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Outsourcing under Incomplete Information

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Abstract: We consider outsourcing decision of a firm in a Cournot duopoly with incomplete information. It is shown that outsourcing can occur as outcome of a separating or pooling perfect Bayesian equilibrium, although it is not profitable under compete information. Thus, our paper shows that asymmetric information can itself be a reason for outsourcing.

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1. Introduction

Outsourcing or in-house production of the relevant inputs is a crucial decision that every firm has to take. If a firm gets inputs from outside at a lower price than the in-house input production cost, it is natural that the firm will go for outsourcing. There is a growing literature which focuses on the strategic reasons for outsourcing even if that involves shutting down the option of producing the input in-house cheaply. These strategic reasons are present in oligopolistic market structure where a firm uses the option of outsourcing as a strategic tool to maximise the overall profit in the market rather than minimizing simply the cost of production. In other words, the firms in an oligopoly setup sometimes use the outsourcing option to influence the reaction functions in a manner that helps the outsourcing firm.

In general, there are many reasons for outsourcing. Some studies have focussed on the existence of scale economies in input production and found that it is better for the final goods producers to outsource the inputs from the common input supplier (Shy and Stenbacka, 2003; Buehler and Haucap, 2006; Sinha 2016).[1] Arya et al. (2008) considered how outsourcing by a final good producer increases its competitiveness by raising the input prices for its rival. Chen (2011) shows that the outsourcing decision of an incumbent might prevent entry of a potential entrant as the incumbent can commit to an aggressive post-entry competition. Kabiraj and Sinha (2014 and 2016) first introduce the issue of technology transfer in the outsourcing literature. They consider a final good producer which has a superior input-production technology to that of the independent input supplier. The final good producer then transfers its technology to the independent input supplier by means of patent sale and thereby commits to outsourcing. This establishes that technology transfer is the motive behind outsourcing decision of a firm.[2] However, the role of incomplete or asymmetric information that itself could be a reason for strategic outsourcing is never identified in the literature. This paper is an attempt to fill this gap and raise the issue of outsourcing in an incomplete information environment.

[1]Sinha (2016) re-examines the role of economies of scale in Cournot competition and shows the existence of outsourcing equilibrium crucially depends on the existence of input supplier given its fixed cost.

[2]Though the above papers are concerned with the strategic motives behind outsourcing in closed economy models, there are some interesting papers which analyze the strategic effects of international outsourcing. See Beladi et al. (2012), Marjit and Mukherjee (2008), Pack and Saggi (2001), among others. Recently Lu *et a*l. (2014) consider the FDI and outsourcing in a service industry in the context of liberalization of trade and investment.

In the present paper we construct a model of two firms interacting in the product market under asymmetric information where one firm has private information about its technological capability of producing the final good and it has option to produce inputs in-house or buy inputs from an input market. However, using outsourced inputs (which are substitute to in-house produced) involves a fixed cost at the plant level. It requires setting up new plant or machines to make those inputs usable, given the production technology.

We assume that the firm with private information can be one of two types, viz., high cost type or low cost type. To focus on the role of incomplete information we motivate the structure of the model such that under complete information neither type will go for outsourcing, given the fixed cost of outsourcing. Interestingly however, under incomplete information, depending on the size of the fixed cost, either the low cost type firm or both types will go for outsourcing inputs in equilibrium. We portray situations when separating equilibrium exists under which the low cost type outsources inputs and the high cost type produces inputs in-house. On the other hand, there also exists pooling equilibrium when both high and low types outsource inputs in equilibrium. This happens when the fixed cost associated with outsourcing is small. Actually, the high cost firm pools with the low cost type and makes gain from the fact that the product market rival firm cannot get any clue to know the exact type of the firm, hence the rival firm averages the capability and behaves less aggressively. In our structure while it is possible to have pooling equilibrium on in-house production by both types (this occurs when the fixed cost of outsourcing is large enough), but a separating equilibrium with high cost firm outsourcing inputs and the low cost firm producing inputs in-house will never arise. Thus our paper shows that simply the presence of incomplete information about the type of one interacting firm may motivate it to go for outsourcing.

The next section describes the model and derives the results of the paper. Section 3 concludes the paper.

2. Model

Consider two firms, call firm 1 and firm 2, which compete a la Cournot in a market for homogenous goods. It is assumed that each of these firms has both input production and final goods production technologies. However, they have also the option of buying (substitute)

inputs (therefore, outsourcing inputs) from an input market at a constant input price, $c_H > 0$, per unit.

Given their technologies, if firm 1 produces inputs in-house and produces final goods using those inputs, its per unit cost of producing the final good is assumed to be $c;\ 0 \leq c < c_H$.[3] On the other hand, Firm 2's production technology can be either of two types, namely, high cost technology or low cost technology. We denote the high cost firm 2 by H and the low cost firm 2 by L. The actual type of firm 2 will be determined by nature. We assume that the unit cost of final good production by H using its in-house produced inputs is also c_H, but that by L is c_L; $c_L < c_H$.

On the other hand, if any firm likes to outsource the same input from the input market and produce final goods, we assume that it will first have to incur a fixed cost, $F > 0$, on altering or setting a new plant to accommodate the outsourced inputs. Thus, F represents the plant level adjustment cost for outsourced inputs, which is over and above the cost of procuring the input from the market. On the other hand, if the firms decide to produce the input in-house, then no such additional cost is required for producing the input, but there is marginal cost of in-house input production. Then under outsourcing the unit cost of production for H will remain to be c_H, but that for L will be αc_H; $\alpha < 1$ and $\alpha c_H \geq c_L$. Finally, the market demand function is assumed to be linear and is given by

$$P = a - (X_1 + X_2);\ a > c_H \qquad (1)$$

where P is the price of the final good and X_i is the quantity of the good supplied by firm i $(i = 1, 2)$.

We consider the following game. In stage 1, nature chooses the type of firm 2, high (H) or low (L) and reveals the information only to firm 2 and not to firm 1. In stage 2, both firms simultaneously choose whether to outsource the input or produce input in-house. However, we have restricted the parameters in a manner that for firm 1 outsourcing would never be chosen in equilibrium. In stage 3, they compete in the final good market a la Cournot.

2.1 Complete Information Scenario

[3] In our analysis, this ensures that firm 1 will never find it profitable to outsource the input.

Firm 2's type will be perfectly observable to firm 1 under complete information. Firm 1's unit cost of production is c. Suppose firm 2 is a high cost firm, hence its unit cost of production, both under in-house input production and outsourcing is c_H. Therefore, under complete information, assuming $c_H < \frac{a+c}{2}$ (so that the high cost firm produces positive output), payoffs of firm 2 (i.e., H) under in-house production (I) and outsourcing (O) are respectively,

$$\pi_H^I = (\frac{a-2c_H+c}{3})^2 \text{ and } \pi_H^O = (\frac{a-2c_H+c}{3})^2 - F \quad (2)$$

In case firm 2 is known to be a low cost firm, then firm 2's (i.e., L's) payoffs under in-house production and outsourcing are respectively,

$$\pi_L^I = (\frac{a-2c_L+c}{3})^2 \quad \text{and} \quad \pi_L^O = (\frac{a-2\alpha c_H+c}{3})^2 - F \quad (3)$$

Proposition 1*: Under complete information neither type of firm 2 will go for outsourcing inputs.*

This is obvious from (2) and (3), given $F > 0$ and $\alpha c_H \geq c_L$.

2.2 Incomplete Information Scenario

While firm 1's production technology is always common knowledge, firm 2's production technology (determining unit cost of production) is determined by nature in the first stage of the game and is revealed only to firm 2. Thus, firm 2 has private information about its unit cost of production (c_H or c_L) in the beginning of stage 2 of the game. However, firm 1 does not know that information but holds some prior belief about the type of firm 2. Let us assume that the prior belief of firm 1 about nature's move is that firm 2 is of high cost type occurs with probability θ, $0 \leq \theta \leq 1$, and that firm 2 is of low cost type occurs with probability $(1-\theta)$. All these are common knowledge.

First, suppose that the option of outsourcing of inputs is not available to firm 2 as an alternative to in-house input production. Then under incomplete information the Bayesian Nash equilibrium quantities are (see Gibbons, 1992)

$$X_1^* = \frac{a-2c+\theta c_H+(1-\theta)c_L}{3}, X_H^* = \frac{a-2c_H+c}{3} + \frac{(1-\theta)(c_H-c_L)}{6}, X_L^* = \frac{a-2c_L+c}{3} - \frac{\theta(c_H-c_L)}{6}$$

where X_H^* and X_L^* are the quantities of two types of firm 2 under Bayesian Nash equilibrium.

The corresponding payoffs of firm 2 depending on type are,

$$\pi_H^* = \left(\frac{a-2c_H+c}{3} + \frac{(1-\theta)(c_H-c_L)}{6}\right)^2 \text{ and } \pi_L^* = \left(\frac{a-2c_L+c}{3} - \frac{\theta(c_H-c_L)}{6}\right)^2 \quad (4)$$

Clearly, we have,

$$\pi_H^* > \pi_H^I \quad \text{and} \quad \pi_L^* < \pi_L^I \quad (5)$$

Therefore, without the possibility of outsourcing under incomplete information, the high cost firm gains and the low cost firm suffers a loss compared to complete information situation, and the loss (gain) of the low (high) cost firm increases (decreases) as θ goes up. Therefore, the high cost type firm 2 has no incentive to reveal its cost type to the rival. But the low cost type firm 2 has an incentive to reveal its type. If the low cost firm 2 could convince firm 1 that it is indeed a low cost firm and if firm 1 would believe it with probability one, then the low cost firm 2's profit could be higher than π_L^*. In other words, in a standard Bayesian Cournot equilibrium with one sided asymmetric information, one type gains and the other type loses due to asymmetric information since the rival firm, without knowing that information, would always choose his output as a reaction based on the expected output that would be produced by firm 2 under complete information. This brings us to the point to explore whether the losing type of firm 2 can credibly signal its type by choosing its mode of sourcing input in stage 2 of the game and improve its payoff.

Now we consider the possibility of outsourcing inputs from the input market as an alternative to in-house production to be chosen at the stage 2 of the game. Then our question is: Can the low cost firm 2 signal its type by means of opting outsourcing so that firm 1 be fully convinced? Since outsourcing involves a fixed cost, signalling may not be always possible. So we first derive the condition(s) under which a separating equilibrium exists where the low cost type firm 2 opts for outsourcing whereas the high cost type firm 2 continues with in-house input production. We then explore the possibility of pooling equilibrium on outsourcing, that is, in equilibrium both types prefer outsourcing. We also show that separating equilibrium with high cost type firm outsourcing cannot arise.[4] For the remaining part of the analysis, to simplify the algebra we assume

$$\alpha c_H = c_L \quad (6)$$

[4] Although in this paper we are not interested in pooling on in-house production by both types in equilibrium, but one may easily check that such an equilibrium exists if the fixed cost associated with outsourcing is above a critical level, and this can be supported by an appropriate off-the-equilibrium belief.

In fact, with further restrictions on α, all our results can be followed.

There are different combinations of choices possible for firm 2 at stage 2 depending on its type. The case below represents when the high cost type firm 2 chooses in-house production (I) and the low cost type firm 2 chooses outsourcing (O).

Case 1: (In-house, Outsourcing) as a separating equilibrium

This is the most important scenario because whenever such a separating equilibrium exists, the low cost firm can signal its type convincingly. Under this equilibrium the belief of firm 1 will be the following. If firm 2 is observed to outsource, it is low cost firm with probability one, and if firm 2 opts for in-house production it must be the high cost firm, that is, $\mu(L|O) = 1 = \mu(H|I)$. Then along the equilibrium path, the payoffs of H and L will be, respectively,

$$\pi_H^{(I,O)} = \left(\frac{a-2c_H+c}{3}\right)^2 \quad \text{and} \quad \pi_L^{(I,O)} = \left(\frac{a-2c_L+c}{3}\right)^2 - F \tag{7}$$

Now, (In-house, Outsourcing) to be a separating equilibrium we need to ensure that the neither type of firm 2 has any incentive to deviate. Given the above belief, we can check (see Appendix A) that the defection payoffs of H and L will be respectively,

$$\hat{\pi}_H^{(I,O)} = \left(\frac{a-2c_H+c}{3} + \frac{c_H-c_L}{6}\right)^2 - F \quad \text{and} \quad \hat{\pi}_L^{(I,O)} = \left(\frac{a-2c_L+c}{3} - \frac{c_H-c_L}{6}\right)^2 \tag{8}$$

Therefore, for separating equilibrium the following two conditions must have to be satisfied simultaneously, that is,

$$\pi_H^{(I,O)} > \hat{\pi}_H^{(I,O)} \Leftrightarrow F > \left(\frac{a-2c_H+c}{3} + \frac{c_H-c_L}{6}\right)^2 - \left(\frac{a-2c_H+c}{3}\right)^2 \equiv \underline{F}^O \tag{9a}$$

$$\text{and } \pi_L^{(I,O)} > \hat{\pi}_L^{(I,O)} \Leftrightarrow F < \left(\frac{a-2c_L+c}{3}\right)^2 - \left(\frac{a-2c_L+c}{3} - \frac{c_H-c_L}{6}\right)^2 \equiv \overline{F}^O \tag{9b}$$

We check that $0 < \underline{F}^O < \overline{F}^O$. Hence we can write the following proposition.

Proposition 2: *A separating equilibrium, in which the high cost firm 2 chooses in-house input production and the low cost firm 2 chooses outsourcing, exists for all* $F \epsilon (\underline{F}^O, \overline{F}^O)$.

Therefore, when the fixed cost associated with outsourcing inputs is neither too small nor too high, the low cost firm 2 can credibly signal its type to its rival firm 1. Here outsourcing is

acting as signal. Given the cost structure the high cost firm cannot mimic as low cost firm, that's why firm 1 is fully convinced about firm 2's type.

Case 2: (Outsourcing, Outsourcing) as a polling equilibrium

Consider the following strategies of the firms and belief under this equilibrium. When outsourcing occurs by firm 2, firm 1 will have belief that firm 2 is of high cost type with probability θ and is of low cost type with probability $(1-\theta)$, that is, the prior belief will remain as the posterior. Therefore, under equilibrium strategy, the payoffs of two types of firm 2 are

$$\pi_H^{(O,O)} = \pi_H^* - F \quad \text{and} \quad \pi_L^{(O,O)} = \pi_L^* - F \tag{10}$$

Now consider the belief off-the-equilibrium path. Assume that firm 1's belief is that only the high cost type firm 2 can deviate, if at all, hence $\mu(H|I) = 1 = 1 - \mu(L|I)$. With this belief deviation payoffs of firm 2 are

$$\hat{\pi}_H^{(O,O)} = \left(\frac{a-2c_H+c}{3}\right)^2 \quad \text{and} \quad \hat{\pi}_L^{(O,O)} = \left(\frac{a-2c_L+c}{3} - \frac{c_H-c_L}{6}\right)^2 \tag{11}$$

Therefore, for (Outsourcing, Outsourcing) to be a polling equilibrium, the following two conditions must have to be simultaneously satisfied, that is,

$$\pi_H^{(O,O)} > \hat{\pi}_H^{(O,O)} \Leftrightarrow F < \left(\frac{a-2c_H+c}{3} + \frac{(1-\theta)(c_H-c_L)}{6}\right)^2 - \left(\frac{a-2c_H+c}{3}\right)^2 \equiv \underline{F}^{OO} \tag{12a}$$

$$\text{and} \quad \pi_L^{(O,O)} > \hat{\pi}_L^{(O,O)} \Leftrightarrow F < \left(\frac{a-2c_L+c}{3} - \frac{\theta(c_H-c_L)}{6}\right)^2 - \left(\frac{a-2c_L+c}{3} - \frac{c_H-c_L}{6}\right)^2 \equiv \overline{F}^{OO} \tag{12b}$$

We can simplify to get

$$\underline{F}^{OO} = 2\,\frac{(a-2c_H+c)}{3}\,\frac{(1-\theta)(c_H-c_L)}{6} + \left(\frac{(1-\theta)(c_H-c_L)}{6}\right)^2$$

$$\text{and} \quad \overline{F}^{OO} = 2\,\frac{(a-2c_L+c)}{3}\,\frac{(1-\theta)(c_H-c_L)}{6} - (1-\theta^2)\left(\frac{c_H-c_L}{6}\right)^2$$

Finally, since $\overline{F}^{OO} > \underline{F}^{OO}$ holds, therefore (Outsourcing, Outsourcing) as a polling equilibrium always exists for all $F < \underline{F}^{OO}$. To write it formally,

Proposition 3: *A pooling equilibrium exists for all* $F < \underline{F}^{OO}$ *in which both high cost and low cost types of firm 2 choose outsourcing and the rival firm holds off-the-equilibrium belief that if there is any deviation it must have been done by only the high cost type firm.*

Note that both types of firm 2 are choosing outsourcing option leading to a Cournot Bayesian equilibrium. Therefore, the low cost type firm 2 is not able to separate out from the high cost type firm 2. However, given the off-the-equilibrium belief held by firm 1, it is not worthwhile for low cost type firm 2 to choose the other option of in-house production for this parameter range. This equilibrium is happening for low values of F. Hence, the high cost type does not mind to bear that little extra fixed cost of plant adjustment and pool with the low cost type firm 2 in order to take advantage of the extra profit that it earns in a Cournot Bayesian equilibrium.[5]

We now show that there is no separating equilibrium in which the high cost firm alone outsources. If (Outsourcing, In-house) be an equilibrium, then along the equilibrium path, the belief would be $\mu(H|O) = 1 = \mu(L|I)$. Under this belief if equilibrium would exist, the payoffs of high cost and low cost type firm 2 would be

$$\pi_H^{(O,I)} = \left(\frac{a-2c_H+c}{3}\right)^2 - F \quad \text{and} \quad \pi_L^{(O,I)} = \left(\frac{a-2c_L+c}{3}\right)^2 \tag{13}$$

Then, given the belief, the high cost type by deviation would get

$$\hat{\pi}_H^{(O,I)} = \left(\frac{a-2c_H+c}{3} + \frac{c_H-c_L}{6}\right)^2$$

Then given $F > 0$, we have always $\hat{\pi}_H^{(O,I)} > \pi_H^{(O,I)}$, hence (Outsourcing, In-house) as a separating equilibrium cannot be sustained.

Finally, it may be mentioned that in this paper our purpose is not to characterize all possible equilibria under incomplete information. We may, however, note that when the fixed cost of outsourcing is above a critical level, a pooling equilibrium in which both types of firm 2 produce inputs in-house, can always be sustained with some off-the-equilibrium beliefs.

3. Summary of the results

[5]As it is well known that in Perfect Bayesian equilibrium, the off-the-equilibrium belief can be arbitrary and there is no restriction imposed on it by this equilibrium notion. Here the off-the-equilibrium belief $\mu(H|I) = 1$ is driving the result that both types firm 2 would choose outsourcing in equilibrium. One can generate infinitely many equilibria involving outsourcing by simply altering the off-the-equilibrium belief here.

Suppose that in a quantity setting duopoly with asymmetric information the firms have option to choose between outsourcing and in-house input production, and the firm with private information is either high cost type or low cost type. Then in equilibrium either only the low cost type or both types of firm will go for outsourcing, and there always exist reasonable beliefs supporting these equilibria. This is in contrary to the fact that the firms would never be involved in outsourcing under complete information. Under incomplete information structure of our paper outsourcing equilibria by both types arise when the fixed cost associated with outsourcing activity is below a critical level. When the fixed cost is neither too small not too large, a separating equilibrium occurs in which the low cost type outsources inputs from the input market and the high cost type produces inputs in-house. However, outsourcing by only the high cost type firm 2 can never occur in equilibrium.

Appendix A

Proof of the results underlying Eqn (8):

If H deviates and chooses `outsourcing', given the belief firm 1 will presume firm 2 to be low cost type, hence will chooses a quantity, $X_1 = \frac{a-2c+c_L}{3}$. Against this, H's best response will be $X_2 = \frac{a-X_1-c_H}{2} = \frac{a-2c_H+c}{3} + \frac{c_H-c_L}{6}$. Then $\hat{\pi}_H^{(I,O)} = (X_2)^2$.

Similarly, if L deviates and chooses `in-house', given the belief firm 1 will presume firm 2 to be high cost type, hence will chooses a quantity, $X_1 = \frac{a-2c+c_H}{3}$. Against this, L's best response will be $X_2 = \frac{a-X_1-c_L}{2} = \frac{a-2c_L+c}{3} - \frac{c_H-c_L}{6}$ and the corresponding profit is $(\frac{a-2c_L+c}{3} - \frac{c_H-c_L}{6})^2$.

References

Arya, A., Mittendorf, B. and Sappington, D.E.M. (2008), "The make-or-buy decision in the presence of a rival: strategic outsourcing to a common supplier", *Management Science* **54**, 1747–1758.

Beladi, H., Marjit, S. and Yang, L. (2012), "Outsourcing: volume and composition of R&D", *Review of International Economics* 20, 828-840.

Buehler, S. and Haucap, J. (2006), "Strategic outsourcing revisited", *Journal of Economic Behaviour and Organization* **61**, 325-338.

Chen, Y. (2011), "Strategic sourcing for entry deterrence and tacit collusion", *Journal of Economics* **102**, 137 – 156.

Gibbons, R. (1992), *Game Theory for Applied Economists*, Princeton University Press, Princeton.

Kabiraj, T. and Sinha, U. B. (2014), "Strategic outsourcing with technology transfer under Cournot competition", *Economics Bulletin* **34**, 1133-1140.

Kabiraj, T. and Sinha, U. B. (2016), "Strategic outsourcing with technology transfer under price competition", *International Review of Economics and Finance* **44**, 281-290.

Lu, T., Hu, J-L., and Lin, Y-S. (2014), "FDI and outsourcing in a service industry: welfare effects of liberalising trade and investment", *Economic Record* **90,** 74-86.

Marjit, S. and Mukherjee, A. (2008), "International outsourcing and R&D: long run implications for consumers", *Review of International Economics* 16, 1010–1022.

Pack, H. and Saggi, K. (2001), "Vertical Technology Transfer via International Outsourcing", *Journal of Development Economics* 65, 389–415.

Shy, O. and Stenbacka, R. (2003), "Strategic outsourcing" *Journal of Economic Behaviour and Organization* **50**, 203-224.

Sinha, U. B. (2016), "Economies of scale and (non)existence of strategic outsourcing in Cournot duopoly", *Economics Bulletin* 36, 1260-66.