Entry and Collusion after Market Opening

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Abstract

We analyze a setting typical of industries as they evolve in the years after liberalization, or after structural demand and technology changes have occurred. An incumbent firm has an exogenous capacity, and a new entrant has to decide whether to enter the market, and at what capacity level. We find that, if the incumbent has monopoly capacity, for sufficiently high values of the discount factor, the socially most desirable outcomes require the potential entrant not to enter, or to enter with a small capacity. Indeed, in a dynamic context, higher capacity increases the severity of punishment after deviation, thereby favoring the emergence of cartels. The cartel in this case is hurting welfare, not only because of the standard deadweight loss motive, but also because it duplicates fixed cost and generates the cost inefficiency due to high (and idle) capacity. A competitive arrangement, in which the entrant enters with a small capacity, therefore, would be both welfare enhancing, as well as profit-maximizing for the incumbent.

JEL: L12, L40, L51

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1. Introduction

Many industries evolve through time from an original monopolistic setting towards a more competitive framework, with one or more new entrants adding to the incumbent. As long as the number of new entrants remains small, however, an environment favorable to collusion is likely to emerge. Both regulated and unregulated industries may be good examples to illustrate this industry development path. Among the set of regulated industries, electricity generation represents a good benchmark for the theoretical analysis developed in the present paper. First, in electricity generation, firms engage in a dynamic game, characterized by a high frequency of interactions, by a high degree of information transparency, as well as by high time-sensitivity of demand, so that for most of the time a large portion of the installed industry capacity remains idle: all the above characteristics are well known in the literature as factors that make it easier for collusion to emerge and be maintained (Motta, 2004, Ivaldi et al., 2004). Second, this is an industry typically dominated by a large incumbent, who faces the (potential) competition of new entrants.[2] Within the field of electricity, another good example is given by the transmission line, where – according to the recent rules on merchant lines[3] - an incumbent transmission line owner may face the potential competition by a merchant investor. In this case the interaction between the incumbent and the new entrant is best depicted (and can be accordingly modeled), in a context of a repeated game.[4]

Turning now towards unregulated industries, the airplane industry may fit the framework developed in this paper nicely. The increase in demand, coupled with the development of technologies reducing the optimal size of planes, may generate room for more than one firm in many routes. At the same time, the frequency of interactions lets us suppose that, once capacity is installed, the firms will engage in a repeated game, and hence if the conditions are such to support it, collusion may emerge.

[2] See Boffa et al. (2010) for an analysis of the electricity generation sector in Italy.
[3] Merchant lines are transmission infrastructures built by private investors, who receive a market remuneration for it.
[4] Of course, in electricity the regulatory framework may impose certain requirements to the incumbent that differentiate this framework from a purely market-based one.

The future entry prospects cannot be always reasonably anticipated at the time of the original incumbent's investment. For example, in electricity, the incumbent firms in various countries made their investment decisions in a regulated environment, while they were often enjoying legal monopolies in their home market. The former integrated monopolies had neither the incentives nor the mandate to calibrate their capacity in view of future entry. In the airplane industry, uncertainty over the technological evolution may suggest the monopolists to calibrate their capacities on current demand and cost structure, while revising their choices in the future if needed. Following this motivation, in this paper we regard the incumbent's decision as *exogenous*, and we analyze a two stage game. In the first (entry) stage, a potential new entrant decides whether or not to enter the market. In the (second) productive stage, the firms engage in a repeated game and collude on prices whenever it is rational for them to do so.

The remaining of the paper is organized as follows. Section 2 provides a literature review. Section 3 illustrates the model. Section 4 summarizes the main results, and Section 5 concludes. An appendix illustrates the results when entry is blockaded.

2. Literature Review

The model developed in section 3 has several points of contact with the papers dealing with multiple stage games, and analyzing how firms' capacities affect the outcome, under a variety of game formats, and different hypotheses on both the forms of competition at various stages, and the timing of entry.

The first of these papers is by Kreps and Scheinkman (KS) (1983), who examine a simultaneous capacity game, followed by a price competition stage. They find that this game structure yields the Cournot outcome, highlighting also that a limited capacity has the effect of relaxing price competition. Brock and Scheinkman (BS) (1985) consider capacity as exogenous, and analyze a repeated price game, where firms collude whenever it is rational for them do so. They illustrate how *aggregate capacity* shapes the threat after a deviation, by explicitly analyzing the tradeoffs between the two countervailing effects of a capacity increase. On the one hand, as long as the individual firms' initial capacity stock is not sufficient to cover the entire market demand, a larger capacity (weakly) increases the one-shot deviation profit, by allowing the firm to increase the output produced right after the deviation occurs. This contributes to making collusion more difficult to sustain. On the other hand, as long as the aggregate capacity is sufficiently high that no firm is essential in producing the competitive output (i.e., the capacity of all the firms except the largest one is sufficient to cover the market demand at the competitive price), Bertrand equilibrium involves positive profits. Therefore, if each firm proportionally increases capacity, the individual continuation profit is reduced, thereby increasing the collusive potential. The intensity of each of the two effects depends on the initial capacity stock. When it is low (high), the second (first) effect is prevailing, and adding capacity facilitates (hinders) collusion. Therefore, an increase in aggregate capacity has a non-monotonic effect on the sustainability of the cartel. Benoit and Krishna (BK) (1987) and Davidson and Deneckere (DD) (1990) analyze a framework similar to BS, with the main difference that capacity is endogenously chosen. Benoit and Krishna (1987) allow for the option of adjusting capacity every period, and find a set of equilibria sharing the property that in equilibrium firms carry excess capacity. DD consider a special case of BK, in which capacity is an irreversible investment. Beyond confirming that carrying (idle) excess capacity favors the emergence of collusive behavior, the authors also find that capacity levels and collusion both increase if the discount factor rises or the cost of capacity declines. With a low discount factor, or a high capacity cost, it becomes too costly to carry enough capacity to support the monopoly equilibrium.

The stream of literature on sequential entry has analyzed both static and dynamic competition (in prices or quantities). The standard results for static competition, in both prices and quantities, after sequential entry (see Spence, 1977, and Dixit, 1989) indicate that entry may be deterred by installing a sufficiently high capacity, as this represents a commitment towards an aggressive behavior on the incumbent's part, if entry had to take place. When the post-entry structure is modeled as a dynamic game, the reasoning changes dramatically. As Benoit and Krishna (BK) (1991) point out *"commitments that make predatory behavior in the post-entry game credible also increase the prospects for collusion. This is because in a dynamic setting, a greater degree of collusion may be* *supported by the increased severity of available threats. The entrant may view the incumbent's choice as a commitment to collude"*. While in a static setting high capacity provides the incumbent with a commitment towards aggressive behavior if entry occurred, in a dynamic setting this same strategy may be interpreted as a commitment to collude (as it reduces the continuation profit after deviation).

Finally, Sorgard (1995) adopts a framework very similar to that of our paper. A new entrant has to decide whether or not to enter in a market where an incumbent has exogenous capacity. Prior to a dynamic price game, the new entrant optimally selects capacity. Sorgard (1995) finds that voluntary capacity limitation is almost never optimal, and emerges only when collusion is based upon the static Nash equilibrium punishment, the incumbent has excess capacity, and the entrant is at a cost disadvantage. The following Table provides a useful categorization of the above mentioned papers:

Table 1: Capacity, Entry and Collusion

Paper	Timing of entry	Capacity	Price	Main Results
Kreps & Scheinkman (1983)	Simultaneous	Endogenous	One-shot game (non-cooperative)	Low capacity relaxes price competition
Brock & Scheinkman (1985)	-	Exogenous	Repeated game (potentially collusive)	Collusion is a non-motonic function of capacity
Benoit & Krishna (1987)	Simultaneous	Endogenous, but adjustable	Repeated game (potentially collusive)	Excess capacity allows collusion
Davidson & Deneckere (1990)	Simultaneous	Endogenous, but not adjustable	Repeated game (potentially collusive)	Excess capacity favors collusion
Dixit (1989)	Sequential	Endogenous	One-shot-game (non-cooperative)	High capacity deters entry
Benoit and Krishna (1991)	Sequential	Endogenous	Repeated game (potentially collusive)	Low capacity deters entry, excess capacity favors collusion
Sorgard (1995)	Sequential	Exogenous for incumbent, endogenous for the *less efficient* new entrant	Repeated game (potentially collusive)	The entrant limits capacity in a non-collusive setting, but may set a higher capacity in a collusive setting
This paper	Sequential	Exogenous for incumbent, endogenous for the *equally efficient* new entrant	Repeated game (potentially collusive)	The higher the entrant's capacity, the higher the detriment to welfare; the entrant tends to enter, and to install a higher capacity, if he can collude

While the large majority of the papers considered price competition in the stage following entry, the finding of a pro-collusive excess capacity emerges in Cournot settings too (Brander and Harris, 1984; Dragan, 2004; Guzman and Montero, 2004).

Our paper develops a special case of BK (1991). Differently to Sorgard, we focus on the (more realistic) case where capacity has a positive cost and we consider symmetric marginal costs across firms. Analogously to Sorgard (1995), we consider the incumbent's choice as exogenous, and we model the entrant's response in view of a post-entry dynamic price game. We examine the role of the discount factor in determining the outcome of the new entrant's capacity choice followed by a dynamic price game. We find that the entrant's capacity choices are such that the collusive behavior prevails for sufficiently high discount factor levels, while the static one-shot equilibrium prevails even in the dynamic game for a low level of the discount factor. However, when the equilibrium outcome in the dynamic game replicates that of the static one-shot game, welfare is maximized, along with the incumbent's profit. Indeed, a collusive post-entry game increases the entrant's profit, and, as a result, expands its chances of a profitable entry. When entry followed by collusion actually occurs, while the market outcome remains unchanged (as the cartel replicates the monopoly behavior), inefficiencies emerge for two reasons. First, fixed cost duplication; second, excess capacity, built for the pure strategic purposes of enforcing the cartel (as a mere threat against possible deviations from the collusive behavior), and tending to remain idle. An incumbent, therefore, is likely to stand for a strict anti-collusive policy *ex ante*, before entry actually takes place, while *ex post*, after entry occurs switching to support more collusion-friendly policies. If an Antitrust authority commits to a tough anti-collusive policy, the number of firms is reduced, but welfare increases.

3. The model

We consider an incumbent *I* who installs monopoly capacity. After some (possibly exogenous) regulatory or technological changes, entry becomes a feasible option, so that *I* faces the threat of competition by a potential new entrant *E*. *E* decides whether or not to enter. If he enters, he will tacitly collude with the incumbent when it is rational for him to do so. The stages of the game are the following:

0) *I* is exogenously assigned a capacity level, assumed to be at the monopoly level;

1) *E* decides whether to enter or not, and, if he enters, he chooses the capacity level;

2) an infinitely repeated production game is played.

We aim at investigating how the collusive potential, after the incumbent's monopoly choice, affects the entrant's decisions and the outcome of the game.

We make the following assumptions:

i) Firms face a unit linear demand: $p=1-Q$

ii) There is a fixed/sunk cost of entry *F*, which will remain implicit in the rest of the model.

iii) Each unit of installed capacity has a cost of $r = \frac{1}{2}$

iv) There are zero marginal production cost

v) The following sharing rule is in place $S_E = \frac{k_E}{k_E + k_I}$ and $S_I = 1 - S_E$, where *S* is the market share

vi) $k_E < k_I < 1$.

Assumptions *iii)* and *iv)* differentiate our paper from Sorgard's (1995), as they prescribe a positive cost of capacity and symmetric marginal costs.

Assumption *v)* represents a quite common sharing rule (see Davidson and Deneckere, 1990), which is consistent with most empirical observations.[5]

Assumption *vi)* reflects a feature of recently privatized and liberalized industries, where a large formerly State-owned monopolist faces the prospect of new entrants, which normally will start to operate on a smaller scale.

[5] However, see Dragan (2004), who proposes that firms tacitly agree to produce the *same* level of output, regardless of their ex-post capacity levels.

3.1 Monopoly choice by I

We first derive the investment and price choices for a monopolist wishing to maximize profit neglecting the threat of potential entry. In such case,

$$\pi_I = \frac{k_I(1-k_I)}{1-\delta} - \frac{k_I}{2}.$$

Maximization with respect to k_I yields $\frac{(1-2k_I)}{1-\delta} = \frac{1}{2}$, wich

implies $k_I* = \frac{1-\frac{1}{2}(1-\delta)}{2} = \frac{1}{4}(1+\delta)$.

With a high discount factor, the cost of capital remains constant, while the relative value of future revenue streams increases. It follows that the optimal capacity investments increases with the discount factor.

The single period price is $p* = 1 - \frac{1-\frac{1}{2}(1-\delta)}{2} = \frac{3}{4} - \frac{1}{4}\delta$.

The single period revenue is then: $\left(\frac{3}{4} - \frac{1}{4}\delta\right)\frac{1}{4}(1+\delta) = \frac{3}{16} + \frac{1}{8}\delta - \frac{1}{16}\delta^2$

The *discounted revenue*, the total cost, and the discounted profit ($\pi *_I$ = *TR-TC*) in the dynamic game are respectively:

$$TR = \frac{(1+\delta)}{4(1-\delta)}\frac{(3-\delta)}{4} = \frac{3+2\delta-\delta^2}{16(1-\delta)}$$

$$\text{TC} = \frac{1}{2}k_I* = \frac{1}{8}(1+\delta)$$

$$\pi *_I = \frac{3+2\delta-\delta^2-2(1-\delta^2)}{16(1-\delta)} = \frac{(1+\delta)^2}{16(1-\delta)}$$

3.2 The new entrant's choice

In choosing his scale of operation, the new entrant considers the three effects of a marginal increase in capacity.

- *First*, the static game profit decreases (as long as capacity is above the static monopoly output). This effect can move *E*'s profit in both directions; it may increase it, by encouraging collusion, through a reduction in the appeal of a deviation, thereby ultimately increasing *E*'s profit. Alternatively, if collusion still cannot be sustained, and firms revert to the static outcome, *E*'s profits are clearly reduced due to this effect.

- *Second*, the deviation profit increases, and this reduces the cartel stability, and (weakly) decreases *E*'s profits.

- *Third*, the capacity cost trivially increases, thereby reducing *E*'s profits.

The interplay among these three effect determines *E*'s choices.

In analyzing the entrant's choice, we are restricting ourselves to our assumption *vi)* $k_E < k_I < 1$

Following Davidson and Deneckere (1990), who build on Kreps and Scheinkman (1983), we split the analysis into many different subcases:

Case a):
$$k_I + k_E \le \frac{1}{2} \quad (1)$$
$$k_E < k_I < 1 \quad (vi)$$

Case b):
$$k_I + k_E \ge \frac{1}{2} \quad (2)$$
$$k_I + \frac{1}{2}k_E \le \frac{1}{2} \quad (3)$$

Case c):
$$k_I \ge \frac{1}{2}\left(1 + \sqrt{k_E(2 - k_E)}\right) \quad (4)$$
$$k_E < k_I < 1 \quad (vi)$$

The logic for the need to separate the analysis into multiple groups is the following. The dynamic game profit, along with the output sustainable in a collusive agreement, depends on the Bertrand profit, which constitutes the continuation profit accruing to a firm that decides to deviate from the arrangement, in a Nash reversion setting. The Bertrand profit function is a step function, with multiple functional forms for different ranges of values for k_I and k_E. Hence the need to analyze each case separately.

3.2.1 Case a)

In this case, the aggregate capacity is below the monopoly output in the stage game (½). Using the fact that $k_I * = \frac{1+\delta}{4}$, we rewrite (1) and *(vi)* as follows:

$$k_E < \frac{1-\delta}{4} \quad (1)$$

$$k_E \leq \frac{1+\delta}{4} \quad (vi)$$

As a consequence, both firms' capacities are entirely absorbed by the market, and the equilibrium price tops the monopoly price. Clearly, (1) is more stringent than (*vi*), and therefore it's the relevant one. Hence, the price equals: $p = 1 - \frac{1+\delta}{4} - k_E$. The objective function for *E* is then:

$$\max_{k_E} \pi_E = \frac{\left(1\text{-}\left(\frac{1+\delta}{4}\right)\text{-}k_E\right)k_E}{1\text{-}\delta} - \frac{k_E}{2}$$

At the unconstrained optimum, we have:

$$k_E * = \frac{1}{8}(1+\delta).$$

We need to verify that the constraint (1) holds:

$k_E * = \frac{1}{8}(1+\delta) < \frac{1-\delta}{4}$, and it holds only for $\delta < \frac{1}{3}$.

It follows that the optimal output in case a) is:

$$k_E^* = \begin{cases} \frac{1+\delta}{8} & if \quad \delta < \frac{1}{3} \\ \frac{1-\delta}{4} & if \quad \delta > \frac{1}{3} \end{cases}$$

The resulting profit is the following:

$$\pi_E^* = \begin{cases} \frac{(1+\delta)^2}{64(1-\delta)} & if \quad \delta < \frac{1}{3} \\ \frac{\delta}{8} & if \quad \delta > \frac{1}{3} \end{cases}$$

In particular, we now compute the profit for some specific values of the discount factor, 0.3, 0.4, 0.7 and 0.9

$$\pi_E^{*A} = \begin{cases} 0.0377 & if \quad \delta = 0.3 \\ 0.05 & if \quad \delta = 0.4 \\ 0.0875 & if \quad \delta = 0.7 \\ 0.1125 & if \quad \delta = 0.9 \end{cases}$$

3.2.2 Case b)

In this case, the aggregate industry capacity $k_I + k_E$ exceeds the monopoly output in the stage game (½), but only by a limited amount.

Using the fact that $k_I^* = \frac{1+\delta}{4}$, we rewrite (2) and (3) in the following fashion:

$$k_E > \frac{1-\delta}{4} \qquad (2)$$

$$k_E < \frac{1-\delta}{2} \qquad (3)$$

$$k_E \leq \frac{1+\delta}{4} \qquad (vi)$$

In this case, the Bertrand equilibrium involves no capacity restriction: Every firm entirely utilizes its capacity. Since aggregate industry capacity is only slightly higher than ½, the profit in the static game is only modestly lower than the optimal (i.e., monopoly) profit. The significance of the deviation profit makes collusive agreements very unstable, and ultimately hinders collusion. Even in this case the outcome is a repetition, at each stage, of the static game outcome: $k_E{*}=\frac{1}{8}(1+\delta)$. We verify the compatibility with constraints (2), (3), and *(vi)*

$$\frac{1+\delta}{8} > \frac{1-\delta}{4} \quad \text{(2) which holds for } \delta > \frac{1}{3}$$

$$\frac{1+\delta}{8} < \frac{1-\delta}{2} \quad \text{(3) which holds for } \delta < \frac{3}{5}$$

$$\frac{1+\delta}{8} \leq \frac{1+\delta}{4} \quad (vi) \text{ which always holds}$$

It follows that the optimal output in case b) is the following:

$$k_E{*}=\begin{cases} \frac{1-\delta}{4} \;\; if \;\; \delta<\frac{1}{3} \\ \frac{1}{8}(1+\delta) \;\; if \;\; \frac{1}{3}<\delta<\frac{3}{5} \\ \frac{1-\delta}{2} \;\; if \;\; \delta>\frac{3}{5} \end{cases}$$

Observe that the new entrant's output increases with the discount factor, as the value of capacity relative to its cost increases with it.

The profit is the following:

$$\pi_E^{*A}=\begin{cases} \frac{\delta}{8} \;\; if \;\; \delta<\frac{1}{3} \\ \frac{(1+\delta)^2}{64(1-\delta)} \;\; if \;\; \frac{1}{3}<\delta<\frac{3}{5} \\ \frac{3\delta-1}{8} \;\; if \;\; \delta>\frac{3}{5} \end{cases}$$

The optimal capacity choice and profit levels, for some specific values of the discount factor, are reported in the central columns of table 2 below.

3.2.3 Case c)

Case c) is the only one where we observe equilibrium excess capacity.

$$k_I \geq \frac{1}{2}\left(1 + \sqrt{k_E\left(2 - k_E\right)}\right) \quad (4)$$

For such a high (relative to cases a) and b)) aggregate capacity, the Bertrand equilibrium involves a capacity restriction, as each firm's optimal response to the rival's prescribes a limited production. This implies that there does not exist a Bertrand equilibrium of the one-shot game in pure strategies, but all the mixed strategy equilibria yield the same expected profit level (one for the incumbent, one for the new entrant).

Aggregate capacity under this circumstance is relatively high, so that the threat to resort to a competitive outcome is sufficiently severe to constitute a deterrent from deviation, and, as a consequence, to allow for a monopolistic outcome. Observe that the prevalence of the collusive outcome entails the enactment of the sharing rule, at least for large enough discount factors. Hence, when excess capacity is large, profits decline significantly.

Table 2: The outcome of the game in the three cases

	Monopoly		Case a)			Case b)			Case c)		
	k_I	π_I	k_E	π_E	π_I	k_E	π_E	π_I	k_E	π_E	π_I
$\delta=0$	0.25	0.0625	0.125	**0.0156**	0.03125	0.25	0	0	Collusion is not an equilibrium		
$\delta=0.3$	0.325	0.15089	0.1625	**0.0377**	0.0754	0.175	0.0375	0.0696	0.175	0.0375	0.00696
$\delta=\frac{1}{3}$	0.3333	0.16666	0.1666	**0.04166**	0.0833	0.1666	**0.04166**	0.0833	0.1666	**0.04166**	0.0833
$\delta<\frac{1}{3}$	$\frac{(1+\delta)}{4}$	$\frac{(1+\delta)^2}{16(1-\delta)}$	$\frac{1}{8}(1+\delta)$	$\frac{(1+\delta)^2}{64(1-\delta)}$	$\frac{(1+\delta)^2}{32(1-\delta)}$	$\frac{1-\delta}{4}$	$\frac{\delta}{8}$	$\frac{\delta(1+\delta)}{8(1-\delta)}$	$\frac{1-\delta}{4}$	$\frac{\delta}{8}$	$\frac{\delta(1+\delta)}{8(1-\delta)}$
$\delta=0.4$	0.35	0.20416	0.15	0.05	0.11667	0.175	0.0510	0.10208	0.1901	**0.0516**	0.095032
$\frac{1}{3}<\delta<\frac{3}{5}$	$\frac{(1+\delta)}{4}$	$\frac{(1+\delta)^2}{16(1-\delta)}$	$\frac{1-\delta}{4}$	$\frac{\delta}{8}$	$\frac{\delta(1+\delta)}{8(1-\delta)}$	$\frac{1}{8}(1+\delta)$	$\frac{(1+\delta)^2}{64(1-\delta)}$	$\frac{(1+\delta)^2}{32(1-\delta)}$	$\sqrt{\frac{(1+\delta)}{(1-\delta)8}}-\frac{(1+\delta)}{4}$	$\frac{3-\delta^2-\sqrt{8(1-\delta^2)}}{8(1-\delta)}$	$\frac{1}{2}\sqrt{\frac{(1+\delta)}{(1-\delta)8}}-\frac{1+\delta}{8}$
$\delta=0.5$	0.375	0.28125	0.125	0.0625	0.1875	0.1875	0.0703	0.14063	0.2373	**0.0751**	0.11869
$\delta>\frac{3}{5}$	$\frac{(1+\delta)}{4}$	$\frac{(1+\delta)^2}{16(1-\delta)}$	$\frac{1-\delta}{4}$	$\frac{\delta}{8}$	$\frac{\delta(1+\delta)}{8(1-\delta)}$	$\frac{1-\delta}{2}$	$\frac{3\delta-1}{8}$	$\frac{(3\delta-1)(\delta+1)}{16(1-\delta)}$	$\sqrt{\frac{(1+\delta)}{(1-\delta)8}}-\frac{(1+\delta)}{4}$	$\frac{3-\delta^2-\sqrt{8(1-\delta^2)}}{8(1-\delta)}$	$\frac{1}{2}\sqrt{\frac{(1+\delta)}{(1-\delta)8}}-\frac{1+\delta}{8}$
$\delta=0.7$	0.425	0.60208	0.075	0.0875	0.49583	0.15	0.1375	0.38958	0.417	**0.204**	0.20831
$\delta>\sqrt{1/2}$	$\frac{(1+\delta)}{4}$	$\frac{(1+\delta)^2}{16(1-\delta)}$	$\frac{1-\delta}{4}$	$\frac{\delta}{8}$	$\frac{\delta(1+\delta)}{8(1-\delta)}$	$\frac{1-\delta}{2}$	$\frac{3\delta-1}{8}$	$\frac{(3\delta-1)(\delta+1)}{16(1-\delta)}$	$\frac{(1+\delta)}{4}$	$\frac{\delta^2}{8(1-\delta)}$	$\frac{\delta^2}{8(1-\delta)}$
$\delta=0.9$	0.475	2.25625	0.025	0.1125	2.1375	0.05	0.2125	2.0188	0.475	**1.0125**	1.0125

Note that, for an easier comparison with the figures in the first two columns, in cases a), b) and c) the cost of capacity is included in the computation of the incumbent's profit.

Rewriting (4) and replacing for the incumbent's capacity level, we have:

$$k_E \geq 1-\sqrt{\frac{3-\delta^2+2\delta}{4}} \quad (4)$$

$$k_E \leq \frac{1+\delta}{4} \quad (vi)$$

In this case, the size of capacity is relevant enough to generate a relatively low Bertrand profit. The low continuation profit reduces the temptations to deviate, thereby increasing the prospects of an effective cartel enforcement. Clearly, however, the chances to support a collusive equilibrium depend on the discount factor, which has to be sufficiently high. From the standard collusive individual rationality constraint, one for *E* and one for *I*:

$$\frac{S_E \pi_E^{mon}}{1-\delta} \geq \pi^{mon} + \frac{\delta}{1-\delta} E\left(\pi_E^{bertrand}\right) \ (5a)$$

$$\frac{S_I \pi_I^{mon}}{1-\delta} \geq \pi^{mon} + \frac{\delta}{1-\delta} E\left(\pi_I^{bertrand}\right) \ (5b)$$

Aggregating 5a) and 5b), we derive condition 6):

$$\frac{1-\delta}{\delta} < \frac{2\left(\frac{1+\delta}{4}+k_E\right)\left(\sqrt{k_E(2-k_E)}\right)}{2\left(\frac{1+\delta}{4}+k_E\right)-1} - 1 \ (6)$$

We do not solve analytically for equation (6). However, we compute the maximal value of $\underline{k_E}$ compatible with a variety of given levels of discount factors.

In choosing the optimal k_E, the entrant solves the following maximization problem:

$$\max_{k_E} \frac{\left(\frac{k_E}{k_I+k_E}\right)\frac{1}{4}}{1-\delta} - \frac{k_E}{2} \ for\, k_I + k_E \geq \frac{1}{2} \quad (7)$$

under the constraint (6)[6] and under the fact that $k_I \geq k_E$

[6] Observe that, on the other hand, if $k_I + k_E \leq \frac{1}{2}$, $k_E = \frac{1}{2} - k_I$.

Equation (7) specifies that the collusive profit is given by the difference between the collusive revenue $\frac{\left(\frac{k_E}{k_I+k_E}\right)\frac{1}{4}}{1-\delta}$ and the cost $\frac{k_E}{2}$. The collusive revenue is composed of the share of the collusive output (1/2) computed according to the previously described sharing rule multiplied by the collusive price ½.

Given the first order conditions, Equation (7) yields $k^*_E = \sqrt{\frac{(1+\delta)}{(1-\delta)8}} - \frac{(1+\delta)}{4}$

(7) is compatible with $k_I \geq k_E$ only for $\delta \leq \frac{\sqrt{2}}{2}$.

It follows that the optimal collusive k_E has the features indicated in Table 2.

Illustrative Example

We report here an example of all the computations for a discount factor δ=0.7. In such a case, the constraint (6) holds for $k_E < 1.1802$

The profit-maximization objective function requires:

$$\max_{k_E} \pi_E = \frac{\left(\frac{k_E}{k_E+0.425}\right)\frac{1}{4}}{1\text{-}0.7} - \frac{k_E}{2}$$

where ¼ is the total revenues of the two firms (and the collusive, i.e. monopoly, quantity in the static game is ½). At the optimum, $k_E = 0.4166$ *, corresponding to which constraints (4) and vi) hold as well.*

The profit is finally:

$\pi_E(\delta = 0.7) =$ *0.20421*

4. Results

With the help of Figures 1 and 2 and table 3, we summarize the results for the different discount factors.

For 0<δ<1/3, the non-cooperative *Bertrand* game outcome prevails.[7]

For 1/3<δ< $\sqrt{1/2}$, the *collusive* monopolistic outcome prevails, and there is an excess capacity which increases steadily with δ.

For δ> $\sqrt{1/2}$, the constraint *vi)* is binding, and $k_E=k_I$. Even in this case, collusion prevails.

Table 3: The equilibrium outcome for the various discount factors

	k_I^*	k_E^*	π_I	π_E^*	P	Q
$\delta=0$	0.25	0.125	0.03125	0.015625	0.625	0.375
$\delta=0.3$	0.325	0.1625	0.0754	0.0377	0.5125	0.4875
$\delta=0.4$	0.35	0.1901	0.0950	0.051605	0.5	0.5
$\delta=0.7$	0.425	0.417	0.20831	0.204	0.5	0.5
$\delta=0.9$	0.475	0.475	1.0125	1.0125	0.5	0.5

The graphs illustrate the above reasoning. Figure 1 compares case a), where the aggregate capacity is below ½, and case b), which is associated with a higher aggregate capacity. As it is shown, the entrant's profits in case b) bypass profits in case a) for δ >1/3. Figure 2 compares the "competitive" case, by taking, for each δ, the highest profit value between cases a) and b), versus the collusive one. For δ >1/3 collusion prevails.

The corresponding aggregate quantities Q and prices are, for case a), $Q = \frac{3(1+\delta)}{8}$ and $p = \frac{5-3\delta}{8}$, and, in the collusive case, Q = 1/2 and p=1/2, respectively.

[7] Notice that, for δ=0.3, the collusive monopolistic outcome would imply an (incompatible) aggregate capacity below ½, so that case b) coincides with case c), $k_I* = 0.325$ and $k_E* = 0.175$, and $\pi_E*(\delta = 0.3) = 0.0375$. This happens until δ=1/3.

Figure 1: Cases a) and b): Entrants' profits for different discount factors

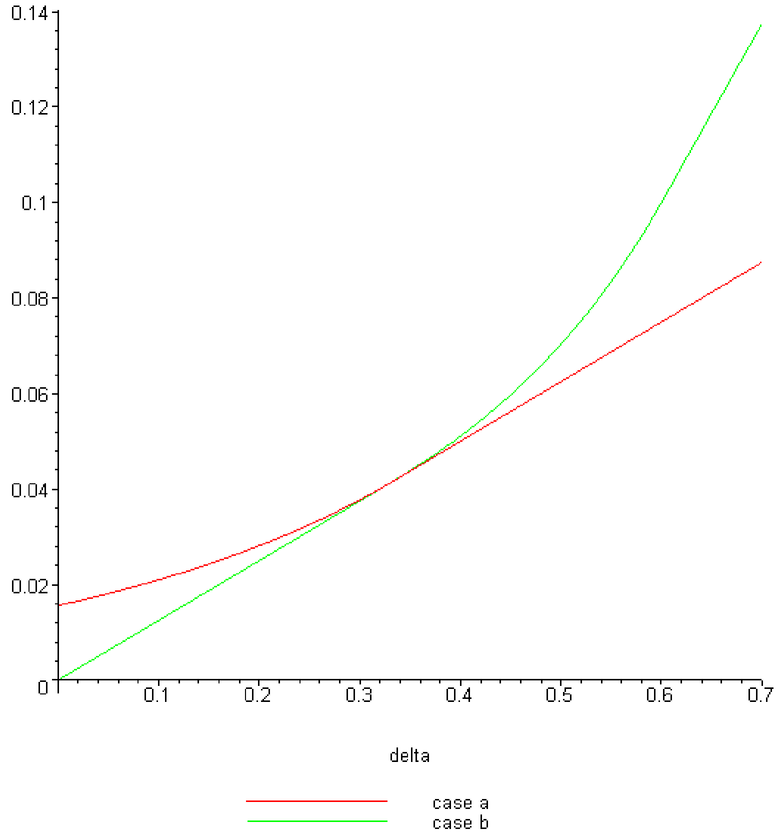
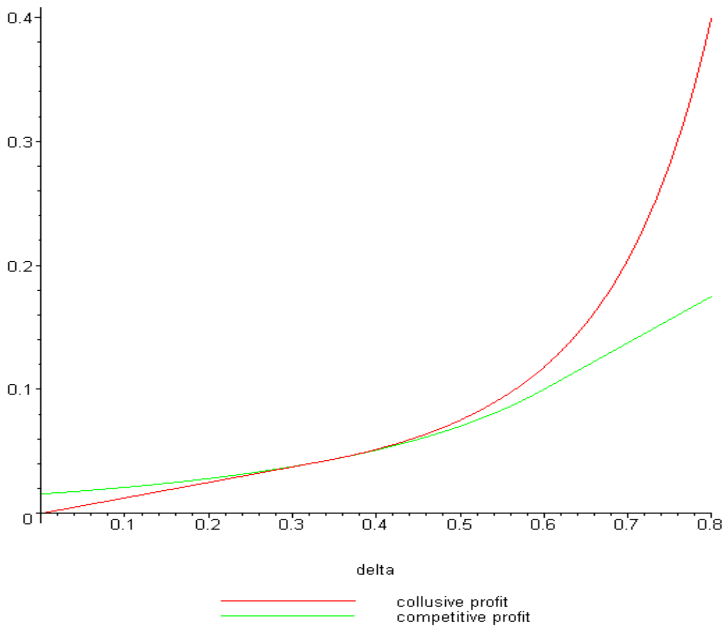


Figure 2: Competition versus collusion (case c): Entrants' profits for different discount factors



5. Conclusions

In the model developed in this paper, both the incumbent is better off and efficiency is enhanced when the new entrant enters with a small capacity, or when he doesn't enter at all. That is because, whatever the aggregate capacity in this framework is, the involved players manage to coordinate on the monopoly outcome. Hence, the market outcome is invariant to the market structure. However, when entry does not occur, there is an efficiency saving, in that fixed cost are not duplicated; when entry occurs on a small capacity, the efficiency saving is in the form of lower (costly) capacity investment. The consideration of a capacity cost is the major difference (and hence our contribution) with respect to Sorgard's (1995) paper.

An interesting result is that both blockaded entry, and entry with small capacity, occur when the Antitrust Authority enforces a competitive behavior, which is also improving the position of the incumbent. This can bear some implications on the variables that an Antitrust Authority should observe in deciding on the competitiveness of a behavior. For example, forcing the firms to use to a great extent (if not fully) their capacities would help to avoid collusion. Moreover, it could be interesting to examine the case in which the incumbent is forced to give a share of his capacity to the entrant, since both pro-collusive forces and pro-competitive forces are at stake.

This paper could be fruitfully extended in two directions. First, one might analyze a sequential capacity choice game, followed by dynamic Cournot competition. A second interesting addition might consist in considering alternative capacity choices by the incumbent, so as, for example, to be able to deal with cases in which regulation imposes higher production than the one considered in section 3.1. Our preliminary intuition is that, as I's capacity gets larger, a collusive behavior gets more likely.

References

Benoit, J.P, and V. Krishna “Dynamic duopoly: Prices and Quantities”, *Review of Economic Studies* 54, 1987, pp. 32-35.

Benoit, J.P, and V. Krishna “Entry Deterrence and Dynamic Competition: the Role of Capacity Reconsidered”, *International Journal of Industrial Organization,* 9, 1991, pp. 477-495.

Boffa F., Pingali V., Vannoni D. “Increasing Market Interconnection: An Analysis of the Italian Electricity Spot Market”, *International Journal of Industrial Organization*, 2010, forthcoming.

Brander J.A. and R. Harris “Anticipated Collusion and Excess Capacity”, *working paper 530*, 1984, Queen's University, Department of Economics.

Brock, W. and J. Scheinkman “Price Setting Supergames with Capacity Constraints”, *Review of Economic Studies*, 52, 1985, pp. 371-382.

Davidson, C. and R. Deneckere “Excess Capacity and Collusion”, *International Economic Review,* 31, 1990, pp. 521-541

Dixit, A. “The Role of Investment in Entry Deterrence”, *Economic Journal*, 90, 1989, pp. 95-106

Dragan G. “Supporting Collusion with Insufficient Capacity”, *mimeo*, 2004, Deparment of Economics, University of Winnipeg.

Guzman J.I. and J.P. Montero “Eleccion de Capacidad y Collusion en Mercados Oligopolicos à la Cournot”, *mimeo*, 2004, Pontificia Universidad Catolica de Chile.

Ivaldi, M., Jullien B., Rey, P., Seabright, P., Tirole, J. “*The Economics of Tacit Collusion*”, 2003, March, Final Report for DG Competition, European Commission.

Kreps, D. and J. Scheinkman “Cournot Pre-Commitment and Bertrand Competition Yields Cournot Outcome”, *Bell Journal of Economics,* 14, 1983, 326-337

Motta, M. “*Competition Policy. Theory and Practice*”, 2004, Cambridge University Press.

Sorgard, L. “Judo Economics Reconsidered: Capacity Limitation, Entry and Collusion”, *International Journal of Industrial Organization*, 15, 1995, pp. 349-368

Spence, A.M. “Entry, Capacity, Investment and Oligopolistic Pricing”, *Bell Journal of Economics* 8, 1977, pp. 534-544

Appendix

Having the paper examined the optimal capacity choice for the new entrant, assuming *E* finds entry profitable, it is straightforward to analyze the case of blockaded entry. We therefore explicitly consider the fixed cost *F*, and analyze, for the various discount factors, the thresholds of fixed cost above which entry is blockaded. The latter are reported in the following Table A1:

Table A1: Blockaded Entry

Discount factor	Fixed cost above which entry is blockaded
$\delta = 0.3$	$F \geq 0.0377$
$\delta \leq \frac{1}{3}$	$F \geq \frac{(1+\delta)^2}{64(1-\delta)}$
$\frac{1}{3} \leq \delta \leq \frac{\sqrt{2}}{2}$	$F \geq \frac{3-\delta^2-\sqrt{8(1-\delta^2)}}{8(1-\delta)}$
$\delta = 0.4$	$F \geq 0.0516$
$\delta = 0.5$	$F \geq 0.0751$
$\delta = 0.7$	$F \geq 0.204$
$\delta \geq \frac{\sqrt{2}}{2}$	$F \geq \frac{\delta^2}{8(1-\delta)}$
$\delta = 0.9$	$F \geq 1.0125$

Observe that the fixed costs correspond to the maximum profit achievable by the potential entrant, as a function of the various discount factors. As previously mentioned, such profits correspond to the non-cooperative Bertrand profits for $\delta \leq \frac{1}{3}$, and to the collusive profits otherwise.