Theoretical and Applied Economics
Volume XXIX (2022), No. 4(633), Winter, pp. 231-238

Cost structures, technology levels and collusion

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Abstract. *We analyze the role of technology levels in collusion and welfare in Cournot duopoly set up with a linear demand and quadratic costs. We show that for relatively inefficient technologies, the collusive profit is dominated by the Cournot-Nash profit; thus, the firms with not-so good technologies would not collude. We also show that as technology improves, the collusive profit dominates the Cournot-Nash profit, which creates an incentive for collusion, i.e., innovation would lead to collusion. We also show that, for very good/bad technology, innovation would not be anti-consumers' welfare, whereas for the intermediate one, it may be.*

Keywords: technology, innovation, collusion, Cournot-Nash, profit, welfare, costs.

JEL Classification: C72, C73, D21, D43, L13.

1. Introduction

Oligopoly theory has been an extensively researched area of work dealing with market structure, collusion, competitive strategies, predation etc. Time and again results derived in theory have been tested and debated in policy domain. Anyone working in this area of research is familiar with the well-known texts of Tirole (1988) and later ones such as that of Shy (1996), Martin (2001) etc. Oligopoly models and game theory are inseparably linked. An interesting and elegant treatment dealing with such links is available in Gibbons (1992). Cournot-Nash non-cooperative equilibrium lies in the core of this voluminous literature. Cournot duopoly model is one the most utilized analytical tool in the theory of industrial organization. In particular the popular combination of 'linear demand-constant marginal cost' examples have been used to reflect on complex and critical issues related to various aspects of modern problems of industrial economics. Treatise on regulation policies such as Viscusi, Vernon and Harrington (2005) or on industrial organization of the open developing economics such as Singh and Marjit (2003) demonstrated the usefulness of such models.

In this paper we replace the constant marginal cost function with increasing quadratic costs and focus on the probability of collusion in a linear-demand Cournot duopoly. While increasing marginal cost is the starting point of the firm behavior in the competitive markets, constant marginal cost is more popular in oligopoly theory. One reason being that the constant returns to scale technology makes firm size indeterminate in a competitive industry. Hence, increasing marginal cost guarantees an increasing supply function for a price taking firm. Constant marginal cost does not pose a problem in oligopoly as firms decide size of the output strategically by internalizing price impact of their decisions. Whatever it is, linear demand constant marginal cost combination helps deriving many interesting results which are readily generalized with concave demand functions. But one major outcome of this assumption turns out to be that the probability of collusion in an infinitely repeated game is independent of technology (Gibbons, 1992). In fact such probability is also independent of the size of the market. It is also well known that in the linear demand constant-cost example, the prisoner's dilemma outcome is a standard one. The non-cooperative payoff is strictly dominated by the monopoly profit. Hence, cooperation or collusion is always desirable. The rising cost example alters both these results drastically.

First, with linear demand and quadratic costs, Cournot-Nash profit dominates collusive or monopoly profit for relatively inefficient technologies. Therefore firms using not so-good technologies will not collude. As technology level improves possibility of collusion emerges. Thus innovations may lead to collusion. This opens up the probability that technology is a factor that drives collusion in a market; a probability that is absent in the constant cost example. Whether firms will collude does not depend on their levels of efficiency in this class of models. With increasing marginal cost, better technology may lead to collusion which will be impossible with less advanced technology. Once collusion becomes a possibility, innovation may accompany a welfare loss for the consumers since collusion will reduce consumers' surplus.

This is an interesting result on two counts. First, it explicitly shows that infeasibility of collusion is removed with technological advancement. One can show that as better and better technological conditions prevail, collusion becomes more likely and so is the threat of a loss in a consumers' welfare. However, for very good or very bad technology, innovation would not lead to a decline in consumers' surplus; but, for the intermediate levels, there exist possibilities that it may.

In a different context Mukherjee (2014) as a follow up of Sen and Tauman (2007) show that an outside innovator may be better off by licensing the newly innovated technology to multiple users instead of starting up a monopoly business. This uses the idea that with increasing marginal cost Cournot profit can be greater than Monopoly profit. If this is the case then collusive equilibrium will not be opted by the firms.

The second interesting aspect of the exercise is to argue that closer the innovations are to the frontier more likely it is that post-innovations collusion will reduce consumers' welfare. That is pre-innovation Cournot output will be larger than the post-innovation monopoly output with a better technology.

Our paper is about cost cutting innovations. But it has interesting implications for outsourcing or arm's length international contracts that reduce cost of production and is related to the recent body of literature Marjit and Mukherjee (2008), Marjit et al. (2012) and Bandyopadhyay et al. (2015). As long as market structure is kept unaltered outsourcing will increase users' welfare. Alteration of market structure may lead to welfare reducing outsourcing activity. Usually with linear demand and constant marginal cost such alteration is not possible as the possibility of collusion does not depend on the marginal cost. But in this paper that is a genuine possibility.

Policy implication of our paper is quite revealing and instructive. Significant cost cutting in spite of alteration in market structure will lead to higher consumer's surplus. Cost cutting as such which does not alter market structure will be desirable. But moderate or significant cost cutting around the switch point between market structures will not be desirable. Thus, such type of cost-cutting should be discouraged to protect consumers' welfare. Taxing such innovations seem to be a good policy choice and policy intervention which apparently seems undesirable leads to higher welfare for the consumers as in Kabiraj and Marjit (2003) in a different context. It is also related to the literature on open economic policies and welfare such as Long and Vorsden (2006), Lahiri and Ono (2004), Beladi and Mukherjee (2012), Mukherjee and Sinha (2012), Marjit and Roychoudhury (2004) etc.

The rest of the paper is laid out as follows. The second section develops the model and results and the last section concludes.

2. Model

Consider a Cournot duopoly with a demand

$$p = a - q \tag{1}$$

and a cost

$$c(q) = \frac{1}{2}sq^2,\ s > 0. \tag{2}$$

The Cournot-Nash equilibrium is derived from the F.O.C. of profit maximization

$$(s + 2)q_1 + q_2 = a \tag{3}$$

$$q_1 + (s + 2)q_2 = a \tag{4}$$

In symmetric equilibrium

$$q_1 = q_2 = q_d = \frac{a}{s+3}. \tag{5}$$

Profit is given by

$$\left[(a - 2q_d) - \left(\frac{1}{2}\right)sq_d\right]q_d$$

$$or, \pi_d = \left(1 + \frac{1}{2}s\right)\frac{a^2}{(s+3)^2}. \tag{6}$$

Similarly, the monopoly output and profit will be

$$q_m = \frac{a}{(s+2)}\ and\ \pi_m = \frac{\left(1+\frac{1}{2}s\right)a^2}{(s+2)^2}. \tag{7}$$

Note that $\left(\frac{a}{s+2} - \frac{2a}{s+3}\right) < 0$. Implying the usual result, i.e.,

$$q_m < 2q_d. \tag{8}$$

The interesting comparison is between $\frac{\pi_m}{2}\ and\ \pi_d$

$$\frac{\pi_m}{2} - \pi_d = \frac{\left(1 + \frac{1}{2}s\right)a^2}{2(s + 2)^2} - \frac{\left(1 + \frac{1}{2}s\right)a^2}{(s + 3)^2}$$

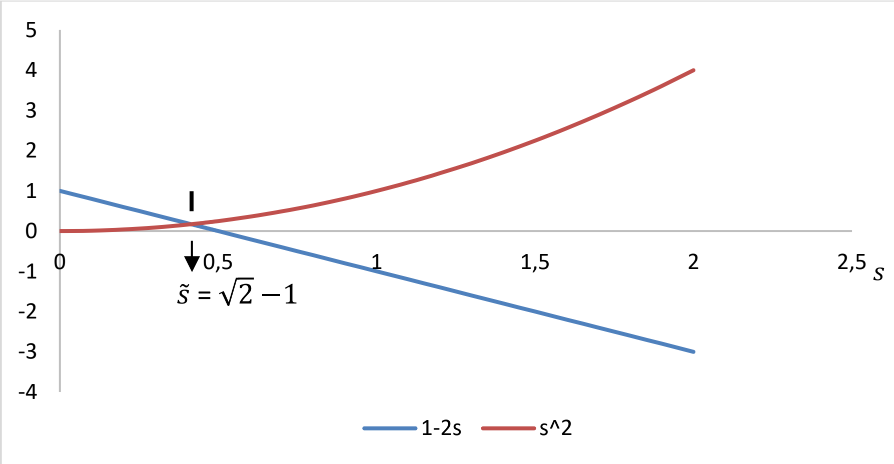
$$\Rightarrow \frac{\pi_m}{2} - \pi_d = \left(1 + \frac{1}{2}s\right)a^2\left[\frac{s^2 + 6s + 9 - 2s^2 - 8s - 8}{2(s + 2)^2(s + 3)^2}\right]$$

$$\Rightarrow \frac{\pi_m}{2} - \pi_d \gtreqless 0\ iff\ (1 - 2s) \gtreqless s^2. \tag{9}$$

It is clear from (9) that for s $\to 0, \frac{\pi_m}{2} > \pi_d$ and for $s \to \infty, \frac{\pi_m}{2} < \pi_d$.

Figure 1 defines the range of s for which $\frac{\pi_m}{2} > \pi_d$ i.e., we get the conventional result.

Figure 1. *Collusion and Cournot profits*



Thus, as shown in the above diagram (Fig 1) $\forall\, s \in (0, \tilde{s})\; \pi_d < \frac{\pi_m}{2}$ and $\forall\, s \in (\tilde{s}, \infty), \pi_d > \frac{\pi_m}{2}$. Hence, proposition 1 is immediate.

Proposition 1: Firms will not like to collude if $s \in (\tilde{s}, \infty)$.

Proof: Follows from (9) and Figure 1. QED.

Note that in the tacit collusion in an infinitely repeated game in this set up as per Friedman (1971) and Gibbons (1992) will yield a critical $\hat{\delta} > 1\; as \frac{\pi_m}{2} > \pi_d\; for\; s \in (0, \tilde{s})$.

Hence there will be no δ which will implement collusion. It is well known that $\delta > \hat{\delta}$ is the condition for collusion. We would assume that δ is very close to 1, so that once we enter the range $s \in (0, \tilde{s})$, collusion will be the outcome. For $s = \tilde{s}, \pi_d = \frac{\pi_m}{2}$ with a slight drop in π_d below $\frac{\pi_m}{2}\; for\; s = \tilde{s} - \varepsilon,\; \varepsilon \to 0$. We can define $\tilde{\delta}$ as the critical δ

$$\tilde{\delta} = \tilde{\delta}(\,\varepsilon) \tag{10}$$

and assume $\tilde{\delta} > \tilde{\delta}(\varepsilon)$ for $\varepsilon \to 0$, so that collusion is the outcome once s crosses the critical threshold $\tilde{s}$. This assumption is to highlight the consequence of an alteration in market structure.

Note that within each range i.e. without any switch in the market structure, we have standard welfare result as we reduce $s, q_m\; and\; q_d$ will increase. Let us consider some initial $s_0 \in (\tilde{s}, \infty)$ and suppose that s_0 is reduced to s_1 through innovation and $s_1 \in [0, \tilde{s}]$.

$$q_m\,(s_1) = \frac{a}{s_1+2} \tag{11}$$

$$2q_d\,(s_0) = \frac{2a}{s_0+3} \tag{12}$$

Equations (11) and (12) imply that $(s_1) \gtreqless 2q_d\ (s_0)$ if $s_0\ \gtreqless (1 + 2s_1)$. Thus,

$$s_1\ \lesseqgtr \frac{1}{2}\ s_0 - \frac{1}{2} \tag{13}$$

Thus, $s_0 > s_1$.

Let us define $\tilde{s}_0\ as\ \frac{1}{2}\ s_0 - \frac{1}{2} =\ \tilde{s}$. Thus,

$$\tilde{s}_0 = 1 + 2\tilde{s} \tag{14}$$

Since $1 - 2s = s^2$ at $s = \sqrt{2}\ - 1$, $\tilde{s} = \sqrt{2}\ - 1$. Therefore, $\tilde{s}_0 >\ \tilde{s} = \sqrt{2}\ - 1$ from (14). Thus, $s_0 > s_1$ as well as $\tilde{s}_0 >\ \tilde{s}$.

Proposition 2: For $s_0 \in (1, \tilde{s}_0)$, there exists a corresponding $s_1 \in (0, \tilde{s})$, where the post-innovation collusion output will be smaller than the pre-innovation Cournot output.

Proof: We know that $\tilde{s} =\ \sqrt{2}\ - 1$, thus, we get $\tilde{s}_0 = 1 + 2\tilde{s}$ (from (14)). This implies that $\tilde{s}_0 = 2\sqrt{2}\ - 1$.

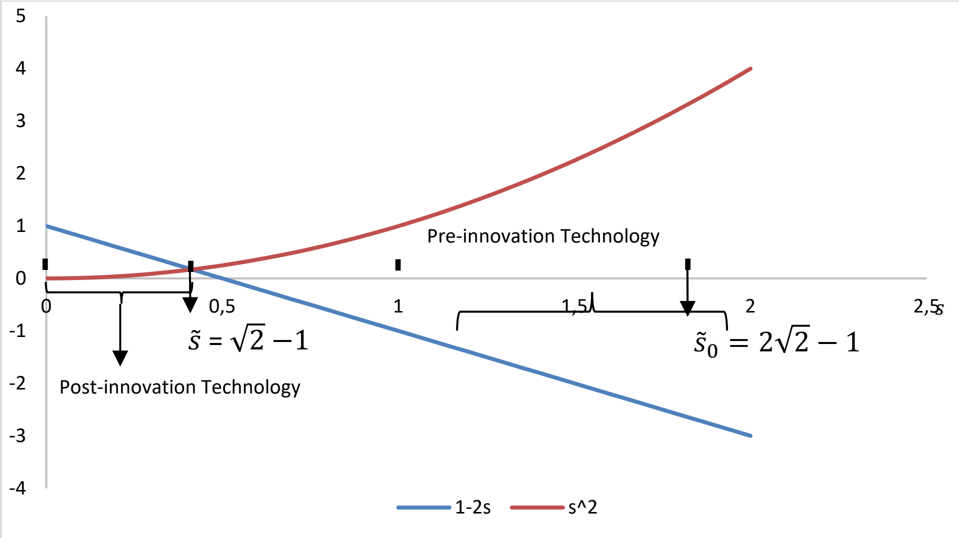
At $\tilde{s}_0 = 2\sqrt{2}\ - 1$, $s_1 =\ \tilde{s} =\ \sqrt{2}\ - 1$. We get that, $\tilde{s}_0 = 1 \Rightarrow\ s_1 = 0\ \Rightarrow \tilde{s}_0 < 1 \Rightarrow s_1 < 0$. And for $\tilde{s}_0 > 2\sqrt{2}\ - 1 \Rightarrow\ s_1 > \tilde{s} = \sqrt{2}\ - 1$ which is beyond the collusive region, i.e., $\left(0,\ \tilde{s} =\ \sqrt{2}\ - 1\right)$. Thus, for $s_1 \in (0, \tilde{s})$, $\tilde{s}_0 \in \left(1, 2\sqrt{2}\ - 1\right)$.

However, the exact location of s_1 depends on the exact location of $s_0 \in \left(1, 2\sqrt{2}\ - 1\right)$. Hence, for $s_0 \in \left(1, 2\sqrt{2}\ - 1\right)$ we would have the corresponding $s_1 \in (0, \tilde{s})$ where the resultant post-innovation collusion output will be smaller than the initial Cournot output.

QED.

Proposition 2 is depicted in Figure 2. Initial technology has to be beyond $\tilde{s}$ for collusion not to be an equilibrium outcome. However, an initial s_0 and a possible $s_1$that exceeds $\tilde{s} = \sqrt{2}\ - 1$ cannot sustain collusion. Any point between $1\ and\ \tilde{s}_0$ that leads to a post-innovation technology between 0 and $\tilde{s}$, satisfy both criteria. Output in the collusive equilibrium is smaller. Hence $(1, \tilde{s}_0)$ denotes the admissible pre-innovation technologies and $(0, \tilde{s})$ denotes the feasible set of post- innovation technology. If innovation sends s from higher than $\tilde{s}_0$ to something lower than $\sqrt{2} - 1$, output must increase.

Figure 2. *Technology ranges and collusion and Cournot outputs*



's'can be decomposed into per unit input cost and the increase of the productivity level, such as wage rate and increase of labor productivity. Therefore, given productivity level, outsourcing to a country with a lower wage may in fact increase price of the product so long as we start from a point within $(1, \tilde{s}_0)$ and move into somewhere within $(0, \tilde{s})$.

3. Concluding remarks

Cournot model has been the core workhorse of the conventional industrial organization theory. In particular linear demand with constant marginal cost has been used as a benchmark for an extensive set of results. In this paper we have introduced increasing marginal cost and derived drastically different results.

Cournot profit can dominate monopoly profit. Technology level can determine the possibility of collusion in the standard repeated game model. Thus, outsourcing or innovations by increasing the possibility of collusion may reduce consumers' welfare (related to Fuess and Lowerstein, 1991).

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