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There is a free lunch after all

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Abstract

This paper shows that there is a simple way for a financial institution to make a positive profit, free of risk, under imperfect competition. The institution plays a very limited role. It offers firms in the industry a per-unit subsidy in return for a predetermined upfront fee. It neither produces its own output nor sells the products of the subsidized firms. In equilibrium, firms accept the offer although they end up with lower net profits. The institution makes a positive profit as it collects upfront fees which exceed its subsidy payments. The resulting outcome in a Cournot industry is welfare improvement.

Keywords: Free lunch; Subsidy; Cournot model; Welfare improvement

JEL classification: D21; D43; D60; L13

1. Introduction

In this paper, it is shown that a reliable financial institution, *F*, can make a positive profit by selling very simple contracts to the firms in certain oligopoly industries. A contract between *F* and a firm is just a commitment of *F* to pay the firm a certain subsidy for every unit it produces. It turns out that *F* can choose a subsidy, for which a firm's

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willingness to pay for the contract exceeds the revenue it extracts from the subsidy. That is, F will make a positive profit while every subsidized firm will end up with a lower profit.

Furthermore, since a per-unit subsidy is in fact a reduction of the marginal costs, F may induce stronger competition in the market and hence increase total welfare. This is the case in a general nondifferentiated Cournot industry. Namely, welfare improvement in a Cournot market can be achieved by private initiatives motivated by profit maximizing and without government regulation. It should be emphasized that F plays no role in this market, other than offering these contracts for sale. In particular, F neither produces its own output nor sells the products of some other firms. In addition, F takes no risk because the upfront revenue it obtains in the first stage from selling these contracts exceeds its subsidy payments to the firms in the second stage.

We can regard F as an innovator of a cost-reducing innovation who is reducing the marginal cost of production in a magnitude which is equal to the per-unit subsidy. In return, F charges every licensee firm a fixed upfront payment. Equivalently, we can think of F's "invention" to be of zero magnitude where it sells its zero invention to the firms, for a combination of upfront fee and royalty, except that the royalty here is negative. Namely, F pays a firm a per-unit subsidy and collects in return a positive upfront fee.

The fact that F can make positive profits adds to the literature on licensing of innovations the observation that a cost-reducing inventor can make significant profits even if the magnitude of the innovation is negligible (or actually zero).

The same results are obtained if F subsidizes firms in return for a certain percentage of their profits (and not for upfront fees). This follows immediately from the simple fact that the Cournot quantities are invariant under positive linear transformations of the firms' profit functions. In this case, F becomes a shareholder in return for an investment which takes the form of a per-unit payment.

The phenomenon where F obtains positive profits using the above subsidization method is quite robust and exists in industries other than the Cournot industry for homogeneous products. It is shown that F obtains positive profits in the standard Hotelling industry with heterogeneous consumers and with firms that produce differentiated products and compete in prices. However, in the Hotelling industry (and contrary to the Cournot industry) F may have a negative social impact. For instance, F decreases total welfare if the competing firms have identical marginal costs of production.

In most industries, the proposed scheme seems unlikely to be practical. One explanation is that the implementation of this scheme requires no expertise and any financial institution can use it. Such a competition will raise the per-unit subsidy to a level that the bids collected are equal to the subsidies paid, and each institution will make zero profit.

Another explanation is that the Cournot and the Hotelling models are imperfect descriptions of competition. But perhaps a more realistic explanation is that the subsidization method described above assumes the financial institution has a perfect knowledge of both market demand and production costs. An extension of this paper to an incomplete information environment is challenging.

Using the same method, it is straightforward to show that a government is able to increase the total welfare in a Cournot market without generating a deficit. It can offer the firms a per-unit subsidy in return for upfront fees that can cover the subsidy cost. Total production will increase, and consequently, welfare will be improved.

There is a vast literature dealing with subsidization of firms and its impact on total welfare. Strategic trade policy is one example. The government subsidizes firms to provide them with an edge against foreign competition; see Helpman and Krugman (1989) and Brander (2000). Another example is Lahiri and Ono (1988) which deals with subsidizing firms with heterogenous marginal costs. The major difference between this literature and the current paper is that here the subsidizing entity is profit maximizing and not welfare maximizing. Nevertheless, the profit-maximizing entity offers subsidies which in some industries is welfare improving. Every firm willingly accepts the subsidy offer, and consequently, the subsidizer ends up with positive profits, and the total welfare is improved.

Another related literature deals with strategic delegation (see Fershtman and Judd, 1987; Fershtman et al., 1991; Fershtman and Kalai, 1997). The players in a strategic game can employ delegates that play the game for them. It is assumed that player can sign with his delegate a contract which specifies both the strategy to be implemented and the payoff of the delegate as a function of his action as well as the actions of the others. The players (firms) are not allowed to sign contracts with each other, but can only sign contracts with their delegates. Similarly, in our model, only F can sign contracts with players. But in contrast, neither F nor the firms act as agents of each other. They all act independently and represent their own interests only.

Another related paper is Spiegler (2000). He shows that an outsider party, F, who has sufficient initial resources can extract most of the economic surplus which is generated by two interacting agents. Neither agent can produce any surplus on his own but together they can generate a net payoff of one unit each. The party F can force the two agents into a prisoner's dilemma type of game where; thus, F extracts most of the two-unit surplus. This happens if F offers each agent a contingent contact which prohibits an agent who accepts the contract from interacting with the agent who rejects the contract, in return for a monetary compensation which exceeds his lost surplus of one unit. If both agents accept the contract, then each one of them obtains a positive but negligible amount (which is better than the no-interaction outcome) and F collects most of the interaction surplus.

It is a dominant strategy for each agent to accept F's contract, and hence the two agents interact with each other and F indeed obtains most of the surplus. It is essential in Spiegler (2000) that the contracts are offered to all the parties involved in generating the surplus. In both the Cournot and the Hotelling industries, the economic surplus is generated by all market participants: the consumers and the producers. It is certainly impractical to offer contracts to all of them. What we show here is that F, by selling very simple contracts to one side of the Cournot market (the firms), costlessly generates a higher economic surplus and extracts part of it.

2. The Cournot model

Consider a Cournot oligopoly industry with $n \geq 2$ firms that produce a homogeneous good. The technology of firm i is represented by the cost function $c_i(q_i)$, where q_i is the quantity produced by i. The inverse demand function is $P(Q)$, where $Q=\sum_{j=1}^{n} q_j$ is the total industry output.

Assumptions:

(1) $P(Q)$ and $c_i(q_i)$ are twice continuously difrentiable.
(2) $P'(Q)<0$.
(3) $c_i(q_i)$ is convex (i.e., $c_i''(q_i)\geq 0$).
(4) $P'(Q)+QP''(Q)<0$.

By Assumption 4,

$$P'(Q)+qP''(Q)<0 \tag{1}$$

for all $0\leq q\leq Q$.[1,2]

The profit of firm i is

$$\Pi_i(q_1,\ldots,q_n)=q_iP(Q)-c_i(q_i).$$

Hence

$$\frac{\partial \Pi_i}{\partial q_i}=P(Q)+q_iP'(Q)-c_i'(q_i)$$

and

$$\frac{\partial^2 \Pi_i}{\partial q_i^2}=2P'(Q)+q_iP''(Q)-c_i''(q_i)<0,$$

by Eq. (1) and by Assumptions (2) and (3). Namely, Π_i is strictly concave in q_i for every $q_{-i}=(q_1,\ldots,q_{i-1},\ q_{i+1},\ldots,q_n)$. This guarantees the existence of a Cournot equilibrium $(q_1^*,\ldots,q_n^*)$. The first-order condition $\frac{\partial \Pi_i}{\partial q_i}=0$ uniquely defines the reaction function $q_i=R_i(q_{-i})$ of firm i to the quantities q_{-i} of the other firms. By Eq. (1)

$$\frac{\partial^2 \Pi_i}{\partial q_i \partial q_k}=P'(Q)+q_iP''(Q)<0, \quad k\neq i,$$

meaning that the quantities are strategic substitutes. This implies that

$$\frac{\partial R_i}{\partial q_k}(q_{-i})<0, \quad k\neq i \tag{2}$$

(see Bulow et al., 1985), which is the key property of our result.

[1] If $P''(Q)\leq 0$, then Eq. (1) certainly holds. If $P''(Q)>0$, then $P'(Q)+qP''(Q)<P'(Q)+QP''(Q)<0$.
[2] Note also that $P'(Q)+QP''(Q)<0$ is equivalent to the assumption that the consumer surplus at Q is strictly convex.

Suppose next that an entity F can credibly commit to pay a per-unit subsidy, s, to firms in the industry. Let us show that by subsidizing one firm, say Firm 1, F can obtain a positive profit.

Let $q^{N}=(q_1^{N},\ldots,q_n^{N})$ be the "new" Cournot equilibrium for the case where Firm 1 is subsidized by s per unit of its output. It is assumed throughout that the Cournot equilibrium is unique. For every $q=(q_1,\ldots,q_n)$, let

$$\Pi_1^{N}(q_1,\ldots,q_n) = q_1P(Q) - c_1(q_1) + sq_1 = \Pi_1(q_1,\ldots,q_n) + sq_1$$

be the profit function of Firm 1. Because only Firm 1 is subsidized, for $k>1$

$$\Pi_k^{N}(q_1,\ldots,q_n) = \Pi_k(q_1,\ldots,q_n).$$

Lemma. $\frac{\partial q_1^{N}}{\partial s} > 0$ *and* $\frac{\partial q_k^{N}}{\partial s} < 0$ *for* $k > 1$.

Proof.

$$\frac{\partial \Pi_1^{N}}{\partial q1}(q^{N}) = P(Q^{N}) + q_1^{N}P'(Q^{N}) - c_1'(q_1^{N}) + s = 0 \tag{3}$$

where $Q^{N} = \sum_{j=1}^{n} q_j^{N}$. Differentiating both sides of Eq. (3) with respect to s, we have

$$\frac{\partial Q^{N}}{\partial s}[P'(Q^{N}) + q_1^{N}P''(Q^{N})] + \frac{\partial q_1^{N}}{\partial s}[P'(Q^{N}) - c_1''(q_1^{N})] = -1. \tag{4}$$

Similarly, because $\Pi_k^{N}=\Pi_k$ for $k>1$,

$$\frac{\partial \Pi_k^{N}}{\partial q_k}(q^{N}) = P(Q^{N}) + q_k^{N}P'(Q^{N}) - c_k'(q_k^{N}) = 0. \tag{5}$$

Hence, differentiating both sides of Eq. (5) with respect to s,

$$\frac{\partial Q^{N}}{\partial s}[P'(Q^{N}) + q_k^{N}P''(Q^{N})] + \frac{\partial q_k^{N}}{\partial s}[P'(Q^{N}) - c_k''(q_k^{N})] = 0. \tag{6}$$

Suppose to the contrary that $\frac{\partial q_1^{N}}{\partial s} \leq 0$. Then $\frac{\partial q_k^{N}}{\partial s} \geq 0$ (because quantities are strategic substitutes), for $k>1$. By Eqs. (1) and (6) and by Assumptions (2) and (3) $\frac{\partial Q^{N}}{\partial s} \leq 0$. However, this implies that the left-hand side of Eq. (4) is nonnegative, a contradiction. □

Corollary. $\frac{\partial Q^{N}}{\partial s} > 0$. *This follows from the Lemma together with Eq. (6).*
It follows by the Lemma that

$$q_1^{N} > q_1^{*} \text{ and } q_k^{N} < q_k^{*}, \qquad k > 1. \tag{7}$$

Next recall that $\frac{\partial \Pi_1}{\partial q_1}(q_1^{*},\ldots,q_n^{*}) = 0$ *and* $\frac{\partial^2 \Pi_1}{\partial q_1 \partial q_k} < 0$ *for* $k>1$. *Consequently, by Eq. (7)*

$$0 = \frac{\partial \Pi_1}{\partial q_1}(q_1^{*},\ldots,q_n^{*}) < \frac{\partial \Pi_1}{\partial q_1}(q_1^{*},q_2^{N},\ldots,q_n^{N}).$$

This together with $q_1^N > q_1^*$ [see Eq. (7)] imply that

$$\Pi_1(q_1^N, q_2^N, \ldots, q_n^N) > \Pi_1(q_1^*, q_2^N, \ldots, q_n^N). \tag{8}$$

Because $\frac{\partial \Pi_1}{\partial q_k} = q_1 P'(Q) < 0$ *and* $q_k^N k < q_k^*$ *for* $k > 1$,

$$\Pi_1(q_1^*, q_2^N, \ldots, q_n^N) > \Pi_1(q_1^*, q_2^*, \ldots, q_n^*). \tag{9}$$

Eqs. (8) and (9) imply that

$$\Pi_1(q_1^N, \ldots q_n^N) > \Pi_1(q_1^*, \ldots, q_n^*).$$

Because

$$\Pi_1^N(q_1^N, \ldots, q_n^N) = \Pi_1(q_1^N, \ldots, q_n^N) + s q_1^N,$$

we have

$$\Pi_1^N(q_1^N, \ldots, q_n^N) - \Pi_1(q_1^*, \ldots, q_n^*) > s q_1^N.$$

This implies that F increases the equilibrium profit of Firm 1 by more than the subsidy cost sq_1^N. If F can extract the entire surplus from Firm 1, F will obtain a positive profit. This can be achieved if, for instance, F auctions off an exclusive contract in a first price auction.

Finally, by the Corollary, $\frac{\partial Q^N}{\partial s} > 0$ and for $s = 0$, $Q^N = Q^*$. Consequently, $Q^N > Q^*$ for $s > 0$. This implies that the market price decreases and the total welfare increases, as a result of F's activity.

3. The linear symmetric case

Suppose that $P(Q) = a - Q$, $c_i(q) = c \cdot q$ for $i = 1, \ldots, n$, and $a > c$. In addition, suppose that F offers k firms identical contracts to pay them a subsidy s per unit of their outputs and that F can extract their entire surplus (e.g., by auctioning off k contracts to k highest bidders). Let T be the set of subsidized firms, $|T| = k$. The Cournot outputs are given by:

(I) If $s \leq \frac{a-c}{k}$,

$$q_i(k,s) = \begin{cases} \dfrac{a - c + (n-k+1)s}{n+1} & i \in T, \\ \dfrac{a-c-ks}{n+1} & i \notin T. \end{cases} \tag{10}$$

(II) If $s \geq \frac{a-c}{k}$,

$$q_i(k,s) = \begin{cases} \dfrac{a-c+s}{k+1} & i \in T, \\ 0 & i \notin T. \end{cases} \tag{11}$$

The operating profit of every firm is

$$\Pi_i(k,s) = q_i^2(k,s). \tag{12}$$

The net profit of i is $\Pi_i(k,s)-\alpha$ if $i\in T$, where α is the upfront payment to F (the bid of i), and it is $\Pi_i(k,s)$ if $i\notin T$.By Eqs. (10) and (11), the willingness to pay of a firm for a contract is

$$\mathrm{WTP}(k,s) = \begin{cases} \left(\dfrac{a-c+(n-k+1)s}{n+1}\right)^2 - \left(\dfrac{a-c-ks}{n+1}\right)^2 & s\leq\dfrac{a-c}{k}, \\ \left(\dfrac{a-c+s}{k+1}\right)^2 & s\geq\dfrac{a-c}{k}. \end{cases} \tag{13}$$

The profit of F is thus

$$\Pi_F(k,s) = \begin{cases} k\cdot\mathrm{WTP}(k,s) - k\cdot s\cdot\dfrac{a-c+(n-k+1)s}{n+1} & s\leq\dfrac{a-c}{k}, \\ k\cdot\mathrm{WTP}(k,s) - k\cdot s\cdot\dfrac{a-c+s}{k+1} & s\geq\dfrac{a-c}{k}. \end{cases}$$

Consider first the case where $s\leq\frac{a-c}{k}$ (or $k\leq\frac{a-c}{s}$). It is easy to verify $\frac{\partial\Pi_F}{\partial K}(k,s)\geq 0$ iff $K\leq\frac{a-c}{2s}$. Hence, the optimal number of subsidized firms is $k^*=\frac{a-c}{2s}$ and

$$\Pi_F(k^*,s) = \frac{(a-c)^2}{4(n+1)},$$

irrespectively of the magnitude of s. Varying s in the interval $\left[\frac{a-c}{2n},\frac{a-c}{2}\right]$ one can support any number k^* between 1 and n.

Next consider the case where $k\geq\frac{a-c}{s}$. It is easy to verify that

$$\frac{\partial\Pi_F}{\partial k}(k,s) = -\frac{k-1}{k+1}(a-c+s) - s < 0.$$

Namely, Π_F decreases with k and hence, $k^*=\frac{a-c}{s}$ is optimal and $\Pi_F(k^*,s)=0$ for all s. We conclude that F's highest profit is $(a-c)^2/4(n+1)$ and it is obtained for any number k of subsidized firms provided that $s=\frac{a-c}{2k}$. If one assumes positive contracting costs (even negligible), then F is best of subsidizing one firm only.

In this case, the market price is

$$P = \frac{1}{2(n+1)}[a+(2n+1)c],$$

which is smaller than $\frac{a+nc}{n+1}$, the Cournot price in the absence of F. Thus, the total welfare increases as a result of F's entry.

Remark. The same outcome is obtained if F offers a subsidy s in return for a certain share α of the firm's profit. The reason is that the Cournot quantity of a firm is invariant under positive linear transformation of its profit function.

In equilibrium, α_i* is determined by

$$\alpha_i^* \cdot \Pi_i(k^*, s^*) = \mathrm{WTP}_i(k^*, s^*),$$

where k* is the optimal number of firms (from the stand point of F) to be subsidized and s* is the equilibrium subsidy. For the linear symmetric case, $k^* = 1$ and $s^* = \frac{a-c}{2}$ is an equilibrium outcome and by Eqs. (10) (12) (13)

$$\alpha^* = \frac{\mathrm{WTP}_i\left(1, \frac{a-c}{2}\right)}{\Pi_i\left(1, \frac{a-c}{2}\right)} = \frac{n+1}{n+2}.$$

4. The Hotelling model

The free lunch phenomenon is obtained not only for the homogeneous product case. We show that F can make positive profits in Hotelling model of product differentiation price competition.

Consider the standard Hotelling model of a "linear city" of length 1 where consumers are uniformly distributed with density 1 along the city. Two firms which are located at the extremes of the city produce the same physical good. The unit cost of Firm i is c_i, $i = 1, 2$ and consumers incur a transportation cost t per unit of length. The consumers have unit demands and each derives a surplus α from consumption (gross of price and transportation cost). The firms choose their prices P_1 and P_2 simultaneously and consumers purchase from the firm which yields them the highest surplus.

The demands for the two products are

$$D_1(P_1, P_2) = \frac{P_2 - P_1 + t}{2t}, \tag{14a}$$

$$D_2(P_1, P_2) = \frac{P_1 - P_2 + t}{2t}, \tag{14b}$$

provided that both firms face positive demands and the surplus of every consumer is positive. The firms' profit functions are

$$\Pi_i(P_1, P_2) = (P_i - c_i) \cdot D_i(P_1, P_2), \qquad i = 1, 2.$$

The equilibrium prices are

$$P_1^* = t + \frac{2_{c_1+c_2}}{3},$$

$$P_2^* = t + \frac{2_{c_2+c_1}}{3}.$$

Consequently, the equilibrium profit levels are

$$\Pi_1^* = \frac{1}{2t}\left(t + \frac{c_2 - c_1}{3}\right)^2 \equiv \Pi_1^*(c_1, c_2), \tag{15a}$$

$$\Pi_2^* = \frac{1}{2t}\left(t + \frac{c_1 - c_2}{3}\right)^2 \equiv \Pi_2^*(c_1, c_2), \tag{15b}$$

Suppose that F offers an exclusive contract to pay the highest bidder a subsidy s per unit of sale. Denote by w_1 and w_2 the willingness to pay of the firms. Then

$$w_1 = \Pi_1^*(c_1 - s, c_2) - \Pi_1^*(c_1, c_2 - s), \tag{16a}$$

$$w_2 = \Pi_2^*(c_1, c_2 - s) - \Pi_2^*(c_1, -s, c_2). \tag{16b}$$

By Eqs. (15a)–(16b)

$$w_1 = \frac{2s}{3t}\left[t + \frac{1}{3}(c_2 - c_1)\right],$$

$$w_2 = \frac{2s}{3t}\left[t + \frac{1}{3}(c_1 - c_2)\right].$$

If $c_2 > c_1$, then $w_1 > w_2$ and Firm 1 will win the contract and will pay at least w_2 to F. If $c_2 = c_1$, $c_2 = c_1$, then $w_1 = w_2$ and the firm are equally likely to win the contract. Hence, for $c_1 \geq c_2$ we can assume w.l.o.g. that Firm 1 obtains the contract and pays at least w_2 to F. Hence,

$$\Pi_F \geq w_2 - sD_1,$$

and

$$D_1 = \frac{1}{2t}\left[t + \frac{1}{3}(c_2 - c_1) + \frac{1}{3}s\right].$$

Thus

$$\Pi_F \geq \frac{2s}{3t}\left[t + \frac{1}{3}(c_1 - c_2)\right] - \frac{s}{2t}\left[t + \frac{1}{3}(c_2 - c_1) + \frac{1}{3}s\right],$$

or

$$\Pi_F \geq \frac{s}{18t}[3t - 7(c_2 - c_1) - 3s]. \tag{17}$$

The right-hand side of Eq. (17) is maximized for

$$s^* = \frac{3t - 7(c_2 - c_1)}{6}.$$

Substituting s = s* in (17) we have

$$\Pi_F^* \geq \frac{1}{6t}\left(\frac{3t - 7(c_2 - c_1)}{6}\right)^2.$$

To guarantee a nonnegative subsidy, one has to assume that $c_2 - c_1 \leq \frac{3}{7}t$. In particular, if the firms have the same marginal costs ($c_1 = c_2$), then

$$s^* = \frac{1}{2}t, \quad \Pi_F^* = \frac{t}{24},$$

and by Eqs. (16a) Eqs. (16b), the net payoff of Firm 1, $\tilde{\Pi}_1$, is

$$\tilde{\Pi}_1 = \Pi_1^*(c_1 - s, c_1) - w_2$$

$$= \Pi_2^*(c_1 - s, c_1) = \Pi_1^*(c_1, c_1 - s).$$

By Eq. (15a), $\tilde{\Pi}_1 = \frac{25}{72}$. Similarly, $\tilde{\Pi}_2 = \tilde{\Pi}_1 = \frac{25}{72}$. In addition, $P_1^* = \frac{2}{3}t + c_1$ and $P_2^* = \frac{5}{6}t + c_1$. Note that prior to F's offer, $\Pi_1^* = \Pi_2^* = \frac{1}{2}t$ and $P_1^* = P_2^* = t + c_1$. Hence, the firms are worse off and consumers are better off from F's entry. However, contrary to Cournot model where F increases the total welfare, in the Hotelling model F decreases the total welfare from $\alpha - c_1 - \frac{36}{144}t$ to $\alpha - c_1 - \frac{37}{144}t$.

Finally, suppose that the firms are engaged in a price competition (rather than in a Cournot competition). We show that F is best off subsidizing no firm. In order for F to possibly make a positive profit it has to sell just one contract. The winner of the contract will be the only active producer, as it would be able to charge a price lower than c. The best strategy of F is therefore to auction off an exclusive contract. Because a losing firm obtains zero, the winning bid is the profit of the subsidized firm, which is $sQ(c)$,[3] where $Q(\cdot)$ is the demand function. But $sQ(c)$ is also F's cost. Hence, $\Pi_F(s) = 0$ for each s and F has no incentive to subsidize any firm.

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[3]Provided that s is not so large that the monopolist price, P_m, under the marginal cost $c-s$, is below c. This is indeed the case. Otherwise, if $P_m < c$, the winning firm will charge the price P_m and F's net profit will be $(P_m - c)Q(P_m) < 0$. It should also be noted that no pure strategy equilibrium exists in a Bertrand competition with two nonsymmetric firms with marginal costs $c-s$ and c where $c>0$, unless the prices are discrete. In the latter case, there exists a unique pure strategy equilibrium such that no firm uses a weakly dominated strategy. The efficient firm charges the price c and the inefficient firm charges the price which is one unit above c. The profit of the efficient firm is then $sQ(c)$.

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