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Strategic Outsourcing between Rivals

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By outsourcing key intermediate goods to a downstream competitor, a firm can credibly reveals its future quantity of the final good to its competitor, therefore force the latter to act as a Stackelberg follower in the downstream market. As a result, whether outsourcing occurs or not depends on the nature of the downstream competition. If firms compete in quantities, outsourcing occurs only if it generates a sufficiently large efficiency gain. Instead, if firms compete in prices, outsourcing always occurs whenever there is potential efficiency gain.

Key Words: Outsourcing; Cournot duopoly; Bertrand duopoly.
JEL Classification Numbers: D43, L11, L13.

1. INTRODUCTION

This age witnesses a rapid growth in outsourcing. While outsourcing has attracted lots of interests from research community, one strategic element in outsourcing has mainly gone unnoticed. That is, when outsourcing occurs between rival firms, it can alter the timing of firms' actions in their competition, therefore give rise to strategic considerations in outsourcing decisions.

We consider a model consisting of a duopoly market for a final good. To produce the final good, a critical intermediate good is required, which both duopolists can produce in-house. However, their production costs for the intermediate good are asymmetric,[1] leading to the potential of efficiency gain through the outsourcing of the intermediate good from the high-cost firm to the low-cost one. However, we shows that, whether outsourcing occurs or not can hinge on the nature of competition in the final-good

[1]The asymmetry can arise because they are in different locations hence face different labor cost; or because one of them is technically more advanced with the intermediate good.

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market: outsourcing occurs only when the efficiency gain is sufficiently large if firms engage in Cournot competition; whereas, outsourcing always occurs if firms engage in Bertrand competition.

The reason is, when the less efficient firm puts its order for the intermediate good with the more efficient firm, it naturally reveals the quantity the latter is obligated to supply. Such quantity information, to some extent, credibly informs the more efficient firm with its quantity for the final good. As a result, the more efficient firm is forced into a Stackelberg follower in their future competition in the downstream market, while the less efficient firm is established as a Stackelberg leader. If they compete in quantity for the final good, the less efficient firm always exploits its leader's advantage by producing more, which in turn puts the more efficient firm into a disadvantageous status. Foreseeing such a disadvantage through supplying its rival, the more efficient firm will correspondingly charge a high price for the intermediate good to at least recoup its loss from being a follower. However, unless the efficiency gain of outsourcing is sufficiently large, the high price will drive the less efficient firm to turn to in-house production. Instead, if firms compete in prices for the final good, the high-cost firm will not exploit the leader's advantage by producing more, because doing so drives down the downstream price and leads to its detriment. As a result, both firms can benefit from outsourcing as long as there is efficiency gain.

The strategic interaction between the duopolists is modelled into a three-stage game. In stage one, the more efficient firms announces the price at which it is willing to supply the intermediate good. In stage two, the less efficient firm decides to outsource or not, together with the quantity to outsource. In stage three, they compete in the final-good market. We find that, the equilibrium outsourcing pattern depends on the nature of downstream competition. With Cournot competition, outsourcing does not occur if the more efficient firm only possesses a moderate cost advantage. However, with price competition, there is always outsourcing and production of the intermediate good is efficient.

We do not impose exclusivity in the less efficient firm's sourcing strategy. In our model, the less efficient firm can always expand the outsourced quantity of the intermediate good by producing in-house. Nevertheless, exclusivity in the sourcing mode arises endogenously in our model. In equilibrium, the less efficient firm never mixes between in-house production and outsourcing.

Our finding therefore offers a possible explanation on the mixed real world observations on firms' willingness to purchase from direct competitors. For example, in 1980s, IBM outsourced the micro-processor for its PC to Intel and the operating system to Microsoft (see p. 102, Hira and Hira, 2005). A counter example is between Merdedes and BMW. AEG was a traditional supplier to both BMW and Mercedes Benz. However, as soon as Mercedes Benz acquired AEG, BMW started to look for a different supplier (see p. 67, Jarillo, 1993).

Literature has identified alternative explanations to firms' reluctance to purchase from competitors. Heavner (2004) finds that, the buyer has incentive to avoid purchasing from direct competitors because of a potential "hold-up" in quality by its competitors. As a complementary explanation, our work shows that, there can be incentive on the supplier's side to drive away its competitor in order to avoid the second mover's disadvantage in their future competition.

In our work, the commitment power of the outsourced quantity is analogous to the commitment power of capacity in Dixit (1980) and of costly inventory storage in Saloner (1986). While both of their works focus on the effect of such commitment on the downstream competition, our work instead analyzes its impact on firms' choice of upstream supply. Baake et al. (1998) explores the phenomenon when competing firms supply one another with their final good. It is assumed in their work that the buyer automatically becomes a Stackelberg leader by ordering from a competitor. Our work does not make such assumption. Instead, the leadership to the buyer endogenously arises in our work. Spiegel (1993) illustrates the efficiency gains when firms subcontract part of their production to competitors when product costs are strictly convex. Instead, outsourcing in our work does not depend on the strict convexity of production costs.

Our work is also related to literature on strategic outsourcing. Shy and Stenbacka (2003) shows that driven by economies of scale, firms who outsource will congregate on a unique supplier. In the context of Bertrand competition, Chen et al. (2004) identify a collusive effect when a domestic firm outsources to a more efficient foreign competitor. Buehler and Haucap (2006) shows that outsourcing can relax downstream competition when in-house production incurs fixed cost. Arya et al. (2008a) compares outcomes and welfare implications of outsourcing between rival firms in the context of Cournot and Bertrand competition. Arya et al. (2008b) finds that, driven by the incentive to raise rival's cost, a final-good retailer has incentive to outsource to a monopoly supplier which also supplies its retailer rival. Chen et al. (2010) shows that when there exists pure outside suppliers for the intermediate good, a similar strategic consideration as in the present work can drive a disintegrated final good producer to outsource to the outsider, even if the outsider has cost disadvantage compared to its integrated direct competitor.

The rest of the paper is organized as follows. Section 2 analyzes the benchmark model with Cournot competition. Section 3 derives the major finding with Bertrand competition. Section 4 concludes.

2. THE MODEL

Two duopolists, firm H and firm L, compete in the market of a final good denoted as good F. An intermediate good, denoted as good I, is required to produce good F. Both firms H and L can produce good I in-house, but firm L is more efficient, Their constant marginal cost for good I is given by c_H, c_L, respectively, with $c_L < c_H$. Firms H and L are equally efficient in converting good I into good F, and one unit of good I can be converted into one unit of good F. W.l.o.g., the constant average cost for converting good I into good F for each firm is normalized to be zero.

The inverse demand for good F is linear and given by $P(Q) = \max\{0, a - Q\}$, with $Q = q_H + q_L$, the total quantity of good F. Assume the following condition holds:

$$\frac{a + c_L}{2} > c_H > c_L > 0, \quad 5c_L > a > 2c_L. \tag{1}$$

The first inequality in Condition (1) guarantees that both firms will produce positive quantities of good F when each of them produces good I in-house. The second part in Condition (1) is to guarantee interior solution in Stackelberg competition. It is meant to simplify our analysis and has no effect on the qualitative part of our findings.

The strategic interaction between firms H and L is modelled into a three-stage game. In stage one, firm L announces its price p, at which it is willing to supply firm H with the intermediate good I.[2] In stage two, firm H decides quantity $x \geq 0$ of good I to outsource to firm L. In stage three, firms L and H compete in good F by setting quantities q_H, q_L respectively. In this stage, if firm H wants to produce q_H beyond its acquired quantity x of good I, it can expand x by producing good I in-house, which is unobservable to firm L. Denote the quantity of good I it produces in-house as x_H. On the other side, if it leaves some of x unused without being converted into good F, there is no additional cost.

The solution concept to the game is subgame perfect Nash equilibrium (SPNE), simplified as equilibrium in the following text. We start solving the game from stage three. With (p, x) determined in stages one and two, firm L's problem is

$$\max_{q_L} \pi_L(q_H, q_L) = (a - q_H - q_L)q_L + px - c_L(x + q_H).$$

[2]Our major finding is not affected if instead firm H is the one who sets price p, then firm L decides to accept or not; or if p is determined through their negotiation.

Since producing good I in-house entails firm H positive cost, it must be $x_H = q_H - x$ if $x_H > 0$. firm H's problem is

$$\max_{q_H} \pi_H(q_H, q_L) = \begin{cases} (a - q_H - q_L)q_H - px - c_H(q_H - x) & \text{if} \quad q_H > x \\ (a - q_H - q_L)q_H - px & \text{o.w.} \end{cases}$$

With the outsourcing cost px becoming sunk for firm H in stage three, firm H's marginal cost is either 0 if $q_H \leq x$, or c_H if $q_H > x$. Its reaction function is

$$\begin{cases} a - 2q_H - q_L - c_H = 0 & \text{if} \quad q_H > x \\ a - 2q_H - q_L = 0 & \text{o.w.} \end{cases}$$

There is a jump in firm H's reaction function. The reaction function for firm L is

$$a - q_H - 2q_L - c_L = 0.$$

At a given x, if $q_H > x$, these two reaction functions intersect at (W_H, W_L), with $W_H \equiv \frac{a-2c_H+c_L}{3}$ the standard Cournot quantity for firm H and $W_L \equiv \frac{a+c_H-2c_L}{3}$ the standard Cournot quantity for firm L. Instead, if $q_H \leq x$, the intersection of these two reaction functions are given by (V_H, V_L), with quantity for firms H as $V_H = \frac{a+c_L}{3}$ and for firm L as $V_L = \frac{a-2c_L}{3}$.

In equilibrium, if $x < W_H$, firm H will expand x by producing inside $W_H - x$ amount of good I, and the Cournot result of their competition on good F is W_H, W_L; if $x > V_H$, then $V_H - x$ amount of good I will be dropped by firm H and V_H, V_L is the equilibrium quantity. For $x \in [W_H, V_H]$, firm H produces exactly x quantity for good F without any in-house production. Firm L understands this and will correspondingly maximize its profit. In this scenario, firm H becomes a Stackelberg leader and firm L becomes a Stackelberg follower. The Stackelberg follower's quantity for firm L is solved from $\max_{q_L}(a - x - q_L - c_L)q_L$ as

$$q_L^f(x) \equiv \frac{a - c_L - x}{2}.$$

By Condition (1), $q_L^f(x)$ is positive for $x < V_H$. Thus depending on the value of x, solution in stage three is

$$(q_H(x), q_L(x)) = \begin{cases} (W_H, W_L) & \text{if} \quad x < W_H \\ (V_H, V_L) & \text{if} \quad x > V_H \\ (x, q_L^f(x)) & \text{if} \quad x \in [W_H, V_H] \end{cases}$$

Now we are ready to move back to stage two. In this stage, firm H decides the quantity x to outsource at the given price p. Its profit is

$$\pi_H(p,x) = \begin{cases} \frac{(a+c_L-2c_H)^2}{9} - (p-c_H)x & \text{if} \quad x < W_H \\ \frac{(a+c_L)^2}{9} - px & \text{if} \quad x > V_H \\ \frac{x(a+c_L-x)}{2} - px & \text{if} \quad x \in [W_H, V_H] \end{cases} \tag{2}$$

Firstly, notice that $x > V_H$ is off-equilibrium since firm H can strictly improve by deviating to $x = V_H$ to save $p(x - V_H) > 0$. Secondly, notice that for $x \leq W_H$, $\pi_H(p,x)$ is strictly increasing in x as long as $p < c_H$. Thirdly, for $x \in [W_H, V_H]$, firm H becomes a Stackelberg leader. Maximizing its profit gives its Stackelberg leader's quantity as $S_H(p) \equiv \frac{a+c_L-2p}{2}$ for $p < \frac{a+c_L}{2}$, and zero otherwise. The following lemma summarizes the equilibrium quantity of firm H when it outsources.

LEMMA 1. *If firm H outsources $x > 0$ in stage two, we must have*
i. $p \leq \frac{a+c_L+4c_H}{6}$*;*
ii. for $p \in [\frac{a+c_L}{6}, \frac{a+c_L+4c_H}{6}]$*, firm H sets* $x = S_H(p)$*, and in stage three firms H and L produces* $S_H(p), q_L^f(S_H(p))$ *respectively; for* $p < \frac{a+c_L}{6}$*, firm H sets* $x = V_H$*, and in stage three firms H and L produce* V_H, V_L *respectively.*

Proof. i. By Condition (1), $\frac{a+c_L+4c_H}{6} > c_H$. Besides, for $p > \frac{a+c_L+4c_H}{6}$, firm H's Stackelberg quantity $S_H(p) < W_H$. Thus if $x > 0$ with $p > \frac{a+c_L+4c_H}{6}$, firm H is better off deviating to $x = 0$ and producing good I exclusively in-house. Thus for $x > 0$, it must be $p \leq \frac{a+c_L+4c_H}{6}$; otherwise $x = 0$ and firms H and L produce their standard Cournot quantities (W_H, W_L) in stage three. ii. Firstly, notice that for $p \leq \frac{a+c_L+4c_H}{6}$, $S_H(p) > W_H$. If $p > c_H$, by (2), $\pi_H(p,x)$ is decreasing for $x < W_H$ and is strictly increasing for $x \in [W_1, S_H(p)]$, then is strictly decreasing for $x \in (S_H(p), V_H]$ if $S_H(p) < V_H$. Instead, if $p \leq c_H$, by (2), $\pi_H(p,x)$ is increasing in $x \in [0, S_H(p)]$. Secondly, notice that $S_H(p) \geq V_H$ if $p \leq \frac{a+c_L}{6}$. Thus if $x > 0$, firm H is optimal producing its Stackelberg quantity $S_H(p)$ for $p \geq \frac{a+c_L}{6}$, or the corner solution V_H for $p < \frac{a+c_L}{6}$. ∎

Without outsourcing, each of firms H and L produces their standard Cournot quantity (W_H, W_L), and the corresponding profits are $\pi_H^W \equiv (\frac{a-2c_H+c_L}{3})^2$ for firm H and $\pi_L^W \equiv (\frac{a+c_H-2c_L}{3})^2$ for firm L. Instead, if outsourcing occurs in equilibrium, firm H can get the Stackelberg leader's advantage by ordering a quantity larger than W_H from firm L, and firm L is forced into a Stackelberg follower. Firm H compares its profit under outsourcing to π_H^W when deciding to outsource or not in stage two.

According to Lemma 1, equilibrium profits with outsourcing are

$$\pi_H(p) = \begin{cases} \frac{(a+c_L-2p)^2}{8} & \text{if} \quad p \in [\frac{a+c_L}{6}, \frac{a+c_L+4c_H}{6}] \\ \frac{(a+c_L)^2}{9} - \frac{p(a+c_L)}{3} & \text{if} \quad p < \frac{a+c_L}{6} \end{cases}$$

for firm H and

$$\pi_L(p) = \begin{cases} \frac{(a-3c_L+2p)^2}{16} + (p-c_L)S_H(p) & \text{if} \quad p \in [\frac{a+c_L}{6}, \frac{a+c_L+4c_H}{6}] \\ \frac{(a-2c_L)^2}{9} + \frac{(p-c_L)(a+c_L)}{3} & \text{if} \quad p < \frac{a+c_L}{6} \end{cases}$$

for firm L. It is clear that firm L shall never set $p < \frac{a+c_L}{6}$ since by Condition (1), $\frac{a+c_L}{6} < c_L$, so $p < c_L$ and firm L can improve at least by deviating to $p = c_L$. Thus the condition for firm H to outsource can be derived by comparing its profits with and without outsourcing under $p \geq \frac{a+c_L}{6}$. Without loss of generality, when firm H is indifferent between outsourcing $x = S_H(p)$ and producing in-house all of its demand of good I (the autarky scenario), assume no outsourcing shall occur. The equilibrium outsourcing pattern is summarized in the following lemma.

LEMMA 2. *In any equilibrium, firm H outsources $x > 0$ if and only if $p < \frac{3-2\sqrt{2}}{6}(a + 16c_H + 12\sqrt{2}c_H + c_L)$.*

Proof. The result follows from straightforward comparison between firm H's profit with and without outsourcing. ∎

Now we check firm L's pricing strategy in stage one. Denote

$$\underline{p} \equiv \frac{a+c_L}{2} - \frac{\sqrt{2}}{9}\sqrt{(a-2c_H+c_L)(5a+2c_H-7c_L)}.$$

We have $\underline{p} > c_L$ under Condition (1). Again without loss of generality, if firm L is indifferent between setting a low price so that firm H outsources $S^H(p)$, or setting a high price so that $x = 0$, assume that firm L sets a high price to drive firm H away. We have the following lemma.

LEMMA 3. *In any equilibrium, if $x > 0$, it must be $p > \underline{p}$.*

Proof. It follows from straightforward comparison between firm L's profit with and without outsourcing. ∎

The condition for outsourcing to occur in equilibrium is summarized in the theorem below.

Theorem 1. *A unique SPNE exists when firms H and L compete in quantities for good F. In SPNE, outsourcing occurs if and only if $c_H - c_L > \frac{1}{14}(a - c_L)$. Whenever this condition holds, firm H exclusively outsources good I to firm L.*

Proof. The first part of the theorem follows immediately from Lemma 2 and Lemma 3. The last sentence is obvious by Lemma 1. ∎

Outsourcing from firm H to firm L has two sides of effects on total profits: on one side, total quantity produced for the final good is larger under the Stackelberg game, leading to a lower total profit; on the other side, production cost is reduced since the more efficient firm is producing for both firms, leading to a higher total profit. Only when the second effect dominates, outsourcing generates surplus for both firms compared to the autarky scenario, hence will arise in equilibrium. Theorem 1 says that, for the second effect to dominate, the cost gap between these two firms must be large enough.

3. BERTRAND COMPETITION

Suppose firm H and firm L are producing differentiated good F, and in the last stage they compete in prices. The demand function of good F for each firm is $q_i = a - p_i + \lambda p_j, i, j = L, H$ with $\lambda \in (0, 1)$, the parameter of differentiation. Assume that $a > c_H > c_L > 0$. The following proposition shows that, outsourcing always occurs when firms H and L engage in Bertrand competition.

Proposition 1. *When firms H and L compete in prices for good F, in any SPNE, firm H exclusively outsources good I to firm L.*

Proof. If $x = 0$ in stage two, it is easy to check that firms H and L's Bertrand competition leads to equilibrium prices $\tilde{W}_H = \frac{(2+\lambda)a+2c_H+\lambda c_L}{4-\lambda^2}$, $\tilde{W}_L = \frac{(2+\lambda)a+2c_L+\lambda c_H}{4-\lambda^2}$, with the corresponding profits $\tilde{\pi}_H^W = [\frac{(2+\lambda)a-(2-\lambda^2)c_H+\lambda c_L}{(2-\lambda)(2+\lambda)}]^2$, $\tilde{\pi}_L^W = [\frac{(2+\lambda)a-(2-\lambda^2)c_L+\lambda c_H}{(2-\lambda)(2+\lambda)}]^2$. Now suppose $x > 0$ in stage two. For $x \geq q_H(\tilde{W}_H, \tilde{W}_L)$, firm H is able to commit on $p_H \leq \tilde{W}_H$ in stage three. However, firm H will not be able to commit on $p_H > \tilde{W}_H$ through $x < q_H(\tilde{W}_H, \tilde{W}_L)$, since following $x < q_H(\tilde{W}_H, \tilde{W}_L)$, firm H will expand its quantity until $x = q_H(\tilde{W}_H, \tilde{W}_L)$ by producing inside in stage three, and firm L understands this. At a given value of p set in stage one, solving the Stackelberg game gives firm H's Stackelberg leader's price $\tilde{S}_H(p) \equiv \frac{(2+\lambda)a+(2-\lambda^2)p+\lambda c_L}{2(2-\lambda^2)}$. Notice that $\tilde{S}_H(p) > \tilde{W}_H$ if

$p > \underset{\sim}{\tilde{p}} \equiv \frac{8c_H-(2+\lambda^2+\lambda^3)a-\lambda^3 c_L-4\lambda^2 c_H}{(2-\lambda^2)(2-\lambda)(2+\lambda)}$. Thus whenever $p > \underset{\sim}{\tilde{p}}$, corner solution arises: firm H sets $x = p_H(\tilde{W}_H, \tilde{W}_L)$ in stage two, and then in stage three prices are $p_H = \tilde{W}_H, p_L = \tilde{W}_L$. Notice that $\underset{\sim}{\tilde{p}} < c_H$ is true.

Suppose in equilibrium $x = 0$ for some p. However, firm L is always able to deviate to $p' = c_H - \epsilon$ with ϵ small enough so that $p' \in (\max(c_L, \underset{\sim}{\tilde{p}}), c_H)$. At p', firm H will outsource $x = q_H(\tilde{W}_H, \tilde{W}_L)$, and the ensuing competition on good F yields $(\tilde{W}_H, \tilde{W}_L)$, the same prices as without outsourcing. Both firms H and L are better off through their transaction in the market of good I: firm H saves $\epsilon q_H(\tilde{W}_H, \tilde{W}_L)$ in its cost and firm L gets $(p' - c_L)q_H(\tilde{W}_H, \tilde{W}_L)$ extra amount of profit, compared to what they get in the autarky scenario. A contradiction to $x = 0$. Thus $x > 0$ must be true in any equilibrium, and then firm H produces zero amount of good I inhouse. ▌

With Bertrand competition, firm H is able to commit to its future price for good F by ordering $x > 0$ in stage two. If firm H orders a small x from firm L, firm L understands that firm H will expand x by producing inside, and the outcome of their competition is the same as in the standard Bertrand game. Instead, if firm H orders a large x, then firm L understands that firm H will set a correspondingly low p_H in order to sell, which induces firm L to also set a low p_L. However, such a harsh future competition in good F is detrimental to both firms. To avoid this scenario, firm L can pick up $p < c_H$ to induce firm H to outsource, and at the same time $p > \max(c_L, \underset{\sim}{\tilde{p}})$, hence firm H's quantity is the same as in the standard Bertrand competition, i.e. $x = q_H(\tilde{W}_H, \tilde{W}_L)$. In this case, the equilibrium prices for good F is not affected by outsourcing, and each firm can be better off through their transaction on good I due to the efficiency gain.

The reason for different outsourcing patterns to arise with Cournot and Bertrand competition is that, with Bertrand competition, it is not in firm H's interests to expand its quantity when ordering from firm L, since that tightens future price competition and in turn hurts firm H. Instead, with Cournot competition, it is in firm H's interests to commit to a larger quantity for good F. By doing so, firm H can benefit from forcing its rival to produce less. Such a difference between Cournot competition and Bertrand competition leads to diversified sourcing modes when there is only moderate cost advantage with firm L: outsourcing occurs under Bertrand competition but not under Cournot competition.

4. CONCLUSION

This paper investigates the strategic role of outsourcing between rivalrous firms when they face asymmetric production costs for a key intermediate good. We find that, by outsourcing the intermediate good to the more efficient firm, the less efficient firm acquires the Stackelberg leadership in the final good market since the quantity outsourced commits to its future production. As a consequence, the more efficient firm is forced into a Stackelberg follower. When firms compete in quantities, the more efficient firm suffers a Stackelberg follower's disadvantage. Foreseeing such a disadvantage, it charges a high price of the intermediate good, which could drive the less efficient firm to turn to in-house production. The upshot is, outsourcing does not occur unless their cost gap is sufficiently large. Instead, with Bertrand competition, the incentive for the less efficient firm to expand its duopoly quantity is not there as a Stackelberg leader. As a result, the more efficient firm can always profitably supplies the intermediate good for its rival and both firms enjoy the efficiency gain of outsourcing.

Although we consider only duopoly market for the final good, our major finding will not be affected if there are more than two competitors, where one of them is more efficient with the intermediate-good production. One caveat in interpreting our result is that, to highlight the strategic effect of outsourcing of our central interests, the pricing scheme we consider here is unit-based (in fact, unit-based pricing is the most prevalent practice in outsourcing. See, e.g., Robinson and Kalakota, 2004 and Vagadia, 2007). Our future work should investigate alternative pricing schemes and their influence on the pattern of outsourcing. Another interesting future work would consider a dynamic setting: when the game is infinitely repeated, there are chances for rival firms to cooperate by letting the more efficient firm to produce the duopoly quantity in order to achieve the efficiency gain.

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