Firm-asymmetry and strategic outsourcing[☆]

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A R T I C L E   I N F O

A B S T R A C T

In contrast to the conventional wisdom, we show that a final goods producer may outsource input production to an outside supplier even if the final goods producer possesses a superior input-production technology compared to the outside supplier. Such an outsourcing may reduce consumer surplus and social welfare. We also show that, in the presence of outsourcing, innovation by the firm doing outsourcing to reduce the cost of in-house input production and to reduce the input coefficient in the final goods production may have significantly different implications for the consumers and the society.

1. Introduction

Outsourcing occurs in several industries such as aviation, automobiles, computers and electronics. Among some well-known cases, consider the aircraft giant Boeing, which outsources products of over 34,000 components to different manufacturers for the production of 747 passenger aircraft. It is particularly interesting to note that Boeing signed agreements with a Japanese consortium[1] whose costs are just as high as or higher than Boeing. According to the agreements, Boeing would purchase from them the 767-X fuselage during the 1990s, and then wings, together with related research and development during the 2000s (Chen, 2011). In computer industry *Sun* purchases about 75% of components from other companies. It is also common that outsourcing activities sometimes take place in a manner where the arch rivals purchases from common suppliers. For example, in 2004, Shanghai Automotive Industry Corporation (SAIC) manufactured for Volkswagen and GM.[2] In the United States, more than 60% of auto parts suppliers make components for the big three car manufacturers, viz., GM, Chrysler and Ford (Alexandrov, 2010). Spirit AeroSystems Inc., the world's largest first-tier aerostructures manufacturer and the former Boeing Commercial Airplanes site that was divested from Boeing in 2005, is a supplier of fuselage sections for both Boeing and Airbus.[3]

[1] It is composed of the three biggest industrial giants of Japan: Mitsubishi Heavy Industries, Kawasaki Heavy Industries LTD, and Fuji Heavy Industries (Chen, 2011).
[2] See: https://hbr.org/2006/09/when-your-contract-manufacturer-becomes-your-competitor.
[3] See: https://en.wikipedia.org/wiki/Spirit_AeroSystems.

Conventional wisdom suggests that the sourcing decision (i.e., producing in-house or purchasing from an outside supplier) may simply be a matter of choosing the least cost alternative by comparing internal production costs with the prices charged by the independent suppliers.[4] However, in today's world where strategic interactions among the final goods producers are evident, we show that a final goods producer may outsource input production to an outside supplier even if the final goods producer possesses a superior input-production technology compared to the outside supplier. The final goods producer with a superior input-production technology does this in order to get a strategic advantage in the final goods market.

We consider a situation where there are three firms. There is a final goods producer, which can produce both the final good and a critical input required to produce the final good. There is another final goods producer, which cannot produce the input but may purchase it from an outside input supplier that is technologically inferior compared to the final goods producer producing the input. We show in this framework that outsourcing by the final goods producer, which is most capable of producing the input, increases outside input supplier's input demand, which, in turn, increases the input price for both final goods producers. However, if the final goods producer with the input-production technology has a significantly superior technology to produce the final good compared to the final goods producer without the input-production technology, the burden of a higher input price is significantly more on the final goods producer without input-production technology compared to the other final goods producer, which increases the competitive advantage of the final goods producer with the input-production technology and creates the incentive for outsourcing. Although this type of strategic outsourcing to raise the rival's cost[5] is profitable for the final goods producer with the input-production technology, it may hurt the consumers and the society by increasing the input cost for the final goods producers. Thus, our paper, considering outsourcing in a closed economy, complements the literature showing a growing concern about the negative welfare effects of international outsourcing (Chen, Ishikawa, & Yu, 2004;; Marjit & Mukherjee, 2008;; Mukherjee & Tsai, 2010).

Our paper also contributes to the existing literature showing the effects of outsourcing on innovation (Marjit & Mukherjee, 2008;; Chen & Sen, 2010;; Beladi, Marjit, & Yang, 2012). Unlike the existing papers, which consider innovation to improve efficiency in final goods production, we consider and compare the welfare effects of innovation to improve efficiency in input production and final goods production. We show that the welfare effects of innovation for improving input production are significantly different to that of the final goods production. An increase in cost efficiency in input production will increase consumer surplus if it induces the final goods producer with the input-production technology to change its strategy from outsourcing to in-house input production. However, an increase in efficiency in final goods production may reduce consumer surplus if it induces the final goods producer with the input-production technology to change its strategy from in-house input production to outsourcing. While an increase in cost efficiency in input production will increase (may decrease) social welfare by inducing the final goods producer with the input-production technology to change its strategy from outsourcing to in-house input production, an increase in efficiency in final goods production may decrease (increase) social welfare by inducing the final goods producer with the input-production technology to change its strategy from in-house input production to outsourcing if its efficiency in processing input to the final good is (not) high enough to that of the final goods producer with no input-production technology.

There is a growing literature showing how outsourcing by a final good producer increases its competitiveness compared to the competitors by raising the input prices (Arya, Mittendorf, & Sappington, 2008;; Beladi & Mukherjee, 2012). However, unlike our paper, outsourcing occurs in those papers provided the independent input supplier possesses a better technology compared to the input producing final goods producer. Chen (2011) and Kabiraj and Sinha (2014, 2016) show the incentive for outsourcing by a final goods producer that has a better input-production technology than the independent input supplier. However, the reasons for outsourcing in those papers are different from ours. While entry-deterrence is the motive in Chen (2011), the benefit from technology transfer is the driving force for outsourcing in Kabiraj and Sinha (2014, 2016).[6] In contrast, the benefit from raising rival's cost is the main motive for outsourcing in our paper.

It may be worth noting that although we consider that the independent input supplier and the final goods producers are in the same country, outsourcing in our paper occurs even if the independent input supplier is from a different country. Thus, our paper also complements the literature on international outsourcing (Feenstra & Hanson, 1999; Glass & Saggi, 2001; Grossman & Helpman, 2002;, 2003;; Antràs & Helpman, 2004; Jones, 2005;; Marjit & Mukherjee, 2008). However, unlike these papers, raising rival's cost is the motive for outsourcing in our paper.

Our paper highlights the issue that the act of outsourcing raises some serious competitive concerns because of its negative impact on consumer surplus and social welfare. It shows the incentive for raising rival's cost in the starkest way despite having more efficient production method available in-house for input production. Thus, our analysis raises several important questions both for the policy makers and for future empirical analysis. Are there significant differences in input production technologies between an outsourcing firm and the input producers? Are the technological leaders having larger market shares choose outsourcing to throttle competition from technologically weak rivals? Most industries are abuzz with anti-competitive practices and the competition authorities typically believe that outsourcing activities are for minimizing the cost of production rather than raising rival's cost. In view of our finding, the competition authorities must consider the outsourcing activities more carefully and especially, where the technology leaders are engaged in outsourcing activities.

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[4] The sourcing decision can be far more complex in reality. The literature reveals many strategic elements which may play a pivotal role in firms' sourcing decisions. For example, sourcing decision can be influenced by fears of supplier hold-up, concerns about leakage of proprietary information, the need to ensure timely and reliable supply of high-quality inputs, prospective gains from cultivating long term alliances with suppliers, strategic competitive considerations and anti-competitive purpose.

[5] One may refer to Salop and Scheffman (1987) and Mason (2002) for earlier work on raising rival's cost strategy.

[6] For other interesting papers on strategic outsourcing, see Shy and Stenbacka (2003) and Buehler and Haucap (2006).

The remainder of the paper is organized as follows. Section 2 describes the model and shows the results. Section 3 discusses the implications of cost reducing innovation, either in the final good production or in input production, on the outsourcing decision of the firm and social welfare. Section 4 concludes.

2. The model and the results

Assume that there are two final goods producers, producing a homogeneous product like Cournot duopolists. One of them, called firm 1, can produce a critical input, which is required for the final good, and assume that the marginal cost of input production by firm 1 is c. The other one, called firm 2, cannot produce this critical input and it always purchases this critical input from the input market. There is an outside input supplier, firm I, who can produce this critical input at a constant marginal cost d.

We assume that only this input is required for the final good, and firm 1 is more efficient in processing the input to final good compared to firm 2. Assume that firm 1 requires λ $(0 < \lambda < 1)$ units of the input to produce 1 unit of the final good, while firm 2 requires 1 unit of the input to produce 1 unit of the final good.

We assume that the inverse market demand function for the final good is $P = 1 - q$, where P is the price and q is the total output. To make our following analysis meaningful for any value of λ, we also assume $0 \leq c < 1$.

We consider the following four-stage game. At stage 1, firm 1 decides whether to produce the input in-house or to outsource the input from the input market where firm I would be sole seller. At stage 2, in case of in-house production decision, firm 1 decides whether to enter the input market to compete with firm I or not. Otherwise, the game proceeds to stage 3. At stage 3, in case of in-house production decision and subsequent entry by firm 1, there will be competition in the input market between firm 1 and firm I.[7] Otherwise, firm I determines its input price, w, as a monopoly input producer. At stage 4, firms 1 and 2 produce the final goods like Cournot duopolists. The profits are realized. We solve the game through backward induction.

In order to guarantee that firms 1 and 2 always produce the final good, irrespective of the outsourcing decision of firm 1, we restrict the parameter values for our analysis to satisfy the following two assumptions:

$$A1 : \frac{2d - 1}{\lambda} < c < \frac{5 + 2d}{7\lambda}$$

$$A2 : d < \frac{2 - 5\lambda + 5\lambda^2}{2(2 - \lambda)(1 - \lambda + \lambda^2)}$$

The assumption A1 is the condition under which firms 1 and 2 produce the final good if firm 1 produces the input in-house, while the assumption A2 guarantees that firms 1 and 2 produce the final good when firm 1 outsources its input to firm I. The exact nature of these parameter restrictions would be clear once we derive the profit expressions later. The assumption A2 also implies that $d < 1$ holds under $0 < \lambda < 1$.

2.1. In-house production

If firm 1 decides to produce the input in-house at stage 1, there are two options for firm 1 at stage 2. One is to stay out of the input market, i.e., firm 1 does not sell any input to firm 2. The other is to enter the input market and compete with firm I.

2.1.1. No selling of inputs by firm 1

If firm 1 stays out of the input market at stage 2, given the input price, w^M, charged by firm I, the profits of firms 1 and 2 at stage 4 are as follows:

$$\pi_1^M = \left(1 - q_1^M - q_2^M - \lambda c\right)q_1^M \quad \pi_2^M = \left(1 - q_1^M - q_2^M - w^M\right)q_2^M,$$

where q_i is the output of firm i $(i = 1, 2)$. The superscript M denotes the situation of in-house production and no selling of inputs by firm 1.

We can get the equilibrium outputs of firms 1 and 2 as:

$$q_1^M = \frac{1 - 2\lambda c + w^M}{3} \quad q_2^M = \frac{1 + \lambda c - 2w^M}{3}$$

At stage 3, firm I faces demand for input only from firm 2, and it is equal to $q_2^M = \frac{1 + \lambda c - 2w^M}{3}$. Given this input demand, firm I maximizes its profit π_I^M by choosing the input price w^M, i.e.,

$$\max_{w^M} \pi_I^M = \max_{w^M} \frac{(w^M - d)(1 + \lambda c - 2w^M)}{3}.$$

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[7] We will consider both Cournot and Bertrand competition in the input market.

This yields the equilibrium input price set by firm I as $w^M = \frac{1+\lambda c+2d}{4}$.

Standard calculation shows that the equilibrium outputs of firms 1 and 2, the equilibrium profits of the firms and the equilibrium consumer surplus under in-house input production and no selling of inputs by firm 1 are as follows:

$$q_1^M = \frac{5 - 7\lambda c + 2d}{12} \qquad q_2^M = \frac{1 + \lambda c - 2d}{6} \qquad \pi_I^M = \frac{(5 - 7\lambda c + 2d)^2}{144}$$

$$\pi_2^M = \frac{(1 + \lambda c - 2d)^2}{36} \qquad \pi_I^M = \frac{(1 + \lambda c - 2d)^2}{24} \qquad CS^M = \frac{(7 - 5\lambda c - 2d)^2}{288}.$$

The corresponding social welfare is

$$W^M = \pi_1^M + \pi_2^M + \pi_I^M + CS^M = \frac{119 - 170\lambda c + 143\lambda^2 c^2 - 116\lambda cd - 68d + 92d^2}{288}.$$

2.1.2. Selling of inputs by firm 1

If firm 1 enters the input market at stage 2, it may compete with firm I à la Cournot or Bertrand.

2.1.2.1. Cournot competition in the input market.
Suppose firm 1 competes à la Cournot with firm I at stage 3 after it enters the input market at stage 2. Given the input price, w^C, paid by firm 2, the profits of firms 1 and 2 at stage 4 are as follows:

$$\pi_1^C = (1 - q_1^C - q_2^C - \lambda c)q_1^C + (w^C - c)x_1^C \quad \pi_2^C = (1 - q_1^C - q_2^C - w^C)q_2^C,$$

where $x_1^C (\geq 0)$ is the quantity of inputs sold by firm 1 in the input market. The superscript C denotes the situation of in-house production by firm 1 and Cournot competition in the input market.

We can get the equilibrium outputs of firms 1 and 2 as:

$$q_1^C = \frac{1 - 2\lambda c + w^C}{3} \quad q_2^C = \frac{1 + \lambda c - 2w^C}{3}$$

At stage 3, firm 1 and firm I face the demand for input from firm 2, and it is equal to $x_1^C + x_I^C = q_2^C = \frac{1+\lambda c - 2w^C}{3}$, where $x_I^C (\geq 0)$ is the quantity of inputs sold by firm I. Hence, the inverse demand function for input is $w^C = \frac{1+\lambda c-3(x_1^C+x_I^C)}{2}$. Given this inverse demand function for input, firm 1 maximizes its profit π_1^C by choosing x_1^C, i.e.,

$$\max_{x_1^C} \pi_1^C = \max_{x_1^C} \frac{\left[1 - \lambda c - (x_1^C + x_I^C)\right]^2}{4} + \frac{\left[1 + \lambda c - 3(x_1^C + x_I^C)\right]x_1^C}{2}.$$

We get $\frac{\partial \pi_1^C}{\partial x_1^C} = \frac{2(\lambda-1)c-5x_1^C-2x_I^C}{2} < 0$, indicating that it is optimal for firm 1 to choose $x_1^C = 0$. In other words, firm 1 would not have incentive to compete à la Cournot with firm I in the input market. The intuition is as follows. Although selling inputs to firm 2 by firm 1 increases its profit from the input market, the input price paid by its rival (firm 2) falls, which reduces firm 1's profit from the final goods market, and overall firm 1 loses by participating in the input market under quantity competition.

2.1.2.2. Bertrand competition in the input market.
Obviously, firm 1 has no incentive to enter the input market at stage 2 if competition between firm 1 and firm I is characterized by Bertrand competition, when its marginal cost of input production is not less than that of firm I. So, firm 1 may compete with firm I à la Bertrand in the input market only for $c < d$.

The Bertrand competition in the input market makes firm 2 purchase all of its inputs from firm 1 at a limiting input price, $w^B = d$ under $c < d$. Accordingly, the profits of firms 1 and 2 at stage 4 are as follows:

$$\pi_1^B = (1 - q_1^B - q_2^B - \lambda c)q_1^B + (d - c)q_2^B \quad \pi_2^B = (1 - q_1^B - q_2^B - d)q_2^B$$

The superscript B denotes the situation of in-house production by firm 1 and Bertrand competition in the input market.

We get the equilibrium outputs of firms 1 and 2 as $q_1^B = \frac{1-2\lambda c+d}{3}$ and $q_2^B = \frac{1+\lambda c-2d}{3}$ respectively. Thus, the profit of firm 1 in this situation is $\pi_1^B = \frac{(1-2\lambda c+d)^2}{9} + \frac{(d-c)(1+\lambda c-2d)}{3}$.

Comparing π_1^M with π_1^B under $c < d$, we get that $\pi_1^M \gtreqless \pi_1^B$ if $c \gtreqless \frac{14d-3}{16-5\lambda}$, implying that firm 1 will enter the input market and compete with firm I à la Bertrand only for $c < \frac{14d-3}{16-5\lambda}$ if it decides to produce inputs in-house. In other words, if firm 1 produces the inputs in-house, it will

compete with firm I à la Bertrand for $Max\left[0, \frac{2d-1}{\lambda}\right] < c < Max\left[0, \frac{14d-3}{16-5\lambda}\right]$, and will not sell its input to firm 2 for $Max\left[0, \frac{14d-3}{16-5\lambda}\right] \le c < Min\left[1, \frac{5+2d}{7\lambda}\right]$. Accordingly, the equilibrium outcomes under in-house input production for $Max\left[0, \frac{14d-3}{16-5\lambda}\right] \le c < Min\left[1, \frac{5+2d}{7\lambda}\right]$ have been shown in subsection 2.1.1.[8]

2.2. Outsourcing

If firm 1 decides to outsource its input production to firm I at stage 1, given the input price, w^O, charged by firm I, the profits of firms 1 and 2 at stage 4 are as follows:

$$\pi_1^O = \left(1 - q_1^O - q_2^O - \lambda w^O\right)q_1^O \quad \pi_2^O = \left(1 - q_1^O - q_2^O - w^O\right)q_2^O.$$

The superscript O donates the situation of outsourcing.

We can get the equilibrium outputs of firms 1 and 2 as:

$$q_1^O = \frac{1 + (1 - 2\lambda)w^O}{3} \quad q_2^O = \frac{1 - (2 - \lambda)w^O}{3}.$$

Firm I faces demand from both firms 1 and 2, and it is equal to $\lambda q_1^O + q_2^O = \frac{\lambda[1+(1-2\lambda)w^O]+1-(2-\lambda)w^O}{3}$. At stage 3, firm I sets its input price w^O to maximize profit π_I^O, i.e.,

$$\max_{w^O} \pi_I^O = \max_{w^O} \frac{(w^O - d)\{\lambda[1 + (1 - 2\lambda)w^O] + 1 - (2 - \lambda)w^O\}}{3}.$$

We get the equilibrium input price as $w^O = \frac{1+\lambda+2d(1-\lambda+\lambda^2)}{4(1-\lambda+\lambda^2)}$.

Standard calculation shows that the equilibrium outputs of firms 1 and 2, the equilibrium profits of the firms and the equilibrium consumer surplus under outsourcing are respectively:

$$q_1^O = \frac{5 - 5\lambda + 2\lambda^2 + 2d(1 - 2\lambda)\left(1 - \lambda + \lambda^2\right)}{12\left(1 - \lambda + \lambda^2\right)} \qquad q_2^O = \frac{2 - 5\lambda + 5\lambda^2 - 2d(2 - \lambda)\left(1 - \lambda + \lambda^2\right)}{12\left(1 - \lambda + \lambda^2\right)}$$

$$\pi_1^O = \frac{\left[5 - 5\lambda + 2\lambda^2 + 2d(1 - 2\lambda)\left(1 - \lambda + \lambda^2\right)\right]^2}{144\left(1 - \lambda + \lambda^2\right)^2} \quad \pi_2^O = \frac{\left[2 - 5\lambda + 5\lambda^2 - 2d(2 - \lambda)\left(1 - \lambda + \lambda^2\right)\right]^2}{144\left(1 - \lambda + \lambda^2\right)^2} \quad .$$

$$\pi_I^O = \frac{\left[1 + \lambda - 2d\left(1 - \lambda + \lambda^2\right)\right]^2}{24\left(1 - \lambda + \lambda^2\right)} \qquad\qquad CS^O = \frac{\left[7 - 10\lambda + 7\lambda^2 - 2d(1 + \lambda)\left(1 - \lambda + \lambda^2\right)\right]^2}{288\left(1 - \lambda + \lambda^2\right)^2}$$

Social welfare under outsourcing is

$$W^O = \pi_1^O + \pi_2^O + \pi_I^O + CS^O$$

$$= \frac{119 - 268\lambda + 378\lambda^2 - 268\lambda^3 + 119\lambda^4 - 4d\left(17 - 14\lambda + 17\lambda^2 + 17\lambda^3 - 14\lambda^4 + 17\lambda^5\right) + 4d^2\left(1 - \lambda + \lambda^2\right)^2\left(23 - 26\lambda + 23\lambda^2\right)}{288\left(1 - \lambda + \lambda^2\right)^2}.$$

2.3. Outsourcing decision

At stage 1, firm 1 compares its profit under outsourcing and under in-house production to decide its strategy of input production.

We have seen in subsection 2.1.2 that, if firm 1 produces the input in-house, it has no incentive to compete with firm I in the input market if the input market is characterized by Cournot competition, or if the input market is characterized by Bertrand competition and $Max\left[0, \frac{14d-3}{16-5\lambda}\right] \le c < Min\left[1, \frac{5+2d}{7\lambda}\right]$. However, it has the incentive to compete with firm I in the input market if the input market is characterized by Bertrand competition and $Max\left[0, \frac{2d-1}{\lambda}\right] < c < Max\left[0, \frac{14d-3}{16-5\lambda}\right]$.

If the input market is characterized by Cournot competition, or if the input market is characterized by Bertrand competition and

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[8] As other equilibrium outcomes for $Max\left[0, \frac{2d-1}{\lambda}\right] < c < Max\left[0, \frac{14d-3}{16-5\lambda}\right]$ have no impact on the rest of the analysis, we do not consider them.

$Max\left[0, \frac{14d-3}{16-5\lambda}\right] \leq c < Min\left[1, \frac{5+2d}{7\lambda}\right]$, by comparing firm 1's profit under outsourcing (π_1^O) and under in-house production with no selling of

input (π_1^M), we get $\pi_1^M \gtreqless \pi_1^O$ if $c \lesseqgtr \tilde{c}$, where $\tilde{c} = \frac{3\lambda + 4d(1-\lambda+\lambda^2)}{7(1-\lambda+\lambda^2)}$ and $Max\left[0, \frac{14d-3}{16-5\lambda}\right] < \tilde{c} < Min\left[1, \frac{5+2d}{7\lambda}\right]$.[9] If the input market is characterized by

Bertrand competition and $Max\left[0, \frac{2d-1}{\lambda}\right] < c < Max\left[0, \frac{14d-3}{16-5\lambda}\right]$, by comparing firm 1's profit under outsourcing (π_1^O) and under in-house

production with Bertrand competition in the input market (π_1^B), we get that $\pi_1^B > \pi_1^O$, as $\pi_1^B > \pi_1^M$ and $\pi_1^M > \pi_1^O$ since $Max\left[0, \frac{14d-3}{16-5\lambda}\right] < \tilde{c}$

holds. Therefore, firm 1 prefers to produce the inputs in-house for $Max\left[0, \frac{2d-1}{\lambda}\right] < c \leq \tilde{c}$ under both Cournot competition and Bertrand

competition in the input market.

Under the constraint of A2, $\tilde{c} < d$ may be satisfied, i.e., $\tilde{c}$ may be less than d if $0 < \lambda < \frac{2}{7}$, i.e., if the efficiency of firm 1 in processing input to the final good is sufficiently high to that of firm 2. In other words, firm 1 may prefer outsourcing to in-house production even if its marginal cost of input production is lower than that of the outside input supplier.

We get the following proposition immediately from the above analysis.

Proposition 1. *If firm 1's marginal cost of in-house input production is high (low), i.e. $c > (\leq)\tilde{c}$, it prefers outsourcing (in-house production) of its inputs. Firm 1 may prefer outsourcing even for $d > c (> \tilde{c})$ if $0 < \lambda < \frac{2}{7}$, i.e., if firm 1's efficiency in processing input to the final good is sufficiently high to that of firm 2.*

The intuition for Proposition 1 is as follows. The change from in-house production to outsourcing by firm 1 increases the demand for input faced by the outside input supplier, which leads to a higher input price set by the outside input supplier, i.e., $w^O > w^M$. In other words, this increases firm 2's marginal cost of production by $w^O - w^M = \frac{\lambda[1-c+(1-\lambda)(1+\lambda c)]}{4(1-\lambda+\lambda^2)}$. The increase in rival's cost of production has a beneficial effect on firm 1's profit.

As Fig. 1 shows, if outsourcing allows firm 1 to access a cheaper way of production, i.e. $c > w^O$, which occurs for $c > \check{c}$, where $\check{c} = \frac{1+\lambda+2d(1-\lambda+\lambda^2)}{4(1-\lambda+\lambda^2)} = w^O$ and $\tilde{c} < \check{c} < Min\left[1, \frac{5+2d}{7\lambda}\right]$,[10] outsourcing makes firm 1 better off.

For $\tilde{c} < c < \check{c}$, even though the outside input price under outsourcing is higher than that of firm 1's in-house input cost, firm 1 still has the incentive to outsource its input production to the outside input supplier because outsourcing increases firm 1's marginal cost of production by $\lambda(\check{c} - c)$, which is much less than the increase in firm 2's marginal cost of production. The lower the value of λ, the less is the adverse effect on firm 1 due to a higher marginal cost under outsourcing, and the adverse effect created by a higher own marginal cost of production is less than the beneficial effect created by the rival's higher marginal cost production. In other words, although outsourcing increases the marginal cost of firm 1, the raising rival's cost strategy creates the rationale for outsourcing by firm 1 for $\tilde{c} < c < \check{c}$.

If $c < \tilde{c}$, the input-production technology of firm 1 is sufficiently efficient and the in-house input production by firm 1 outweighs its above-mentioned benefit from outsourcing. Hence, firm 1 prefers in-house input production compared to outsourcing for $c < \tilde{c}$.

2.4. Welfare analysis

2.4.1. Consumer surplus

Comparing consumer surplus under outsourcing with that of under in-house production by firm 1 for $c > \tilde{c}$, we get that $CS^O < CS^M$ for
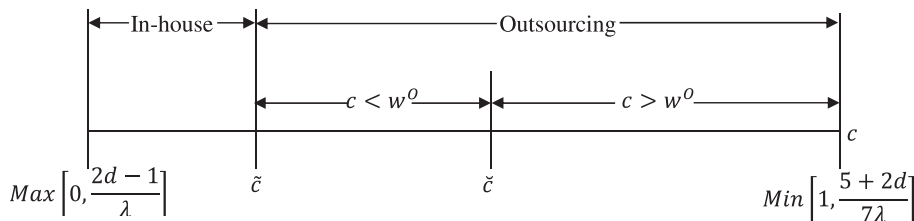

Fig. 1. The equilibrium input production decision of firm 1.

[9] $\frac{14d-3}{16-5\lambda} < \tilde{c}$ can be rearranged as $d < \frac{3(7+9\lambda+2\lambda^2)}{2(17-7\lambda+7\lambda^2+10\lambda^3)}$ which holds under the assumption A2 because of $\frac{2-5\lambda+5\lambda^2}{2(2-\lambda)(1-\lambda+\lambda^2)} < \frac{3(7+9\lambda+2\lambda^2)}{2(17-7\lambda+7\lambda^2+10\lambda^3)}$, i.e., $4(1-\lambda)(1-\lambda+\lambda^2)(4+53\lambda+28\lambda^2) > 0$. $\tilde{c} < 1$ can be rearranged as $4(1-d)(1-\lambda+\lambda^2)+3(1-\lambda)^2 > 0$ which holds always, while $\tilde{c} < \frac{5+2d}{7\lambda}$ can be rearranged as $(2+2d-4d\lambda)(1-\lambda+\lambda^2)+3(1-\lambda) > 0$ which holds always.

[10] $\tilde{c} < \check{c}$ can be rearranged as $d < \frac{7-5\lambda}{2(1-\lambda+\lambda^2)}$ which holds always under the assumption A2 while $\check{c} < Min\left[1, \frac{5+2d}{7\lambda}\right]$ will follow from the next footnote.
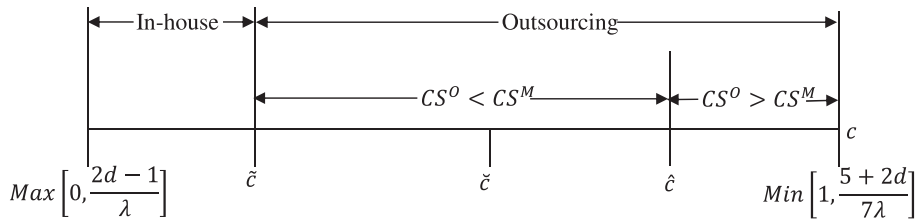
Fig. 2. The effect of outsourcing on consumer surplus.

$\tilde{c} < c < \hat{c}$ as shown in Fig. 2, where $\hat{c} = \frac{3+2d(1-\lambda+\lambda^2)}{5(1-\lambda+\lambda^2)}$ and $\breve{c} < \hat{c} < Min\left[1, \frac{5+2d}{7\lambda}\right]$.[11] We know from subsection 2.3 that, for $\tilde{c} < c < \breve{c}$, outsourcing by firm 1 not only increases the marginal cost of firm 2 but also increases its own marginal cost of production. For $\breve{c} < c < \hat{c}$, although outsourcing reduces firm 1's marginal cost of production, that reduction is less than the increase in firm 2's marginal cost of production. Hence, if $\tilde{c} < c < \hat{c}$, outsourcing by firm 1 increases the total marginal cost of final goods production compared to in-house production by firm 1. Since consumer surplus is positively related to total final goods production, which is negatively related to the total marginal costs of firms 1 and 2, if $\tilde{c} < c < \hat{c}$, outsourcing (compared to in-house input production) by firm 1 reduces consumer surplus.

If $\hat{c} < c$, the reduction in firm 1's marginal cost of production due to outsourcing is more than the increase in firm 2's marginal cost of production. In this situation, outsourcing increases consumer surplus compared to in-house input production by firm 1.

The following proposition is immediate from the above discussion.

Proposition 2.　*Outsourcing by firm 1 makes the consumers worse (better) off compared to in-house input production by firm 1 for $\tilde{c} < c < \hat{c}$ ($\hat{c} < c$).*

2.4.2. Social welfare

Now we consider the effect of outsourcing on social welfare which consists of the profits of all firms and consumer surplus. From the above-mentioned analysis, we know that outsourcing increases the profits of firm 1 and firm I but reduces the profit of firm 2 and may reduce consumer surplus.

Comparing social welfare under outsourcing (W^O) with that of under in-house production (W^M) by firm 1 for $c > \tilde{c}$, we get that $W^O < W^M$ for $c \in (\tilde{c}, \overline{c})$ which would not be empty if the following two conditions hold:

(1) $0 < \lambda < \lambda_1$

(2) $d < \overline{d}$

where　$\overline{c} = \dfrac{85+58d - \sqrt{(85+58d)^2 + 13156\lambda^2 d^2 - 286\lambda(15+40d+52d^2) - \frac{1287\lambda^2}{(1-\lambda+\lambda^2)^2} - \frac{858\lambda^2(5+4d-5\lambda-2d\lambda)}{1-\lambda+\lambda^2}}}{143\lambda}$,　$\overline{d} = \begin{cases} \dfrac{2-5\lambda+5\lambda^2}{2(2-\lambda)(1-\lambda+\lambda^2)}, \\ \end{cases}$

$\dfrac{70+35\lambda-167\lambda^2-84(1-\lambda)\sqrt{-10+27\lambda-16\lambda^2}}{2(154-185\lambda)(1-\lambda+\lambda^2)}$, *for* $0 < \lambda \leq \lambda_0$,　$\lambda_0 \approx 0.557639$ and $\lambda_1 \approx 0.632226$. Under conditions (1) and (2), we

have $\overline{c} < \breve{c}$.[12]

The welfare comparison is shown in Fig. 3.

The following proposition is immediate from the above discussion.

Proposition 3.　*If the marginal cost of the outside input supplier is not high ($d < \overline{d}$) and the efficiency of firm 1 in processing input to the final good is significantly higher compared to firm 2 ($0 < \lambda < \lambda_1$), outsourcing decreases social welfare compared to in-house production for $\tilde{c} < c < \overline{c}$. Otherwise, outsourcing increases social welfare compared to in-house input production by firm 1.*

Outsourcing occurs in our analysis for $c > \tilde{c}$. However, we observe two scenarios with respect to the outsourcing decision: (i) the firm 1 doing outsourcing pays the input price that is lower than its cost of in-house input production, which happens for $\breve{c} < c$, and (ii) the firm 1 doing outsourcing obtains a strategic advantage in the final goods market even though the input price paid by firm 1 is higher than its in-house cost production, which happens for $\tilde{c} < c < \breve{c}$.

First note that the welfare under outsourcing remains constant for all c. Since outsourcing reduces the input cost of firm 1 for $\breve{c} < c$, it increases social welfare compared to in-house input production due to the production-efficiency gain from outsourcing.

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[11] $\breve{c} < \hat{c}$ can be rearranged as $d < \frac{7-5\lambda}{2(1-\lambda+\lambda^2)}$ which holds always under the assumption A2. $\hat{c} < 1$ can be rearranged as $d < \frac{2-5\lambda+5\lambda^2}{2(1-\lambda+\lambda^2)}$ which holds always under the assumption A2, while $\hat{c} < \frac{5+2d}{7\lambda}$ can be rearranged as $(4+10d-14d\lambda)(1-\lambda+\lambda^2)+21(1-\lambda)^2 > 0$ which holds always.

[12] Under the condition of $0 < \lambda < \lambda_1$, $\overline{c} < \breve{c}$ will hold if $4(184-225\lambda)(1-\lambda+\lambda^2)^2 d^2 - 4(136-279\lambda+204\lambda^2-68\lambda^3-75\lambda^4)d - (200+193\lambda-766\lambda^2+537\lambda^3) < 0$ or $\frac{136-143\lambda-75\lambda^2-48\sqrt{24-21\lambda-80\lambda^2+127\lambda^3-50\lambda^4}}{2(184-225\lambda)(1-\lambda+\lambda^2)} < d < \frac{136-143\lambda-75\lambda^2+48\sqrt{24-21\lambda-80\lambda^2+127\lambda^3-50\lambda^4}}{2(184-225\lambda)(1-\lambda+\lambda^2)}$. Thus, we can get $\overline{c} < \breve{c}$ under the conditions of $0 < \lambda < \lambda_1$ and $d < \overline{d}$ because $\frac{70+35\lambda-167\lambda^2-84(1-\lambda)\sqrt{-10+27\lambda-16\lambda^2}}{2(154-185\lambda)(1-\lambda+\lambda^2)} < \frac{2-5\lambda+5\lambda^2}{2(2-\lambda)(1-\lambda+\lambda^2)}$ for $\lambda_0 < \lambda < \lambda_1$, and $\frac{2-5\lambda+5\lambda^2}{2(2-\lambda)(1-\lambda+\lambda^2)} < \frac{136-143\lambda-75\lambda^2+48\sqrt{24-21\lambda-80\lambda^2+127\lambda^3-50\lambda^4}}{2(184-225\lambda)(1-\lambda+\lambda^2)}$ and $\frac{136-143\lambda-75\lambda^2-48\sqrt{24-21\lambda-80\lambda^2+127\lambda^3-50\lambda^4}}{2(184-225\lambda)(1-\lambda+\lambda^2)} < 0$ for $\lambda < \lambda_1$.
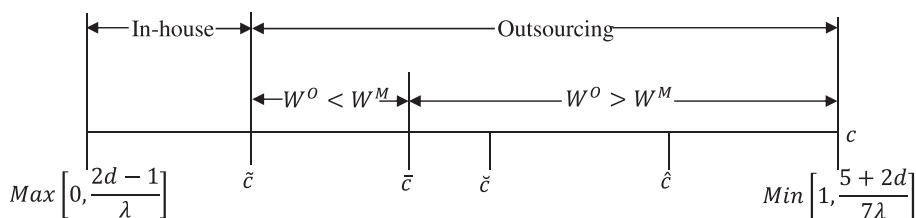
Fig. 3. The effect of outsourcing on social welfare under conditions (1) and (2).

If $\tilde{c} < c < \check{c}$, outsourcing increases firm 1's per-unit input cost compared to its in-house input production. If the marginal cost of the outside input supplier is not high ($d < \bar{d}$) and the efficiency of firm 1 in processing input to the final good is significantly higher to that of firm 2 ($0 < \lambda < \lambda_1$), outsourcing happens, and increases the input price for firm 2 and the input cost for firm 1 significantly compared to firm 1's in-house input production when c is marginally higher than $\tilde{c}$. As a result of these two efficiency gains under firm 1's in-house input production, social welfare is higher under in-house production than under outsourcing. As c increases, social welfare under in-house production decreases. At $c = \check{c}$, the input price under outsourcing and firm 1's in-house cost of input production are the same. However, in this situation, firm I has a more efficient production technology than firm 1. Hence, outsourcing helps to save the cost of input production and creates higher welfare compared to in-house input production by firm 1. Now by continuity, at $c = \bar{c}$, we have the same welfare under outsourcing and in-house input production by firm 1. Hence, for $c > \bar{c}$, the welfare under outsourcing is higher than under in-house input production by firm 1, and for $\tilde{c} < c < \bar{c}$, the welfare under outsourcing is lower than under in-house input production by firm 1.

3. The welfare implications of innovation

Now we can consider the implications of innovation by firm 1. Suppose firm 1 has the option to reduce either its in-house input cost, i.e., c, or the input coefficient in the final good production, i.e., λ, by investing in innovation prior to the outsourcing decision.

There is no doubt that both innovation to reduce the cost of in-house input production and innovation to reduce the input coefficient in the final good of firm 1 will definitely benefit consumers and the social welfare if they don't change firm 1's input production strategy. However, it follows from Proposition 1 that a reduction in λ increases the possibility of outsourcing by reducing the value of $\tilde{c}$, whereas a reduction in c increases the possibility in-house production by firm 1.

Since CS^M is decreasing with c, CS^O is independent of c and $CS^O < CS^M$ at $\tilde{c}$, it can be inferred from Proposition 2 that a reduction in c will increase consumer surplus when it induces firm 1 to change its strategy from outsourcing to in-house input production, which happens if c reduces, say, from c_0 to c_1 and $c_0 < \tilde{c} < c_1$. However, although a reduction in λ increases consumer surplus under outsourcing, it may make the consumers worse off if it induces firm 1 to change its strategy from in-house input production to outsourcing.[13] Thus, investment in innovation to reduce the cost of in-house input production and to reduce input coefficient may have different effect on consumer surplus.
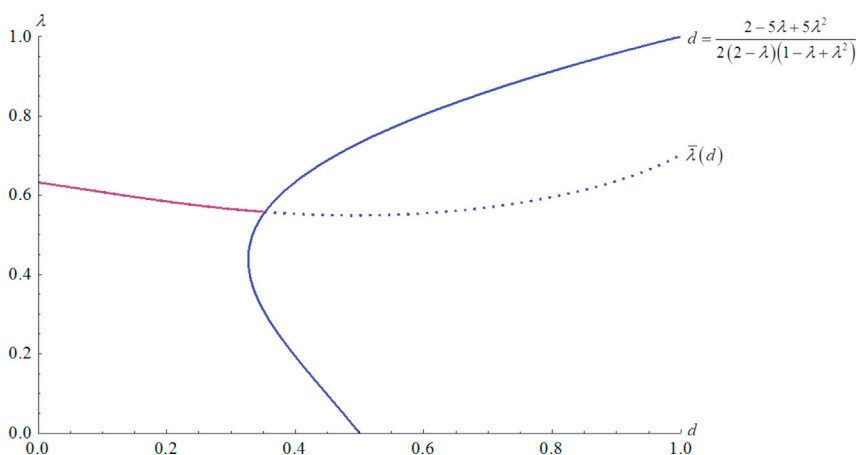

Fig. 4. The value of $\bar{\lambda}$ which varies with d.

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[13] This may happen since a lower λ reduces $\tilde{c}$ and increases the rage of c over which outsourcing occurs.

Next, consider the effect of innovation on social welfare. Ignoring the constraint A2, we can get that at $c = \tilde{c}$, $W^O \gtreqqless W^M$ for $\lambda \gtreqqless \bar{\lambda}$, where the values of $\bar{\lambda}$ varying with d are shown in Fig. 4. The left (right) part of curve $d = \frac{2-5\lambda+5\lambda^2}{2(2-\lambda)(1-\lambda+\lambda^2)}$ is the area where the combinations of d and λ are (not) under consideration in this paper. Thus, the dotted part of curve $\bar{\lambda}(d)$ is the situation where the values of $\bar{\lambda}(d)$ are contradicted with the constraint A2.

We get that the social welfare under outsourcing is always higher than that of under in-house input production by firm 1 for $\tilde{c} < c$ when $\lambda > \bar{\lambda}$ holds. However, as Proposition 3 shows, social welfare under outsourcing is lower compared to in-house production by firm 1 for $\tilde{c} < c < \bar{c}$ when $\lambda < \bar{\lambda}$ holds.[14] Therefore, since W^M is decreasing with c and W^O is independent of c, if c reduces, say, from c_0 to c_1, such that $c_0 < \tilde{c} < c_1$, it will increase (may decrease) social welfare if it induces firm 1 to change its strategy from outsourcing to in-house input production for $\lambda < (>) \bar{\lambda}$.

Similarly, although a reduction in λ increases social welfare under outsourcing, it may decrease (increase) social welfare if it induces firm 1 to change its strategy from in-house input production to outsourcing.[15]

To sum up, in the presence of outsourcing, innovation to reduce the cost of in-house input production and innovation to reduce the input coefficient in the final good of firm 1 may create significantly different effects on the consumers and the society.

4. Conclusion

We provide a new strategic rationale for outsourcing in this paper. We show that although a firm possesses a superior input-production technology, it may still have the incentive for outsourcing if it has significantly higher efficiency in processing input to the final good compared to its rival. This effect was hitherto not recognized in the literature. We also show that outsourcing may make the consumers as well as the society worse off by raising the input price charged by the independent input supplier. Thus, it justifies recent concern about the welfare effects of outsourcing.

We further discuss the welfare implications of innovation by the firm doing outsourcing. We show that, in the presence of outsourcing, innovation to reduce the cost of in-house input production and innovation to reduce the input coefficient in the final goods production may have significantly different implications for the consumers and the society.

We have considered in our analysis that firm 1 has a better technology to produce the final goods compared to firm 2. However, there could be another interpretation of our analysis following Arya et al. (2008).[16] Instead of considering firms 1 and 2 having different technologies to produce the final goods, one can consider a model where the independent intermediate input supplier charges Firm 1 a λ fraction of the price charged to Firm 2. Even if firms 1 and 2 have the same production technologies for the final goods, the independent input supplier charges asymmetric input prices in this way to induce outsourcing by firm 1 (i.e., playing "favoritism" in the terminology of Arya et al., 2008), which allows the independent input supplier to earn higher profits compared to the situation where firm 1 does not outsource. The restriction of $\lambda < \frac{2}{7}$ shown in Proposition 1 suggests that, under this alternative interpretation, the independent supplier may charge firm 1 an input price that is $\frac{2}{7}$ of the input price charged to firm 2. However, this is altogether a separate exercise regarding the optimality of such a discriminatory pricing in the given context.

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[14] Note that $\lambda_1 = \bar{\lambda}(d = 0)$.

[15] This may happen since a lower λ reduces $\tilde{c}$ and increases the rage of c over which outsourcing occurs.

[16] We thank an anonymous referee for this alternative interpretation.