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Strategic Outsourcing

and

Nash Bargaining

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Abstract

This paper focuses on a Cournot duopoly market involving an independent supplier, and clarifies the effect of Nash bargaining between manufacturer and supplier on forms of intra-industry organization. We show that there are multiple equilibria where individual manufacturers behave differently, and that intra-industry organization with respect to any equilibrium will involve a combination of outsourcing and in-house production.

1 Introduction

In some circumstances, manufacturers must choose whether to outsource rather than only choosing what quantities of outsourced parts to purchase. The digital single-lens reflex (DSLR) camera industry is one example. In this industry, two manufacturers with dominant market shares (Canon and Nikon) use outsourcing to obtain complementary metal oxide semiconductor (CMOS) image sensors. A single manufacturer (Sony) dominates the market for CMOS image sensors, which are an essential component of DSLR cameras. Meanwhile, both these DSLR camera manufacturers also have the capability to develop CMOS image sensors internally.

In this paper we suppose that two manufacurers engaged in Cournot competition in a duopoly market can either outsource parts or manufacture them in-house, and we examine the effect of price negotiations between manufacturers and parts suppliers on the outsourcing decisions of these manufacturers.

The oligopoly theory literature on intra-industry outsourcing began with Shy and Stenbacka (2003). Buehler and Haucap (2006) and Sinha (2016) followed, but to date no research incorporates price bargaining between manufacturers and suppliers. However, research on subcontracting more broadly does exist; see for example Kaminen et al. (1989) and Spiegel (1993).

In this paper, we first derive a subgame perfect equilibrium for a three-stage game comprising the manufacturer's outsourcing decision, Nash bargaining, and Cournot competition. We then clarify the effect of Nash bargaining between manufacturer and supplier on the outsourcing decision.

The remainder of this paper is structured as follows. Next, in Section 2, we establish the three-stage game model. Using best response functions derived in Section 3, Section 4 compares subgame perfect equilibria. Finally, Section 5 offers summary conclusions.

2 Model

Let us consider an industry that contains manufacturers i (i=1,2) and a supplier o that manufactures an essential part for the product manufactured by the manufacturers.

The timeline is as follows: Each manufacturer i simultaneously (1) chooses whether to outsource the part to supplier o, or manufacture it in-house. Next, (2) each manufacturer i that has chosen to outsource conducts price bargaining with supplier o. Finally, (3) manufacturers compete in terms of product output quantity.

Note that if, at stage (1), both manufacturers choose to manufacture the part in-house, the game skips stage (2) and proceeds directly to stage (3) and the quantity competition.

Accordingly, this paper analyzes the following three-stage game:

1. A simultaneous-move game (involving choice to outsource)
2. Nash bargaining (involving the price of the part)
3. Cournot competition (involving the final product)

Next, we provide a formula for manufacturer payoff. First, suppose the product market inverse demand function is as follows:

$$p = a - (q_1 + q_2) \tag{1}$$

where $p \in [0, a]$ and q_i (i=1,2) denote product price and output quantity for manufacturer i, respectively. Further, throughout the analysis in this paper, we take $a > 0$ to be a sufficiently large constant.

Marginal cost is taken to be fixed for both manufacturers, and is denoted as c ($> a$). Moreover, suppose there is one product, and one part essential for manufacturing the product. In this case, if manufacturer i manufactures the part in-house, the production cost for manufacturer i is shown as cq_i (fixed costs are abstracted in this paper). Otherwise, if manufacturer i outsources the part (i.e., purchases it from a supplier o at price r), the production cost of manufacturer i is given as rq_i. Note that for part price r, whilst the supplier determines a monopoly equilibrium price in Shy and Stenbacka (2003) and Sinha (2016), in this paper r is determined as a Nash bargaining solution arrived at between manufacturer and supplier.

Under the settings above, the profit of manufacturer i (i=1,2) when manufacturing the part in-house, π_i^I, and outsourcing, π_i^O, is then, respectively:

$$\pi_i^I = (a - q_1 - q_2 - c)q_i, i = 1, 2 \tag{2}$$

and

$$\pi_i^O = (a - q_1 - q_2 - r)q_i, i = 1, 2 \tag{3}$$

If each manufacturer possesses the two options of either outsourcing or manufacturing in-house, the following cases are possible (including a case without outsourcing): both manufacturers outsource; one manufacturer outsources and the other manufactures in-house; both

Table 1: The game in strategic form

		Manuf.1 Outsourcing	*Manuf.1* In-house production
Manuf.2	Outsourcing	π_1^O, π_2^O	π_1^O, π_2^I
	In-house production	π_1^I, π_2^O	π_1^I, π_2^I

manufacturers manufacture in-house. Thus, stage (1) in the timeline above is summarized as follows (Table 1).

3 Best response

Let us find the response functions for each manufacturer. If manufacturer i (i=1,2) chooses to outsource, that manufacturers response function, BR_i^O , for arbitrary q_j, (j=1,2; $j \neq i$), is as follows:

$$BR_i^O(q_j) = (a - q_j - r)/2, i, j = 1, 2, j \neq i \tag{4}$$

Otherwise, if manufacturer i chooses to manufacture in-house, that manufacturers best response function, BR_i^I, for arbitrary q_j, (j=1,2; $j \neq i$), is as follows:

$$BR_i^I(q_j) = (a - q_j - c)/2, i, j = 1, 2, j \neq i \tag{5}$$

4 Subgame perfect equilibria

Let us derive the equilibrium profits for each of the combinations of manufacturer's strategiesi.e., for each of the following cases: outsourcing vs. outsourcing, outsourcing vs. in-house production (alternatively: in-house production vs. outsourcing), and in-house production vs. in-house production. To this end, the three-stage game described above will be solved backwards.

4.1 Outsourcing vs. outsourcing

If both manufacutuerers choose the outsourcing option, the top-left profit pair in the matrix in Table 1 will be realized. In this case, the best response function for manufacturer i is as follows:

$$BR_i^O(q_j) = (a - q_j - r)/2, i, j = 1, 2, j \neq i \tag{6}$$

Accordingly, using these equations simultaneously to find the equilibrium output quantity, we obtain the following:

$$q_i^* = (a - r)/3, i = 1, 2 \tag{7}$$

Let us next find the equilibrium price for the part. Here the marginal cost of manufacturing the part differs from the marginal cost of manufacturing the product; meanwhile, as with the product, the cost is taken to be a constant and denoted as $c_O > 0$.

In this case, if supplier o manufactures a single additional unit of the part at cost c_O, and then sells the part to the manufacturer at price r, the supplier acquires a gain of $r - c_O$. Meanwhile, by paying r to supplier o and purchasing the part, each manufacturer i can reduce their manufacturing costs by c, which is the marginal cost imposed in the case of in-house production.

Now, let the bargaining power ratio between supplier o and manufacturer i be k:$1 - k$, and define the Nash product as follows.

$$\phi = (r - c_O)^k (c - r)^{1-k} \tag{8}$$

In this case, the r that maximizes the value of ϕ is the equilibrium price determined as a Nash bargaining solution.

Solving this problem reveals the following.

$$r^* = kc + (1 - k)c_O, k \in [0, 1] \tag{9}$$

From Equation (9), the relationship between the equilibrium price for part r^* and the bargaining power of supplier k clearly depends on the marginal cost relationship between supplier o and manufacturer i. This relationship is summarized in Lemma 1.

Lemma 1: If $c_O < c$ ($c_O \geq c$, then r^* is decreasing (non-decreasing) in k.

Porter (1979) posits several factors, such as supplier product differentiation that increase supplier bargaining power. Lemma 1 shows that even if such product differentiation became a factor in this respect, and hence supplier bargaining power was increased, the part will not necessarily increase in price following price bargaining with a manufacturer that has chosen to outsource. In this sense, Lemma 1 is therefore counter-intuitive.

Substituting Equation (9) into Equation (7), we obtain the equilibrium output quantity as follows.

$$q_i^* = \frac{a - (kc + (1 - k)c_O)}{3}, i = 1, 2 \tag{10}$$

Furthermore, substituting Equations (10) and (9) into Equation (3), we can obtain an equilibrium profit for manufacturer i, as follows:

$$\pi_i^* = \frac{a - (kc + (1 - k)c_O)^2}{9}, i = 1, 2 \tag{11}$$

When intra-industry cost structure (c_O, c) is given, it is clear from Equation (11) that the relationship between supplier bargaining power and equilibrium profit is dependent on the relationship between c_O and c.

4.2 Outsourcing vs. in-house production

Let us next find the top-right profit pair in the matrix in Table 1. The best response functions for each maker in this case are, respectively:

$$BR_1^O(q_2) = (a - q_2 - r)/2 \tag{12}$$

and

$$BR_2^I(q_2) = (a - q_1 - c)/2 \tag{13}$$

Accordingly, using these equations simultaneously to find the Cournot equilibrium and substituting into Equation (9), we can obtain the following:

$$q_1^* = \frac{a + c - 2(kc + (1-k)c_O)}{3} \tag{14}$$

and

$$q_2^* = \frac{a - 2c + (kc + (1-k)c_O)}{3} \tag{15}$$

Substituting Equations (14) and (15) into Equation (3) in case of $i = 1$, we obtain the following:

$$\pi_1^0 = \frac{(a + c - 2(kc + (1-k)c_O)^2}{9} \tag{16}$$

Meanwhile, substituting Equation (11) into Equation (2) in case of $i = 2$, we obtain the following:

$$\pi_2^I = \frac{(a - 2c + (kc + (1-k)c_O)^2}{9} \tag{17}$$

The pair of equilibrium profits in the bottom-left of the matrix in Table 1 can be obtained in the same manner.

4.3 In-house production vs. in-house production

If both manufacturers choose the in-house production option, the bottom-right profit pair in the matrix in Table 1 will be realized. The best response function BR_i^I for the case where both manufacturers manufacture the part in-house is as follows.

$$BR_i^I(q_j) = (a - q_j - c)/2, i, j = 1, 2, j \neq i \tag{18}$$

Accordingly, using these equations simultaneously to derive the equilibrium output quantity, we can obtain the following:

Table 2: Profits for the various equilibria

		Manuf.1 Outsourcing	*Manuf.1* In-house production
Manuf.2	Outsourcing	$\frac{(a-r^*)^2}{9}, \frac{(a-r^*)^2}{9}$	$\frac{(a+c-2r^*)^2}{9}, \frac{(a-2c+r^*)^2}{9}$
	In-house production	$\frac{(a-2c+r^*)^2}{9}, \frac{(a+c-2r^*)^2}{9}$	$\frac{(a-c)^2}{9}, \frac{(a-c)^2}{9}$

$$q_1^* = q_2^* = \frac{a-c}{3} \tag{19}$$

Thus the equilibrium profit for each manufacuturer is as follows:

$$\pi_i^I = \frac{(a-c)^2}{9}, i = 1, 2 \tag{20}$$

Table 2 summarizes the analytical results above.

Four kinds of equilibrium profit are contained in this form. If $c_O > c$, the following relationship holds between these equilibrium profits:

$$\frac{(a-r^*)^2}{9} < \frac{(a-c)^2}{9} < \frac{(a+c-2r^*)^2}{9} < \frac{(a-2c+r^*)^2}{9} \tag{21}$$

In this case, multiple equilibria emerge as subgame perfect equilibria where each manufacturer behaves differently, and the form of intra-industry organization is outsourcing vs. in-house production. Meanwhile, if $c_O < c$, the relationship between profit levels at equilibrium follows the same order but with the inequality sign reversed, and the subgame perfect equilibrium involves the organization forms outsourcing vs. outsourcing and in-house production vs. in-house production, with both manufacturers choosing the same option.

Thus, the form of intra-industry organization realized in a subgame perfect equilibrium depends on the marginal cost relationship between the manufacturer and the supplier.

Of note, the analysis in this paper has highlighted the following: the prerequisite condition for the coexistence of two manufacturers and one supplier within an industry, and for a manufacturer to outsource even when it possesses the capability to manufacture a part, is that the marginal cost of product manufacture be lower than that of part manufacture. This point is summarized in the following proposition.

Proposition 1: If $c_O > c$, the form of intra-industry organization will involve outsourcing and in-house production.

This proposition indicates the possibility of, for instance, Canon and Nikon, two major DSLR camera manufacturers, being able to coexist within an industry along with Sony, which manufactures CMOS image sensors.

5 Conclusion

This paper has clarified the condition necessary for outsourcing and in-house manufacture to emerge in the subgame perfect equilibrium of a Cournot duopoly market involving an independent supplier. This condition involves the relationship between the marginal costs of the manufacturer and the supplier and has simple economic significance. In our game-theoretical model, this significance requires the presence of Nash bargaining power between the manufacturer and supplier.

In the intra-industry outsourcing literature, following the most recent results of Sinha (2016), the manufactuerers choice of whether to outsource or manufacture in-house is determined by the level of fixed costs. Meanwhile, in this paper we construct a model that abstracts fixed costs, and show that the manufacturers decision to either outsource or manufacture in-house is determined by the relationship between the marginal costs of the manufacturer and the supplier.

References

[1] Buehler, S. and Haucap, J. (2006) Strategic outsourcing revisited, *Journal of Economic Behavior and Organization*,61(3),325-338.

[2] Kamien, M.I., Li, L. and Samet, D. (1989) Bertrand competition with subcontracting,*The RAND Journal of Economics*,20(4),553-567.

[3] Porter, M.E. (1997) How competitive forces shape strategy,*Harvard Business Review*,July-August,137-145.

[4] Shy, O. and Stenbacka, R. (2003) Strategic outsourcing,*Journal of Economic Behavior and Organization*, 50(2),203-224.

[5] Sinha, U.B. (2016) Economies of scale and (non)existence of strategic outsourcing in Cournot Duopoly,*Economics Bulletin*, 36(3),1260-1266.

[6] Spiegel, Y. (1993) Horizontal subcontracting,*The RAND Journal of Economics*, 24(4), 570-590.