Signaling the Strength of a Market Entrant

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Abstract: This article belongs to the game theoretic and information economics literature dealing with the problem of signaling in the context of game theoretical models of entry into the industry. As opposed to the majority of literature we consider the situation of asymmetric information where the private information belongs to the entrant. We model the capacity decision of the entrant as a signal of his strength. We show that in the Stackelberg model of market entry for some values of underlying parameters the entrant fully utilizes his capacity while for other parameter values he builds excess capacity. The model may be empirically relevant for industrial organization analysis of the entry of a new supplier to the existing supply chain.

Keywords: Signaling, Entry, Capacity, Supply chains

JEL classification: D43, D82, L13.

1 Introduction

This article belongs to the game theoretic and information economics literature dealing with the problem of signaling. The beginnings of the formal modeling of signaling are connected with the Spence's (1973) model of job-market signaling, which was eventually rewarded by Nobel prize in economics for the analysis of markets with asymmetric information in in 2001. In this model the major idea of signaling — the informed player takes some costly action to signal his private information to uninformed player — was introduced to the wide mainstream economic audience for the first time. Almost ten years later Milgrom and Roberts (1982) applied this idea to the analysis of industry entry in the theory of industrial organization.

The Milgrom and Roberts (1982) analysis of entry was connected with the notion of limit pricing. The firm engaged in limit pricing purposely reduces its profits by not allowing its price to be higher than ex-ante specified limit value in order to deter entry by firms which are not active in the market so far. The seminal modern limit pricing model of Milgrom and Roberts (1982) is a signaling model. In this model the incumbent firm has high or low cost. Only the incumbent firm knows whether its cost are high or low. The possible entrant is willing to enter the industry only if the incumbent is a high cost one because the subsequent competition with the low cost incumbent would lead to the negative profit for the entrant. Obviously, in order to have interesting non-trivial situation, we assume that the competition with the high cost incumbent will provide positive profit for the entrant. Milgrom and Roberts (1982) show that while in the absence of possible entry, the low cost incumbent would charge a lower price than the high cost incumbent, the possibility of the entry leads to the following situation: The high cost incumbent may wish to pretend that he is the low cost one by charging less than the monopoly price of the high cost firm. Or, if entrant believes that high cost firm might charge low prices, the low cost incumbent may need to signal its identity by charging so low a price that would be unprofitable for a high cost incumbent. This is a standard approach in the signaling models — the informed efficient party engages in the costly action (low price in our case) which would be prohibitively costly to the inefficient party. In any way, some type of incumbent is using limit pricing in the Milgrom and Roberts (1982) model. We should emphasize that the informed party in the Milgrom and Roberts (1982) model is the incumbent. This approach with informed incumbent and uninformed entrant is used in the huge literature inspired by that model.

As pointed out by Riley (2001), there are no well known signaling models dealing with the use of capacity decision as a signal of strength (low unit cost) of an entrant in market entry games of industrial organization. Therefore our paper aims to fill this gap in the industrial organization game theoretic literature dealing with the signaling games in the context of industry entry. Our paper provides a model of industry entry where a capacity decision is made by the informed entrant prior to entering the market. We show that for some values of underlying parameters the strength of an entrant can be revealed by the different choices of capacities between weak and strong entrants.

The model may be empirically relevant for industrial organization analysis of the entry of a new supplier to the existing supply chain. Our paper could be also considered as belonging to an international agricultural trade literature on the use of agricultural commodities quotas since the capacity decision can be also interpreted as a choice of import quota or voluntary export restraint. Our model is relevant for trade in both raw agricultural (or any other) commodities and for processed food industry products (or for other products on any stage of production vertical chain).

2 The Literature Review

The problem of capacity precommitment as a barrier to entry is very rigorously analysed by Allen, Deneckere, Faith, and Kovenock (2000), who, similarly as we do in our paper, reject often assumed Cournot competition in the post-entry game. Their paper studies a model in which the incumbent and entrant sequentially precommit to capacity levels before competing in price. Their approach produces a simple and intuitive set of equilibrium behaviors and generates clear prediction about when these different outcomes are likely to arise. The entry deterrence is also analysed by Bagwell and Ramey (1996), Cave and Salant (1995), and Maskin (1999) on a very sophisticated theoretical level. A more empirical approach is taken by Krishna and Tan (1992, 1999) or Harris (2007).

Our model is also relevant to the international trade literature. In the theory of strategic trade policies, the often raised question is the construction of optimal tariffs or quotas in the asymmetric environment. The capacity variable used in our model may be interpreted as the quota size or the tariff level negotiated in the strategic trade policy framework. One possible approach to the analysis of the strategic trade is presented by Zigic (2005) . His book is primarily concerned with the trade between industrialized North and less industrialized South in the environment characterized by information asymmetry. Among other sources of asymmetry Zigic (2005) considers the difference in the unit cost of production, which is the same approach as we use in our paper. Given this asymmetry, Zigic (2005) explores some properties of optimal strategic trade policy as well as its sensitivity and its social welfare implications with respect to different modes of competition, possible information asymmetry and variations in ability of government to precommit to its policy choice. As opposed to our model, where we consider just the competing firms without any government intervention, he is very much concerned with the role of government. He relaxes the standard assumption that the government can commit to its policy instrument prior to the strategic action of the domestic firm based on the reason that governments and firms are likely to differ in their ability to commit to future actions. Thus, the government may lack credibility with the firms whose behavior it tries to influence. There may also be a time lag between the announcement and implementation of the strategic trade policies. As a consequence, the government may be forced to select its policy only after the strategic choice of domestic firm. This gives a strategic motive to the domestic firm to influence or manipulate the government policy response. In such a situation, it has been claimed that implementing a strategic trade policy can cause inefficiencies and consequently can lead to lower social welfare as compared to the corresponding social welfare under free trade.

The problem of market entry is a frequently analysed topic in the agricultural economics literature, especially in connection with the modeling of agricultural and food industry vertical commodity chains. Duponcel (1998) and Frohberg and Hartmann (1997) are interested in the problems of agricultural trade in European transition economies, which are very much plagued by entry barriers and information asymmetries with respect to their target markets. Analogical situation is in the developing economies as described by Faini, de Melo, and Takacs (1992). Similar problems also arise in the developed market economies as documented by McCorriston (1996) and Paarlerg and Lee (2001) in the context of US agricultural markets and by Veeman (1997) in the Canadian agricultural marketing board situation.

3 The Model

We consider a market for a homogeneous good with the inverse demand function

$$P(Q) = \begin{cases} a - Q & \text{if } Q < a, \\ 0 & \text{otherwise,} \end{cases} \tag{1}$$

where $P(Q)$ is the market clearing price when the aggregate quantity on the market is Q and $a > 0$.

The market is served by an incumbent monopolist (firm 1), who produces the profit maximizing quantity

$$q_1 = \frac{a - c_1}{2} = k_1, \tag{2}$$

where c_1 is his cost per unit of production and k_1 is his production capacity.

We next introduce an entrant (firm 2) which can produce the same homogeneous good. His unit cost is c_L or c_H, where $0 < c_L < c_H < c_1$. The incumbent does not know the entrant's unit cost.

The incumbent and the entrant play a game with the following sequence of steps:

1. The entrant builds the production capacity $k_i, i \in \{L, H\}$ with a variable capacity cost $\gamma \geq 0$ per unit of capacity.

2. The incumbent produces q_1 as a Stackelberg leader.

3. The entrant of type i produces q_i as a Stackelberg follower.

4. Given $Q = q_1 + q_i$, the price is determined by equation (1).

The variable capacity cost is in addition to a possible fixed capacity cost. The marginal capacity cost will be zero if the cost of capacity is fixed and does not change with the capacity size. This case is particularly applicable to the trade quota interpretation of the model.

Throughout the whole paper we assume that the values of the parameters of the model are such that the complete information production of a Stackelberg leader facing a low cost entrant without any capacity restriction is positive. This is satisfied when

$$a + c_L - 2c_1 > 0. \tag{3}$$

Since we are interested in the problem of signaling by entrant, not in the problem of entry deterrence, we set the fixed capacity cost for the entrant equal to zero.

4 Complete Information Case

As derived by Saloner (1985) in a similar game, the capacity constraint induces different production quantities than in the unconstrained Stackelberg game.

We will use the following notation: For $i \in \{L, H\}$, q_{1i}^D is an equilibrium quantity chosen by an incumbent facing an entrant of type i; q_i^D and k_i are an equilibrium quantity and capacity chosen by entrant of type i. The quantity produced by a Stackelberg leader followed by an entrant of the type i in the model without capacity constraint is denoted as q_{1i}^S.

Lemma 1 *The equilibrium quantities when the incumbent knows the type of the entrant with certainty and the variable cost of capacity are zero are:*

$$q_{1i}^D = \frac{a + c_i - 2c_1}{2\sqrt{2}} < q_{1i}^S \tag{4}$$

$$q_i^D = a - c_1 - 2q_{1i}^D = \frac{(\sqrt{2}-1)a - c_i + (2-\sqrt{2})c_1}{\sqrt{2}} = k_i. \tag{5}$$

Proof: See Saloner (1985).

We will assume throughout this paper that the capacity unit cost γ is low enough to allow Stackelberg follower's outcome for both low and high cost entrant. That is, we assume

$$\pi_H^S = (q_H^S)^2 - q_H^S \gamma \geq 0, \tag{6}$$

which leads to the following upper bound on a unit variable cost of capacity:

$$\gamma \leq \bar{\gamma} = q_H^S = \frac{a + 2c_1 - 3c_H}{4}. \tag{7}$$

Proposition 1 *Let $\gamma \leq \bar{\gamma}$. Then in the complete information equilibrium with unit capacity cost γ the capacities and outputs are the same as with zero unit cost of capacity.*

Proof: It follows from Lemma 1 and from the following properties of the entrant's profit function. For all $\gamma \leq \bar{\gamma}$ and for all $q_i \in [q_i^S, q_i^D], i \in \{L, H\}$, the net profit π_i^k of the entrant of the type i is increasing in q_i. For all $\gamma \leq \bar{\gamma}$ the profit π_i^D of the entrant of the type i at the equilibrium production (q_{1i}^D, q_i^D) net of capacity unit cost is nonnegative. For all $\gamma \leq \bar{\gamma}$ $\pi_i^D \geq \pi_i^S$.

Q.E.D.

The profits in the equilibrium are:

$$\pi_{1i}^D = \pi_{1i}^S = (q_{1i}^D)^2 \tag{8}$$

for the incumbent facing an entrant of type i and

$$\pi_i^D = q_i^D(a - q_{1i}^D - q_i^D - c_i - \gamma) \tag{9}$$

for the entrant of type i.

In the following analysis of the imperfect information game we assume that the values of all parameters are such that the full information equilibrium given by (4) and (5) is feasible.

5 Incomplete Information Case

We check under which range of capacity unit cost γ the full information equilibrium survives as a separating equilibrium in the signaling game with the entrant's private information about his variable cost c_i.

Lemma 2 *The incentive compatibility of the complete information outcome is satisfied for the high cost entrant if the variable capacity cost is sufficiently high such that* $\gamma \geq \gamma_1$*, where*

$$\gamma_1 = \frac{1}{\sqrt{2}(c_H - c_L)}\left[\left[\frac{(2\sqrt{2}-1)a - 2\sqrt{2}c_H - c_L + 2c_1}{4\sqrt{2}}\right]^2 - \frac{((\sqrt{2}-1)a - c_H + (2-\sqrt{2})c_1)}{\sqrt{2}}\frac{(a-(2\sqrt{2}-1)c_H + 2(\sqrt{2}-1)c_1)}{2\sqrt{2}}\right]. \quad (10)$$

Proof: The incentive compatibility is satisfied if

$$\pi_H^D \geq R_H(q_{1L}^D)[a - q_{1L}^D - R_H(q_{1L}^D) - c_H] - q_L^D\gamma, \quad (11)$$

where π_H^D is given by an equation (9) and $R_i(q_1)$ is the best response of the entrant of type i to the quantity q_1.

After the substitutions for quantities and some algebraic manipulations this leads to the condition in Lemma (2).

Q.E.D.

Lemma 3 *The incentive compatibility of the complete information outcome is satisfied for the low cost entrant if the variable capacity cost is sufficiently low such that* $\gamma \leq \gamma_2$*, where*

$$\gamma_2 = \frac{(2\sqrt{2}-2)a - (2-\sqrt{2})c_L + \sqrt{2}C_H + (6-4\sqrt{2})c_1}{4}. \quad (12)$$

Proof: Incentive compatibility is satisfied for a low cost entrant if

$$\pi_L^D \geq q_H^D[a - q_H^D - R_1(q_H^D) - c_L - \gamma], \quad (13)$$

where π_L^D is given by equation (9).

After the substitutions for quantities and some algebraic manipulations this leads to the condition in Lemma (3).

Q.E.D.

Proposition 2 *Let* $\gamma_1 \leq \gamma \leq \min\{\gamma_2, \bar{\gamma}\}$. *Then there exists a perfect Bayesian equilibrium of the entry game in which capacities and outputs are the same as under a complete information.*

Proof: The incentive compatibility of the proposed equilibrium is satisfied by Lemmata (2) and (3). The perfectness of the equilibrium is supported by following off the equilibrium path actions of the incumbent:

$$q_{1L}^S \quad \text{if} \quad k > k_L, \tag{14}$$

$$q_{1H}^S \quad \text{if} \quad k \in (k_H, k_L), \tag{15}$$

$$R_1(k) \quad \text{if} \quad k < k_H, \tag{16}$$

which are sequentially rational given the following beliefs of the incumbent:

$$i = L \quad \text{if} \quad k \geq k_L, \tag{17}$$

$$i = H \quad \text{if} \quad k \in [k_H, k_L), \tag{18}$$

$$\text{any beliefs} \quad \text{if} \quad k < k_H. \tag{19}$$

Q.E.D.

While the impossibility of a separation for $\gamma \in (\gamma_2, \bar{\gamma}]$ happens only for some values of parameters for which $\gamma_2 < \bar{\gamma}$, the problem of a separation for $\gamma < \gamma_1$ is a more fundamental issue. In our model, it is not possible for a low cost entrant to ensure a separation by simply increasing the capacity. For any increase of a capacity over $k_L = q_L^D$ the optimal response of an incumbent with a belief that he is facing the low cost entrant leads to Stackelberg equilibrium quantities. Nevertheless, there is still a possibility for separation if the low cost entrant obtains his Stackelberg outcome and the high cost entrant obtains the same outcome as under a complete information.

Lemma 4 *Let the produced quantities be* (q_{1L}^S, q_L^S) *if the incumbent believes that he is facing the low cost entrant and* (q_{1H}^D, q_H^D) *if the incumbent believes that he is facing the high cost entrant. Let* $\underline{q_{1L}^S} = a - c_H - 2\sqrt{\pi_H^D + \gamma(k_L - k_H)}$ *and* $\overline{q_{1L}^S} = a - c_L - 2\sqrt{\pi_L(q_{1H}^D, R_H(q_{1H}^D)) + \gamma(k_L - k_H)}$. *Then for all* $q_{1L}^S \in [\underline{q_{1L}^S}, \overline{q_{1L}^S}]$ *each type of entrant is willing to reveal his type.*

Proof: The incentive constraint for the low cost entrant is satisfied if

$$\pi_L^S - \gamma k_L \geq \pi_L(q_{1H}^D, R_H(q_{1H}^D)) - \gamma k_H, \tag{20}$$

from which we obtain

$$q_{1L}^S \leq \overline{q_{1L}^S} = a - c_L - 2\sqrt{\pi_L(q_{1H}^D, R_H(q_{1H}^D) + \gamma(k_L - k_H)}. \tag{21}$$

The incentive constraint for the high cost entrant is satisfied if for a given q_{1L}^S

$$\pi_H^D - \gamma k_H \geq \pi_H(q_{1L}^S, R_H(q_{1L}^S)) - \gamma k_L, \tag{22}$$

which is satisfied for all q_{1L}^S such that

$$q_{1L}^S \geq \underline{q_{1L}^S} = a - c_H - 2\sqrt{\pi_H^D + \gamma(k_L - k_H)}. \tag{23}$$

Q.E.D.

Since $\pi_L(q_{1H}^D, R_H(q_{1H}^D)) > \pi_H^D$ and square root is a concave function, the relaxation effect of unit capacity cost γ is bigger than its restrictive effect. This means that the increase in unit capacity cost makes the separation of high and cost entrants easier.

Proposition 3 *For all* $\gamma < \gamma_1$ *and for all* $q_{1L}^S \in [\underline{q_{1L}^S}, \overline{q_{1L}^S}]$, *there exists a perfect Bayesian separating equilibrium in which both types of entrant obtain the same import capacity* k_i *as under a full information and the low cost entrant does not fully utilize his capacity.*

Proof: This equilibrium is given by the following strategies and beliefs:

The strategy of an entrant is: entrant of type i plays $k = k_i$.

The strategy of an incumbent is:

$$q_{1L}^S \quad \text{if} \quad k \geq k_L, \tag{24}$$

$$q_{1H}^S \quad \text{if} \quad k \in (k_H, k_L), \tag{25}$$

$$q_{1H}^D \quad \text{if} \quad k = k_H, \tag{26}$$

$$R_1(k) \quad \text{if} \quad k < k_H. \tag{27}$$

This strategy can be supported by the following beliefs of an incumbent:

$$i = L \quad \text{if} \quad k \geq k_L, \tag{28}$$

$$i = H \quad \text{if} \quad k \in [k_H, k_L), \tag{29}$$

$$\text{any beliefs} \quad \text{if} \quad k < k_H. \tag{30}$$

Q.E.D.

In the cases when the separating equilibrium with full information capacities is not possible, the incumbent and the entrant can play a pooling perfect Bayesian equilibrium with the capacity and production equal to the full information outcome of the high cost entrant q_H^D.

6 Conclusion

We have shown that it is possible to use the capacity (or import quota or voluntary export restraint) as a signal of the strength of the entrant. However, in the case of a Stackelberg market entry game this signaling is restricted by the discontinuity in a payoff for an entrant. This discontinuity is caused by an incumbent reacting by his Stackelberg quantity to any increase in the capacity over the complete information equilibrium level for a given type of an entrant.

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