cost, which is assumed to be zero, for simplicity. There is an outsider supplier of the critical input, called firm I, who can produce the critical input at the constant marginal cost d, where $d \leq c$. We assume that if firm 1 wants to the buy the inputs from firm I, it needs to pay the per-unit price w charged by firm I. We further assume that the final goods production requires only this input, and one unit of the final goods requires one unit of input.

Assume that the inverse market demand function is

$$P = a - Q, \tag{1}$$

where P and Q are the price and output of firm 1.

We consider the following game. At stage 1, firm 1 incurs per-unit cost c to build up a capacity level k to produce the input in-house. At stage 2, firm I determines the input price w. At stage 3, firm 1 determines its output and uses the inputs according to its requirement, and the profits are realized. We solve the game through backward induction.

Given that firm 1 installs capacity level k, it is obvious that firm 1 should produce up to k, since it has already incurred the costs for input production and the final goods production does not require further cost. However, we assume that if firm 1 wants to produce more than k, it needs to buy the extra inputs from firm I at the price w. Hence, firm 1 cannot adjust its capacity level after installation. This assumption is similar to the assumption of Spence (1984). However, it must be clear that if firm 1 can adjust the capacity level after installation, but the cost of capacity adjustment is higher than w, it is better for firm 1 to buy the extra inputs from firm I rather than producing them in-house.

Given k and w, firm 1 maximizes the following expression to determine the amount of output it wants to produce by using the inputs of firm I:

$$\underset{q}{Max}(a-q-k-c)k+(a-q-k-w)q$$

or $$\underset{q}{Max}(a-q-k)(k+q)-ck-wq\,, \qquad (2)$$

where q is the outputs produced by using the inputs of firm I. Since, one unit of input is required to produce one unit of output, q also determines the input supply by firm I. Therefore, total output of firm 1 is $Q=k+q$.

The equilibrium value of q can be found as

$$q^* = \frac{a - w - 2k}{2}. \tag{3}$$

The second-order condition for maximization is satisfied.

Firm I maximizes the following expression to determine the input price w:

$$\underset{w}{Max} \frac{(w-d)(a-w-2k)}{2}. \tag{4}$$

The equilibrium input price charged by firm I is

$$w^* = \frac{a - 2k + d}{2}. \tag{5}$$

It is immediate from (5) that the optimal input price charged by firm I is decreasing in k and it is increasing in d. If firm 1 increases the use of its own inputs, it requires relatively lower amount of inputs from firm I. Hence, a higher value of k reduces the input demand of firm I, thus reducing w. On the other hand, a higher value of d increases the cost of production of firm I, thus increasing the input price charged by firm I.

From (3) and (4), we get that, for a given k, the equilibrium value of q is

$$q^* = \frac{a - 2k - d}{4}. \tag{6}$$

Firm 1 maximizes the following expression to determine the optimal value of k:

$$\underset{k}{Max} \frac{4k(3a - 2k + d - 4c) + (a + 2k - d)(a - 2k - d)}{16}.$$

The equilibrium value of k can be found as

$$k^* = \frac{3a + d - 4c}{6}. \tag{7}$$

The equilibrium value of q is

$$q^* = \frac{c - d}{3}. \tag{8}$$

It is intuitive that if $c \le d$, there is no point of buying inputs from firm I, since the price charged by firm I is higher than firm 1's in-house cost of input production. Hence, in this situation, firm I uses only its own inputs and produces the monopoly output corresponding to its marginal cost of production, i.e., $k^* = \frac{a-c}{2}$.

The following proposition is immediate from the above analysis.

Proposition 1: *If there is monopolist final goods producer who can produce the input in-house, and there is an outside input supplier who can produce the inputs at a lower cost than the final good producer, bi-sourcing is the optimal strategy of the final goods producer if* $4c - 3a < d < c$.

Proof: We get from (7) and (8) that $k^* > 0$ for $4c - 3a < d$ and $q^* > 0$ for $d < c$, which proves the result. Q.E.D.

The intuition for Proposition 1 will be clear once we see the effect of bi-sourcing on the input price of firm I. If $4c - 3a > d$ and firm 1 buys all the inputs from outside supplier, the input price charged by the outside supplier is $\frac{a+d}{2}$, which is lower than c. Since the outside input supplier is very efficient in producing the input, the input price charged by the outside supplier is lower than firm 1's in-house cost of input production. In this situation, it is optimal for firm 1 to outsource input production completely.

Next, consider the situation of $4c - 3a < d < c$. Here, firm 1 does bi-sourcing, and the input price charged by the outside supplier is $\frac{d+2c}{3}$, which is lower than c. So, even if the outside input price is lower than the in-house cost of input production, firm 1 still

produces positive amount of input in-house. The reason for this behavior is as follows. If $4c-3a<d<c$ and firm 1 buys all the inputs from the outside supplier, the outside input price is $\frac{a+d}{2}$, which is greater than the outside input price under bi-sourcing (i.e., $\frac{d+2c}{3}$). In-house input production reduces the demand and the price of the outside inputs, and a strategic decision on in-house input production helps firm 1 to increase its output and profit compared to no outsourcing and full-outsourcing of the inputs.[2] Hence, if the outside input supplier is not very much cost efficient compared to firm 1 (i.e., $4c-3a<d<c$), firm 1 chooses the amount of in-house input production strategically to balance the positive effect of lower outside input price and the negative effect of higher cost of in-house input production.

As already mentioned, if $d \geq c$, there is no reason for buying the inputs from the outside supplier. Hence, firm 1 does not outsource input production in this situation.

Since the equilibrium output of firm 1 is higher under bi-sourcing compared to no outsourcing and full-outsourcing of the inputs, it is immediate that bi-sourcing makes the consumers better off under bi-sourcing compared to other two options. Therefore, in an imperfectly competitive input market, certain amount of input production with a relatively high-cost production technology may help the consumers compared to the situation where the entire inputs are produced by a low-cost production technology.

[2] The equilibrium outputs of firm 1 under no outsourcing, under complete outsourcing and under bi-sourcing are respectively $\frac{a-c}{2}$, $\frac{a-d}{4}$ and $\frac{3a-2c-d}{6}$.

3. Competition in the product market

The previous section has considered the case of monopolist final goods producer. Patent protection or higher entry cost may be responsible for creating monopoly of firm 1. Let us now see the implications of competition. Assume that there is another firm, called firm 2, who can produce a perfect substitute of the product of firm 1. We further assume that firm 2 can produce the critical input at the constant marginal cost c. However, to show the implications of competition, we will consider two situations: (i) where only firm 1 decides on bi-sourcing, and (ii) where both firms 1 and 2 have the option for bi-sourcing. The former situation helps us to show the effects of product market competition only, and may be appropriate for the situation where technological reasons may not allow firm 2 to do bi-sourcing. The latter situation shows the implications of strategic interactions in both output stage and bi-sourcing stage.

3.1. Bi-sourcing by firm 1 only

Let us consider a game similar to section 2 with the exception that, at stage 3, both firms 1 and 2 take simultaneous decision on outputs and use the inputs according to their requirements. It may be viewed as a situation where firm 1 has an incumbency advantage compared to firm 2.

Given k and w, firms 1 and 2 maximize the following expressions:

$$\underset{q_1}{Max}(a - q_1 - k - q_2 - c)k + (a - q_1 - k - q_2 - w)q_1 \tag{9}$$

$$\underset{q_2}{Max}(a - q_1 - k - q_2 - c)q_2, \tag{10}$$

where q_1 and k are the outputs of firm 1 by using the inputs of firm I and firm 1 respectively, and q_2 is the output of firm 2, which uses its in-house input.

The equilibrium outputs can be found as

$$q_1^* = \frac{a - 3k - 2w + c}{3} \qquad \text{and} \qquad q_2^* = \frac{a - 2c + w}{3}. \tag{11}$$

Firm I maximizes the following expression to determine w:

$$\underset{w}{Max} \frac{(w - d)(a - 3k - 2w + c)}{3}. \tag{12}$$

The equilibrium input price is

$$w^* = \frac{a - 3k + c + 2d}{4}. \tag{13}$$

We get from (11) and (13) that $q_1^* = \frac{a - 3k - 2d + c}{6}$ and $q_2^* = \frac{5a - 7c - 3k + 2d}{12}$.

Therefore, firm 1 chooses k to maximize the following expression:

$$\underset{k}{Max} \frac{3k(5a - 3k - 7c + 2d) + (a + 3k + c - 2d)(a - 3k + c - 2d)}{36}. \tag{14}$$

The equilibrium k is

$$k^* = \frac{5a - 7c + 2d}{12}. \tag{15}$$

The equilibrium q_1 is

$$q_1^* = \frac{11c - a - 10d}{24}. \tag{16}$$

Proposition 2: *If firms 1 and 2 compete in the product market, but only firm has the option for bi-sourcing, bi-sourcing is the optimal strategy of firm 1 if* $\frac{7c - 5a}{2} < d < \frac{11c - a}{10}$.

Proof: It follows from (15) and (16) that both $k^* > 0$ and $q_1^* > 0$ if $\frac{7c-5a}{2} < d < \frac{11c-a}{10}$. Q.E.D.

Since $4c-3a < \frac{7c-5a}{2} < \frac{11c-a}{10} < c$, the comparison of Propositions 1 and 2 show that the incentive for bi-sourcing is lower under competition in the product market compared to monopoly of firm 1. The commitment to in-house input production helps firm 1 to get the partial advantage of a Stackelberg leader in the product market. However, firm 1 may have the incentive to lower its commitment on input production and to use the inputs of the outside supplier if the input price of the outside supplier is sufficiently lower than firm 1's cost of input production. Therefore, firm 1 finds it profitable to sacrifice the leadership advantage in the product market to some extent, if it gets enough advantage in the input market, which implies that under product market competition firm 1 does bi-sourcing if $d < \frac{11c-a}{10}$. On the other hand, competition in the product market reduces firm 1's outside input demand.[3] Hence, under competition, if $d < \frac{7c-5a}{2}$, the outside input price, which is $\frac{a+c+2d}{4}$, is lower compared to firm 1's in-house cost of input production, which is c, even if firm 1 buys all the inputs from the outside supplier.

[3] Note that for given k and w, firm 1's outside input demand is $\frac{a-2k-w}{2}$ under monopoly, which is greater than its outside input demand under competition, which is $\frac{a-3k-2w+c}{3}$, since $a-2c+w>0$ due to the positive output of firm 2.

Therefore, under product-market competition, firm 1 stop producing inputs in-house if $d < \frac{7c - 5a}{2}$.

3.2. Bi-sourcing by both firms 1 and 2

Let us now consider the situation where both firms 1 and 2 have the option for bi-sourcing. We will consider two situations. First, firms 1 and 2 purchase the inputs from different input suppliers. Specificity of technology may be the reason for buying inputs from different input suppliers. Second, firms 1 and 2 purchase the inputs from a single global supplier. The second situation can also be viewed as the situation where the input suppliers cooperate in determining the input prices.

We consider the following game in this section. At stage 1, firms 1 and 2 simultaneously choose k_1 and k_2 respectively. At stage 2, the input prices, w_1 and w_2, are determined simultaneously. At stage 3, firms 1 and 2 simultaneously determine their outputs and use the inputs according to their requirements, and the profits are realized. We solve the game through backward induction.

3.2.1. Different input suppliers

Let us first consider the situation where, if firms 1 and 2 want to buy inputs from the outside supplier, they buy the inputs from different input suppliers.

Given k_1, k_2, w_1 and w_2, the ith final goods producer maximizes the following expression:

$$\underset{k_i}{Max}(a - q_i - k_i - q_j - k_j - c)k_i + (a - q_i - k_i - q_j - k_j - w_i)q_i, \qquad (16)$$

where $i, j = 1,2$ and $i \neq j$. The equilibrium output of the i th final goods producer can be derived as

$$q_i^* = \frac{a - 3k_i - 2w_i + w_j}{3}, \tag{17}$$

which also gives the input demand for the i th input supplier.

The i th input supplier maximizes the following expression to determine w_i, $i, j = 1,2$ and $i \neq j$:

$$\underset{w_i}{Max} \frac{(w_i - d)(a - 3k_i - 2w_i + w_j)}{3}. \tag{18}$$

The equilibrium input price of the i th input supplier can be derived as

$$w_i^* = \frac{5a - 12k_i - 3k_j + 10d}{16}. \tag{19}$$

From (17) and (19), we get the equilibrium output of the i th final goods producer as

$$q_i^* = \frac{10a - 24k_i - 6k_j - 10d}{45}. \tag{20}$$

The i th final goods producer maximizes the following expression to determine k_i:

$$\underset{k_i}{Max} \frac{45k_i(25a - 15k_i - 15k_j - 45c + 20d) + (10a + 21k_i - 6k_j - 10d)(10a - 24k_i - 6k_j - 10d)}{2025}. \tag{21}$$

Given the symmetry of firms 1 and 2, the maximization of (21) gives us

$$k_1^* = k_2^* = \frac{73a + 62d - 135c}{201}. \tag{22}$$

We get from (20) and (22) that

$$q_1^* = q_2^* = \frac{-36a - 774d + 810c}{1809}. \tag{23}$$

Proposition 3: *If the final goods firms buy inputs from different outside supplier, both firms 1 and 2 find bi-sourcing as the optimal strategy if* $\frac{135c-73a}{62} < d < \frac{45c-2a}{43}$.

Proof: We get from (22) and (23) that $k_1^* = k_2^* > 0$ and $q_1^* = q_2^* > 0$ if $\frac{135c-73a}{62} < d < \frac{45c-2a}{43}$. Q.E.D.

If both firms can commit to in-house production, it reduces firm 1's advantage from in-house production compared to the situation where only firm 1 can commit to in-house production. As a result, firm 1's incentive for purchasing inputs from the outside supplier increases even for a higher value of d compared to the situation where only firm 1 can commit to the in-house production. Hence, if both firms have the option to do bi-sourcing, firm 1 (and due to symmetry both firms 1 and 2) purchases inputs from the outside supplier if $d < \frac{45c-2a}{43}$, where $\frac{11c-a}{10} < \frac{45c-2a}{43}$. On the other hand, since commitment to in-house production by both firms 1 and 2 reduces firm 1's outside input demand compared to the situation where only firm 1 can commit to the in-house input production,[4] firm 1 stops producing inputs in-house under the former situation compared to the latter situation for a relatively cost efficient outside supplier. As a result, firm 1 does not produce inputs in-house when both firms 1 and 2 have the option for bi-sourcing if $d < \frac{135c-73a}{62}$, where $\frac{7c-5a}{2} < \frac{135c-73a}{62}$.

[4] Note that for given k_1 and w_1, firm 1's outside input demand is $\frac{a-3k_1-2w_1+c}{3}$ when only firm 1 does bi-sourcing, and it higher than its outside input demand under bi-sourcing by both firms 1 and 2, which is $\frac{a-3k_1-2w_1+w_2}{3}$, since $c > w_2$, which is necessary for bi-sourcing by firm 2.

3.2.2. The monopolist outside input supplier

Let us now consider the situation when there is monopolist outside input supplier. Hence, if firms 1 and 2 want to buy inputs from the outside supplier, they need to buy from the same input supplier. As mentioned earlier, this situation may also be viewed as cooperation between the input suppliers.

Given k_1, k_2, w_1 and w_2, the equilibrium output of the i th final goods producer is given by (17), where $i, j = 1,2$ and $i \neq j$. However, since there is monopolist outside input supplier, the input supplier maximizes the following expression to determine the input prices:

$$\underset{w_i, w_j}{Max} \frac{(w_i - d)(a - 3k_i - 2w_i + w_j)}{3} + \frac{(w_j - d)(a - 3k_j - 2w_j + w_i)}{3}. \tag{24}$$

The equilibrium input price for the i th final goods producer can be found as

$$w_i = \frac{a - 2k_i - k_j + d}{2}, \tag{25}$$

where $i, j = 1,2$ and $i \neq j$.

From (17) and (25), we get the equilibrium output of the i th final goods producer as

$$q_i^* = \frac{a - 3k_i - d}{6}, \tag{26}$$

where $i, j = 1,2$ and $i \neq j$.

The i th final goods producer maximizes the following expression to determine k_i:

$$\underset{k_i}{Max}\frac{6k_i(4a-3k_i-3k_j+2d-6c)+(a+3k_i-d)(a-3k_i-d)}{36}. \quad (27)$$

Given the symmetry of firms 1 and 2, the maximization of (27) gives us

$$k_1^* = k_2^* = \frac{2a+d-3c}{6}. \quad (28)$$

We get from (26) and (28) that

$$q_1^* = q_2^* = \frac{c-d}{4}. \quad (29)$$

Proposition 4: *If the final goods firms buy inputs from monopolist outside supplier, both firms 1 and 2 find bi-sourcing as the optimal strategy if* $3c-2a<d<c$.

Proof: It follows from (28) and (29) that $k_1^* = k_2^* > 0$ and $q_1^* = q_2^* > 0$ for $3c-2a<d<c$. Q.E.D.

If there is monopolist outside input supplier, it tends to increase outside input price by internalizing competition between the outside input suppliers. Hence, to stop in-house input production by firms 1 and 2, we require relatively more cost efficient outside input supplier compared to the situation with different outside input suppliers. This is confirmed by the conditions in Proposition 3 and 4, which show that in-house input production is zero in Proposition 3 for $d<\frac{135c-73a}{62}$, while it is zero in Proposition 4 for $d<3c-2a$, where $3c-2a<\frac{135c-73a}{62}$. On the other hand, since the monopolist outside input supplier has the flexibility to charge different input prices to different producers, it can always charge input prices lower than the final goods producers' cost of input production to induce the final goods producers to purchase inputs from the outside

supplier, as long as the marginal cost of input production is lower for the outside supplier compared to the final goods producers. As a result, the symmetric final goods producers have the incentive to buy the inputs from the monopolist outside supplier if the marginal cost of input production is lower for the outside supplier than that of the final goods producers.

Figure 1 summarizes the results of this paper. We assume $c > \frac{3a}{4}$ in Figure 1.

Figure 1

It is interesting to note that if there is monopolist outside input supplier, we need lower cost efficiency (i.e., higher d) of the outside input supplier for stopping in-house input production under bi-sourcing by both firms compared to the situation with bi-sourcing by monopolist final goods producer. Competition in the product market (compared to monopolist final goods producer) reduces the demand for outside inputs, thus reducing the price of the outside inputs and encouraging the final goods producers to stop producing inputs at a relatively higher d. However, since the monopolist outside input supplier has the option to charge different input prices to different firms, it can always charge an input price lower than the marginal cost of the in-house input production by the final goods producers. As a result, the condition for purchasing outside inputs is the same under product market competition and no product market competition.

It is immediate from Figure 1 that competition is either product market or in the input market reduces the incentive for bi-sourcing compared to the situation with monopolist final goods producer and monopolist outside input supplier.

4. Conclusion

While the literature has paid most of its attention to explain make-or-buy decision of modern organizations, it is often found that modern organizations take the make-and-buy strategy for input production. However, the theoretical literature did not pay much attention to the latter issue. We develop a simple model to explain the rationale for make-and-buy (or bi-sourcing). We show that bi-sourcing helps the final goods producers to get strategic advantage from the outside input suppliers in terms of lower input prices. Bi-sourcing can be the optimal strategy under both monopoly and product market competition. The incentive for bi-sourcing depends on the product market and outside input market competition. It also follows from our analysis that certain amount of input production with a relatively high-cost technology can make the consumers better off compared to the situation where the entire inputs are produced with a low-cost technology.

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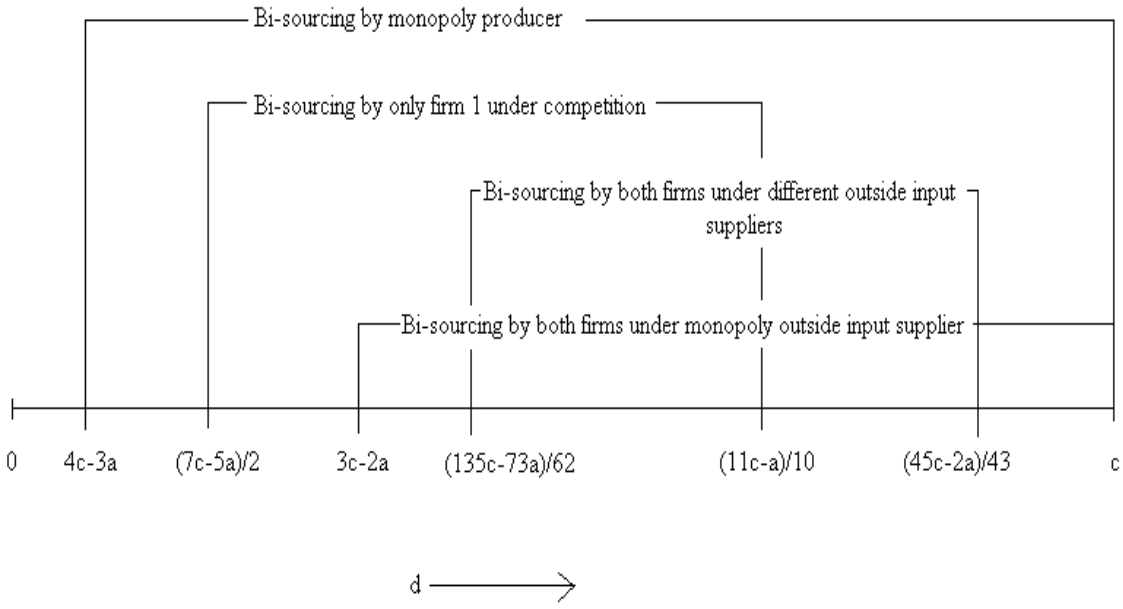

Figure 1: The conditions for bi-sourcing equilibrium

AWPE DATA SHEET

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TI: Strategic bi-sourcing

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AB: We provide a theoretical justification for bi-sourcing, which refers to the situation where a final goods producer buys an input from an outside supplier and also produces it in-house. Bi-sourcing occurs if the marginal cost of producing the input in-house is higher than the marginal cost of outside input supplier. In-house input production helps to reduce the input price charged by the outside supplier, and may make bi-sourcing as a profitable strategy. We show that bi-sourcing can be a profitable strategy under both monopoly and product market competition. The incentive for bi-sourcing depends on the product market and outside input market competition. Our result suggests that certain amount of input production with a relatively high-cost technology can make the consumers better off compared to the situation where the entire inputs are produced with a low-cost technology.