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Conflicting Strategies in Entry Deterrence under Demand Variability. The case of electricity markets

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Abstract

We analyse complexity of strategies of entry deterrence in electricity markets by reference to literature on competition on oligopolistic markets with demand variability. The incumbent firms choose their capacity before entry takes place, and then choose their production. Hence there is a potential conflict between short term incentive to raise prices and long term entry deterrence. We first analyse under which conditions entry can be deterred while incumbents earn positive profit. Without any scale economies, entry can be deterred only if the potential entrant is less efficient than incumbents. But, we establish that even if the entrant is less efficient, there are situations where no capacity level deters entry. And, even if such quantity exists, there is no guarantee that incumbents earn positive profits if choosing this capacity level.

However if the incumbents commit themselves in forward contracts, they decrease their incentives to short term market power exercise. Forward markets increase their ability to deter entry with inefficient technology. Therefore the efficiency of the market could be increased.

Contrary to the certainty case, the number of incumbents influences their ability of entry deterrence. We analyse the welfare effect of different degrees of concentration of oligopoly and we state that consumers' welfare net of short term cost is worst in situation in which the number of incumbents is increased. The long-term effects are ambiguous.

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1. Introduction

The aim of this paper is to analyse entry and incumbency advantage in a homogenous good market with variable and uncertain demand. It is motivated by the current situations of wholesale electricity markets which are highly concentrated in many countries despite their assumed contestability. The particularities of electricity, a non storable product with a highly variable demand, add an important element in the analysis of oligopolistic strategies on a mono-product market, because they oblige the producers to develop different generation technologies of specific ratio fixed costs/variable costs and to compete on the basis of their technology mix.

The decrease of entry barriers in generation helped by the characters of a new generation technology of combined-cycle gas turbine (CCGT) -- absence of scale economies, low capital intensiveness and divisibility -- was one of the arguments pro-liberalisation of the sector. This technology can compete ex ante with more capital intensive technologies (coal plant, nuclear plant) which are developed by incumbents, even if it is the least efficient in long term perspective. The reason is its adaptability for semi-base load production and its key role in the price making on the hourly markets, given the marginal position of CCGT offers on the hourly markets during the major part of the year, given their high variable cost.

Theoretically the energy-only market (the spot market of electricity) is the only ingredient needed to ensure an efficient coordination of production and investment decisions in a decentralised electricity industry[1] (cf. Schweppe and *al.,* 1988). If consumers are price sensitive and producers are price takers, wholesale markets are efficient in the short and long runs. Forward and contingent markets are useless if firms are risk neutral and information shared. Usually, the assumption of price-taker behaviour is justified by the small size of firms. Otherwise, on a concentrated market, firms are assumed to behave strategically exercising their market power to raise prices. Any large firm has an incentive to limit its production and capacity in order to increase market prices and its profit; so it is in the long run perspective by restriction of investment in generation as long as higher price do not attract entries. Therefore, the observed concentration of national and regional electricity markets in Europe is a subject of concern about markets efficiency, as shows the worry of the European Commission's antitrust division (DG Competition, 2007).

Short term and long term aspects of market power exercise which are respectively related to choices of production and capacity development have been extensively analysed in the generalist literature[2]. Most of the literature on electricity markets have analysed the exercise of short term market power within various specific market design and modelling assumptions. For example Green and Newbery (1992) analyse supply functions equilibria with capacity constraints whereas von der Fehr and Harbord (1993) analyse discrete auctions with capacity constraints. The long term dimension of market power has received a growing attention only

[1] The characteristics of electricity generation and transport imply that several ancillary markets or mechanisms are needed (cf Wilson 2002, Stoft 2002). These are not considered in the present paper; we assume that consumers are price sensitive and the demand is known when quantities are chosen.

[2] This has been extensively analysed from the Cournot' s seminal work who establishes that if firms take into account the influence of their production on the price they have an incentive to reduce their production compared to the competitive – optimal – quantity.

recently, despite its relevance to analyse electricity markets competition. The long term dimension of market power is related to the choice of capacity, related or not to the possibility of forward sales.

The simultaneous choice of capacity by a duopoly of producers with demand uncertainty and short term competition *à la Cournot* was analysed by Gabsewicz and Poddar (1997). They establish that the introduction of uncertainty incites to increase capacities by comparison to a situation of certainty. Murphy and Smeers (2005) analyse the case of asymmetric firms and compare open and closed loop dynamic equilibria. Open loop equilibrium describes a situation where electricity production is sold on a forward market simultaneously with investment decision, while closed loop separates investment and sales decisions. They establish that the closed loop game – spot market sales - is more efficient that the open loop one – forward sales - because of the strategic effect of investments decisions on quantities produced. This result is close to those of the Allaz and Villa's analysis (1993) of the impact of forward markets on the competition. They establish that a forward market prior spot competition *à la Cournot* increases competition and welfare. Grimm and Zoetl (2005) analysed a three-stage game with investment prior forward sales prior production and establish that the introduction of a forward market decreases the capacity at the equilibrium.

Despite theoretical support for suspicion against concentration and market power, it might be argued that potential entry with CCGT can discipline incumbents and ensures social efficiency of the market.[3] But, on the short run, there is still an incentive for them to drive prices above variable costs and to use available capacity in their technology mix in an inefficient way. In this logic incumbents can let entries to occur with a less efficient technology. This short term incentive to use market power seems hardly compatible with entry deterrence. Recent experiences of entries in Europe on some of the highly concentrated electricity markets with high prices suggest that incumbents could have an interest in maintaining high prices and to let small independent producers-suppliers to build CCGT plants before they decide to invest in new generation capacities in coal plants and nuclear plants[4].

Despite the role played by market contestability on the justification of deregulation process there are few analyses of entry deterrence on electricity markets. To our knowledge the only contribution is Newbery's (1998). He analyses how incumbents with given capacities can coordinate on a supply function equilibrium to set the forward price, i.e. the average spot price, at the level of the long run marginal cost of new capacity. He establishes that a lack of capacity could prevent incumbents from deterring entry. But he analyses neither the choice of capacity nor the influence of such a strategy on incumbents' profits. Even so, if entrants and incumbents have similar linear cost structures, it is not possible to earn positive profits while maintaining the average spot price at the long term marginal cost.

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[3] It is the position of EDF economists presented by Bouttes and Trochet, (2003).

[4] It is the case in Germany with the investment of independent (a CCGT of 2x400MW of Trianel in Nordrhein-Wesfalen, a CCGT of 400MW of the Norwegian Statkraft in Dortmund, a CCGT of 2x400MW of Saalfald grtoup and Gazprom in Lubmin) besides the oligopoly of E.ON and RWE; in France with the investments of the independent supplier Poweo allied with the Austrian company Verbund (CCGT of 400 MW in Le Havre) and the Swiss company ATEL (CCGT of 400MW in Allier district) besides the oligopoly of EDF and Suez-Electrabel; and in Spain the investment of Electrabel of a CCGT of 760 MW in Aragon, besides the oligopoly of Endesa, Iberdrola and Fenosa.

In the present paper we analyse whether an oligopoly of incumbents can commit to a level of capacity that deters entry by a competitive fringe while earning positive profits. The short term competition is modelled *à la Cournot* with a competitive fringe and capacity constraints[5]. Therefore, the commitment ability of incumbents is contradicted by their short term incentive to restrict production and raise prices.

This work is related to the literature on capacity choice and entry deterrence, but it diverges by the representation of the incentive of short term market power. From the seminal works of Spence (1977) and Dixit (1979, 1980) numerous contributions have analysed the strategic value of investment using dynamic games with a leader and a follower. In these "commitment games", sunk investment are used by incumbents to influence the outcome of subsequent competition. The introduction of demand uncertainty slightly modifies the situation. With uncertainty the capacity constraint is not binding in all states and therefore the commitment ability of incumbents is softened. This is emphasized by Maskin (1999) who establishes that entry deterrence requires more capacity and is less attractive when introducing uncertainty.

Usually representation of scale economies is needed to explain that entry could be profitably deterred. Usual modelling assumptions are either the presence of fixed cost in the production function, or the existence of a plant's minimum scale. Here we do not assume any scale economies but we assume that incumbents and entrants have specific linear cost structures in order to represent the contestability of the market. A cost structure is defined by a couple of variable and capacity costs. Within that framework entry is deterred if the average price is below the average long term production cost of the entrant. It is clear that the entrant should be less efficient than incumbents, so that entry could be profitably deterred[6]. But, we establish that even if the entrant is less efficient, there are situations where no capacity level deters entry. And, even if such quantity exists, there is no guarantee that incumbents earn positive profits if choosing this capacity level. More precisely, we demonstrate that whatever the number of incumbents there is a positive degree of inefficiency such that entry could not be profitably deterred.

The first result is related to the short term incentive for incumbents to reduce production; we show that this incentive limits the credibility of commitment. Our analytical framework allows us to state a sufficient and necessary condition for an entry deterrent capacity to exist.

The second result is related to demand variability. In low demand states, when capacity constraints are not binding, the equilibrium price is strictly above variable cost. Hence, in order to decrease average price to deter entries on long term, incumbents have to invest in sufficient capacity to compensate their short term use of market power. Hence, their profit may be negative at the investment level that deters entry. Contrary to the certainty case, even if entry deterrence is feasible it is not profit maximising to do so.

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[5] The supply function framework used by Newbery is more realistic but less tractable. Cournot competition is sufficient to capture main aspects of short term market power.

[6] To follow up the story of entries of independent on highly concentrated markets in Europe (see above note 2), the entrants are small companies, or eventually are a subsidiary of medium-sized company. Because of their small or medium size they are obliged to finance their equipment in project financing with a higher capital cost than, the larger dominant companies which are able to finance their new equipments in corporate financing and with a large share of equity. This higher cost of capital makes their cost price of generation higher than those of the dominant firms. These ones benefit of a lower capital cost and can develop capital intensive but economically efficient and equipment in generation.

Third result concerns the introduction of a forward market. It increases the commitment ability of incumbents by suppressing incentives to short term market power, and therefore it decreases the entry deterrent capacity. With a forward market entry deterrence is always profit-maximising, and could increase efficiency.

Furthermore, we analyse the influence of concentration. Contrary to the certainty case the entry deterrence ability is influenced by the number of incumbents because of the short term intensity of competition. The entry deterrence ability is decreasing with respect to the number of firms. We analyse the evolution of welfare when the number of firms increases and entry is deterred. And we state that there are situations when an increase of the number of incumbents decreases welfare.

The paper is organized as follows. We began by the introduction of our modelling assumptions (part two), then we analyse the certainty case and the welfare improving effects of forward markets (part three) before analysing the effect of uncertainty and cost structure (part three) before the study of concentration (part four) and a linear example (part five).

2. The model

We analyse an oligopoly of *n* incumbent's producers of a homogenous good. The demand depends on a parameter $\varepsilon \in [0,1]$, homogenously distributed. The inverse demand function is $p(Q,\varepsilon), \forall \varepsilon \in [0,1]$ where Q is aggregated output. The production of the good requires productive capacity. The cost of one unit of capacity is w_1 and the variable cost is c_1: once its capacity is fixed a firm can produce at cost c_1 up to its capacity. As we analyse symmetric situations we only introduce individual capacity *k* and individual production *q*. Aggregate capacity and production are $K = nk, Q = nq$. The competitive fringe has a different technology characterized by variable cost c_2 and capacity cost w_2.

Assumption 1: There is an incentive to produce in each demand state: $\forall \varepsilon, p(0,\varepsilon) \geq c_1$ and to invest: $E(p(0,\varepsilon)) > c_1 + w_1$. The price is strictly increasing with respect to ε and so is marginal revenue $p + p_q q$.

Assumption 2: The inverse demand function is assumed positive, twice differentiable and strictly decreasing with respect to *Q* when positive. And when *p* is positive it satisfies the usual assumption $p_q + p_{qq} q < 0$.

The last condition ensures that short term revenue is concave with respect to individual production, quantities are strategic substitutes and the slope of reaction functions is above -1. The demand state is known prior production decisions. In each state firms produce at the Cournot – Nash equilibrium. Assumptions ensure that there exists a unique Cournot-Nash equilibrium in each demand states. The individual equilibrium quantity when capacity constraint is not binding is noted $q(n,\varepsilon)$ and the aggregate capacity is $Q(n,\varepsilon)$ it satisfies the first order condition:

$$p + p_q q = c_1 \qquad (1)$$

Assumptions ensure that production is increasing with respect to both *n* and ε. Firms produce at full capacity for high demand realisations. The smaller demand state at which capacity constraint is binding is noted $a(k,n)$. For higher demand states firms produce at full capacity. The long term profit of an incumbent without entry is:

$$\pi(k,n)=\int_0^a (p-c_1)qd\varepsilon+\int_a^1 (p-c_1)kd\varepsilon-w_1k \qquad (2)$$

The price in demand state ε for n incumbents with individual capacity k is noted $p^N(k,n,\varepsilon)$ it satisfies:

$$p^N(k,n,\varepsilon)=\begin{cases} p(Q(n,\varepsilon),\varepsilon) \text{ if } \varepsilon \le \text{a} \\ p(nk,\varepsilon) \text{ if } \varepsilon \ge \text{a} \end{cases} \qquad (3)$$

The equilibrium individual capacity chosen in a dynamic game without entry - at the first stage firms choose capacity, at the second stage demand is known and firms choose productions - is noted $k^N(n)$. The aggregate capacity is $K^N=nk^N(n)$. It satisfies the following first order condition:

$$\int_a^1 p+p_qk^N-c_1d\varepsilon=w_1 \qquad (4)$$

The individual capacity $k^N(n)$ is decreasing with respect to n and the aggregate capacity is increasing with respect to *n* (cf. Meunier 2007). The usual properties of Cournot competition are transmitted to the capacity games.

And, finally we introduce the optimal capacity with the cost structure c_1,w_1 i.e. the quantity of capacity that maximises welfare in the absence of short term market power: k^*, and as usual when the number of firms grows the aggregate non-cooperative quantities tend to the first best quantities. The state at which capacity is fully used in the first best case is $a^*=\lim_{+\infty} a(k^N,n)$.

3. Commitment without uncertainty

We first briefly review the situation when demand does not vary. Hence we do not use the notation ε. In this part, we will only analyse the case of a monopoly incumbent with a competitive fringe. We assume that variable costs are similar: $c_1=c_2$ and the fringe capacity cost is above the incumbent's : $w_2 \ge w_1$. The incumbent chooses its capacity k_1 first, then the competitive fringe invests in a quantity k_2 of capacity, and at the production stage the incumbent chooses its production q_1 before the fringe produces q_2. The fringe is price taker; it invests and produces as long as the price is above its marginal cost. The last notation we need to introduce is the reaction function of an incumbent firm: $r(q_2)$.

At the production stage the incumbent chooses its production q_1 considering the reaction of the fringe. The fringe produces as long as the price is above its variable cost and its capacity constraint is not binding. Hence, either the price is $c_2=c_1$ or the fringe produces at full capacity k_2. Hence it is clear that the incumbent produces $\min\{r(k_2),k_1\}$ if $k_2 \le p^{-1}(c_1)$.

The situation is illustrated figure 1. The commitment ability of the incumbent is limited by its reaction function, on the short term he will maximizes its profit and an excessive capacity cannot be a credible threat. This is similar than the usual result with a strategic entrant (Dixit 1980). At the second stage the competitive fringe capacity $k_2^*(k_1)$ satisfies: $p(k_2^* + \min\{r(k_2^*), k_1\}) = c_2 + w_2$. It is therefore clear that the incumbent ability to deter entry is limited by its short term reaction function. Is its incentive to reduce production on the short term is too strong the incumbent is not able to credibly commit to an entry deterring production. The incumbent is able to set prices sufficiently low to deter entry if and only if: $p(r(0)) \le c_2 + w_2$.

Lemma 1: *Entry could be deterred if and only if* $p(r(0)) \le c_2 + w_2$.
If $p(r(0)) > c_2 + w_2$ *the incumbent chooses* k_1^* *such that* $p(k_1^* + r^{-1}(k_1^*)) = c_2 + w_2$, *and the fringe* $k_2^* = r^{-1}(k_1^*)$.
If $p(r(0)) \le c_2 + w_2$, *the incumbents chooses* k_1^* *that maximises* $\left(p(k_1) - c_1 - w_1\right)k_1$ *s.c.* $p(k_1) \ge c_2 + w_2$ *and the fringe do not invest.*

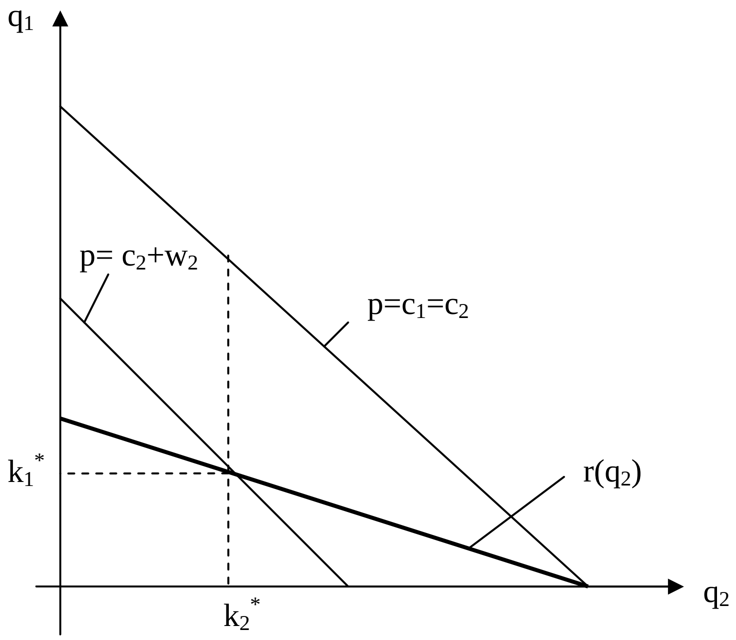

Figure 1: Entry and short term market power
The commitment ability of the incumbent is limited by its short term reaction function r

Therefore, when production decisions take place after the choice of capacities, an efficient incumbent may be unable to deter the entry of an inefficient firm even if costs are linear. If a forward market is introduce at the date of investment decisions, the commitment ability of the incumbent is increased and it is always feasible and profit maximising to prevent entry. Here we considered forward sales as in Murphy and Smeers (2005), to limit the introduction of new notations, we consider that with forward sales the quantity produced and capacity could be chosen simultaneously at the first stage.

Proposition 1:

With a forward market open at the date of capacity choice, at equilibrium the fringe does not invest ($k_e = 0$) and welfare is improved.

Welfare is improved with the introduction of a forward market for its enables the incumbent to commit its production and set $q_1 = k_1$ by forward sales. In that case, if entry is deterred[7] the incumbent chooses a production and a capacity such that $p = c_2 + w_2$. Welfare is increased because of the increase of production efficiency compared to the case without forward sales. If we used the notation of lemma 1: k_1^* is such that $p(k_1^* + r^{-1}(k_1^*)) = c_2 + w_2$ with a forward market the incumbent chooses $q_1 = k_1 = k_1^* + r^{-1}(k_1^*)$ and the efficiency gain is $r^{-1}(k_1^*)(w_2 - w_1)$.

Corollary 1:
With a linear demand $p(q) = a - bq$, entry could not be deterred without forward sales ifand only if $w_2 \le 0,5(a - c_2)$ and the welfare gain from the introduction of a forward market is: $\frac{w_2 - w_1}{b}(a - c_1 - w_2)$.

Proof:

The reaction function of the incumbent is: $r(q) = \frac{a - c_1}{2b} - \frac{q}{2}$.

The price is the long term marginal cost of the fringe at $\frac{a - (c_2 + w_2)}{b}$, entry could not be deterred if $b.r(0) \le a - (c_2 + w_2)$ i.e. $a - c_2 \ge 2w_2$. In that case the equilibrium without forward sales is k_1^* such that $b\left(k_1^* + r^{-1}(k_1^*)\right) = a - (c_2 + w_2)$ i.e. $k_1^* = \frac{w_2}{b}$ and the fringe's capacity and production are $r^{-1}(k_1^*) = \frac{1}{b}(a - c_1 - w_2)$. Therefore, the welfare gain from the introduction of a forward market is $\frac{w_2 - w_1}{b}(a - c_1 - w_2)$.

Q.E.D.

The proof is in appendix 1, the welfare gain from the introduction of a forward market is naturally increasing with respect to the cost advantage of the incumbent and decreasing with respect to the slope of the inverse demand function. This last result reflects the effect of demand elasticity on the incumbent's incentive to reduce production. When demand is very price sensitive the incumbent is more aggressive at the production stage and therefore it's ability to commit is enhanced. For a demand with low price elasticity, the incumbent incentive to raise price on the short term limits its ability to control entry of an inefficient firm, the introduction of a forward market is very valuable in that case. It is therefore true that forward sales limit competition but in an efficient way: potential entry is welfare improving but entry is not.

[7] The other possibility is that the monopoly profit maximising capacity and production $\arg\max\left(p - c_1 - w_1\right)k_1$ prevents entry, in that case entry is blockaded in Bain's (1956) typology.

4. Demand uncertainty and cost structure

The capacity of incumbents is fixed and the entrant has to decide how much capacity to build. In this section we do not analyse the exact amount of capacity chosen by the fringe but only the ability of incumbents to deter entry. Whether the entrant is a Cournot player or a competitive fringe the entry condition is the same:

$$\int_0^1 \left(p^N(k,n,\varepsilon) - c_2 \right)^+ d\varepsilon > w_2 \qquad (5)$$

Where $\left(p - c_2 \right)^+ = \max\left\{ p - c_2, 0 \right\}$, entry occurs if the average difference between price and variable cost is above the capacity cost. This ensures that an infinitesimal amount of capacity is profitable. If this condition is not satisfied, there is no quantity of capacity that could increase average price because even if incumbent's decrease their production when a new capacity is installed, it does not fully compensate the entrant production (for the slope of reaction function is above -1) and the overall production increases.

The important point is that an entrant who chooses a small amount of capacity will use it in all demand states and therefore the sign of the profit does not depend upon this amount. For incumbent to be able to deter entry they should be able to drive the price sufficiently low, a sufficient condition is therefore that condition (6) is satisfied when incumbents' capacities are never binding.

Lemma 2:
There is a quantity of capacity that deters entry if and only if

$$\int_0^1 \left(p(Q(n,\varepsilon),\varepsilon) - c_2 \right)^+ d\varepsilon > w_2 \qquad (6)$$

This result is similar to lemma 1 when uncertainty is introduced. If the condition holds, incumbents can invest in an amount of capacity that deters entry despite the use of short term market power. But, it is not clear that they can do so while earning non negative profits. For it to be the case, the following condition must hold:

$$\int_0^a \left(p - c_1 \right) q(n,\varepsilon) d\varepsilon + \int_a^1 \left(p - c_1 \right) k d\varepsilon \geq w_1 k \qquad (7)$$

Relations (6) and (7) should be satisfied for incumbent firms to be able to deter entry while earning positive profits. If the long term marginal cost of entrants is equal to the one of incumbents: $c_2 + w_2 = c_1 + w_1$ whatever the repartition between variable and sunk cost entry is profitable as long as incumbents earn strictly positive profits. Actually, because of their inability to commit to a short term production schedule it is even possible for an inefficient entrant to produce whatever the choice of capacity satisfying(7). For the rest of this section we assume that demand varies sufficiently so that the capacities constraints of incumbents are not binding in all demand states. For that to be the case, it should be true for the monopoly case.

Assumption 3: $p\left(k^N(1), 0\right) \leq c_1$ the monopoly capacity without entry is not fully used in the lowest demand state.

Proposition 1:

For all n there exist $\delta > 0$, such that if $c_2 + w_2 \leq w_1 + c_1 + \delta$ there is no capacity k that satisfies (6) and (7). Incumbents are not able to deter the entry of a less efficient firm while earning positive profits.

<u>Proof:</u>

For any capacity *k*, the profit of an incumbent firm could be written:

$$\pi(n,k) = \left[\int_0^1 (p - c_1)\, d\varepsilon - w_1\right] k - \int_0^a \underbrace{(p - c_1)}_{>0} \underbrace{(k - q)}_{>0} d\varepsilon \tag{8}$$

The second term is strictly positive if *a>0* because of the use of short term market power $p > c_1$ and because the capacity constraint is not binding: $k > q$. If *a=0,* then $k < k^N$(1) (because of assumption 3), the average price is above the monopoly average price and therefore $\int_0^1 (p - c_1)\, d\varepsilon - w_1 > 0$. Hence, for any capacity k that satisfies property (7) the average price is strictly above the long term marginal cost.

The minimum difference: $\delta = \min\left\{ \int_0^1 (p - c_1)\, d\varepsilon - w_1 \middle/ \pi(k,n) \geq 0 \right\}$ is strictly positive (for π is continuous and k is in the compact set $[0, q(n,1)]$) and satisfies the condition of the proposition.

Q.E.D.

The fact that incumbents do not produce at full capacity in low demand states while maintaining the price above their short term marginal cost prevent them from deterring inefficient entry. It is the combination of the two features: short term market power and demand variation that explain this situation. In that case it is clear that incumbents should allow the entry of some inefficient firms. Contrary to the certainty case, even if there is a quantity of capacity that deters entry i.e. if relation (6) is satisfied, there are situations where entry will not be deterred by incumbents. The welfare implications are not obvious, for inefficient entry could increases production cost while increasing consumers surplus. If incumbents could commit to a more aggressive behaviour in low demand states entry deterrence would be easier. For example the introduction of forward contracts could modify the situation by increasing the commitment ability of incumbents. But for incumbent to deter any inefficient firm the set of forward (and contingent) contracts should be complete, at least for low demand states when capacity constraint is not binding. If there is only one type of contract available on the forward market the entry of some inefficient firms would still be possible for some range of parameters. As capacity constraints are binding for high demand states, forward contracts are not needed to bind production in these states. Forward contract are needed to commit production in low demand states. As in previous section we do not modelled forward contracts and competition explicitly and consider that a forward market allows setting production and capacity simultaneously at the first stage. The introduction of forward market *à la* Allaz and Villa (1993) would yield similar results.

Corollary 1:

If there is a complete forward market open at the date of capacity choice any entry with $c_2 \leq c_1$ and $c_2 + w_2 \geq c_1 + w_1$ could be deterred for any concentration of the industry.

The use of forward contracts allows incumbents to commit their production and therefore decrease the attractiveness of entry. It should be noticed that forward contracts are useful for incumbents because of short term market power. If short term competition were efficient commitment will not be necessary for low demand states.

A second point that deserves some attention is the role of variable cost. For capacities are not use in all states, to maintain the long term marginal cost constant while modifying the respective share of sunk and variable cost has a direct influence on the overall cost of production. It is more efficient to have a high variable cost and a low capacity cost, hence if the entrant's technology has a higher variable cost, even if its long term marginal cost is greater than incumbent's one, entry could not be profitably deterred.

Lemma 3:
If $c_2 > c_1$, there exist δ such that if $c_2 + w_2 \le c_1 + w_1 + \delta$ entry could not be profitably deterred for any n.

Proof:
The proof is straightforward and only need the usual analysis of technology development under demand variability. First the most aggressive commitment of incumbents is to choose k^* capacity and set the price at their marginal cost in low demand states i.e. to mimick the first best situation. In that case, $E\left(p-c_1\right) = E\left(p-c_1\right)^+ = w_1$ and the price equals c_1 in states where capacity constraints are not binding $\varepsilon \le a^*$. Let b be the state at which the price equals c_2: $p\left(k^*, b\right) = c_2$. Hence, the long term marginal cost is $w_1 + c_1 = Ep = \int_0^b p d\varepsilon + \int_b^1 p d\varepsilon$ and $\delta = \int_0^b \left(c_2 - p(k^*, \varepsilon)\right) d\varepsilon$ satisfies the property of the lemma. Let $w_2 > 0$ such that $c_2 + w_2 \le c_1 + w_1 + \delta$, then: $E\left(p - c_2\right)^+ = \int_b^1 p - c_2 d\varepsilon = \left(w_1 + c_1 - \delta\right) - c_2 \ge w_2$.

Q.E.D.

This result emphasizes the value of flexibility for an entrant, entry is easier when more cost are variable and less cost sunk even if there are some strategic advantage to have a lower variable cost. Actually this result is quite natural for the entrant's technology is not really less efficient than incumbent's. It stresses that long term marginal cost is not the sufficient measure of the efficiency of a technology when demand is uncertain or time varying. In that case, flexibility, represented by the relative shares of variable and sunk cost, has a value that should be considered when comparing two technologies.

4. Concentration and welfare

This section analyses the effect of concentration on the entry deterring capacity. And we derive the welfare implications of an increase of the number of symmetric entry deterrent incumbents. In order to do so, we have to consider situations where entry is blockaded. Entry is blockaded if the non cooperative capacity $K^N = nk^N(n)$ satisfies condition(5). There are therefore only two outcomes in our analyses: either entry is deterred by a capacity satisfying (5) above the non cooperative outcome K^N, or entry is blockaded i.e. the non cooperative outcome satisfies (5). We consider that cost difference is high enough so that there is always a capacity that satisfies (5) and (7): entry could be profitably deterred. We assume that variable costs are equal $c_2 = c_1$ but sunk costs are higher for entrant: there is $\delta > 0$ so that $w_2 = w_1 + \delta$.

The feature that we are interested in, is that contrary to the certainty case, the number of firms has an influence on the entry deterring capacity via the intensity of short term competition in low demand states. Let $\overline{K}(n,\delta)$ be the smallest capacity that deters entry. It satisfies the following equation:

$$w_1 + \delta = \int_0^a p\left(Q(n),\varepsilon\right) - c_1 d\varepsilon + \int_a^1 p\left(\overline{K}(n,\delta),\varepsilon\right) - c_1 d\varepsilon \tag{9}$$

Given that production in low demand states increases with respect to the number of firms the entry deterring capacity is decreasing with respect to n. We assume that expression (9) could be differentiated with respect to the number of firms in order to analyse how the entry deterring capacity changes when n increases:

$$\frac{\partial \overline{K}}{\partial n} = -\frac{\int_0^{\bar{\varepsilon}} p_q \frac{\partial Q}{\partial n} d\varepsilon}{\int_{\bar{\varepsilon}}^1 p_q d\varepsilon} \tag{10}$$

The increase of production in low demand states (the numerator) is compensated by a decrease of production in high demand states (the denominator) and therefore the entry deterring capacity decreased when the number of incumbent increases. For a *n* sufficiently high the non cooperative equilibrium capacity satisfies (5) and entry is blockaded. The evolution of capacity with respect to n is represented in figure 2. When n increases the non cooperative capacity K^N tends toward the social optimum K^*. For low number of firms, the entry deterring capacity could be higher than the social optimum as stated below.

Lemma 4:

For any n there exist δ *such that* $\overline{K}(n,\delta) > K^*$ *and* $\pi\left(\bar{k},n\right) \geq 0$

<u>Proof:</u>

For any n, short term market power implies that $\pi\left(\frac{K^*}{n},n\right) > 0$.

Hence, there exists a capacity higher than the welfare maximising one such that firms earn strictly positive profits. Let's set δ as the difference between average price and long term marginal cost for this capacity. This δ satisfies proposition 2.

Q.E.D.

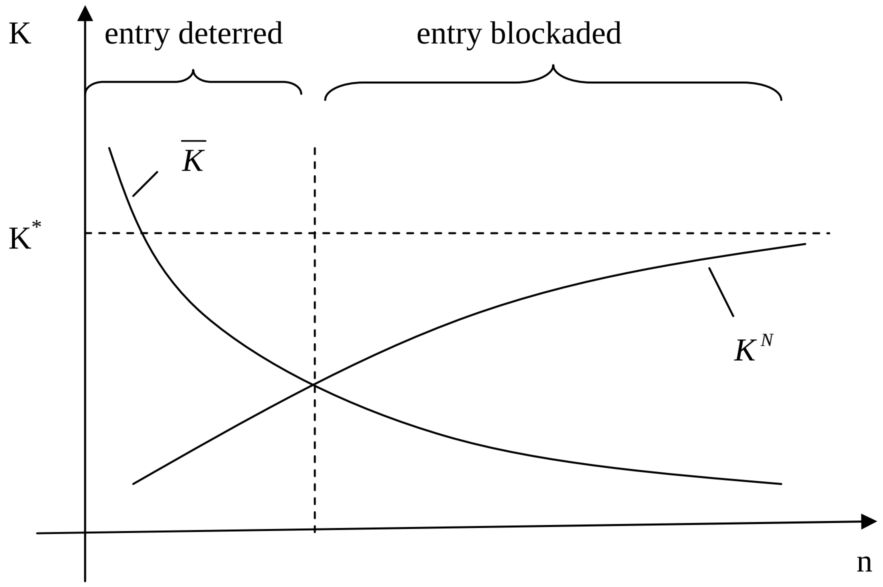

Figure 2: Evolution of capacity with respect to the number of incumbents.
For small n, incumbents choose capacity above the non cooperative level to deter entry and for high n the non cooperative blockades entry

To analyse welfare we introduce consumer surplus $S(Q,\varepsilon)$ with $S_q = p$. The long term welfare is:

$$W(n) = \int \left(S - c_1.Q\right) d\varepsilon - w_1.\overline{K}(n) \tag{11}$$

A change of the number of incumbents has an ambiguous effect because in some demand states production increases but in some others it decreases. We first separate long term and short term effect before analysing a linear example to establish that long term effect is not monotonous. The short term effect is represented by the consumer surplus net of short term production costs, the long term one integrates the investment in production capacity.

Proposition 2:
An increase of the number of incumbents decreases consumers' surplus net of short term cost

Proof:
The derivation of consumer welfare net of short term cost is:

$$\int \frac{\partial S - cQ}{\partial n} d\varepsilon = \underbrace{\int_0^a \left(p-c\right)\frac{\partial Q}{\partial n} d\varepsilon}_{>0} + \underbrace{\int_a^1 \left(p-c\right) d\varepsilon \frac{\partial \overline{K}}{\partial n}}_{<0} \tag{12}$$

Therefore $\operatorname{sgn}\dfrac{\partial E\left[S-cQ\right]}{\partial n} = \operatorname{sgn}\left[-\dfrac{\int_0^{\bar{\varepsilon}}\left(p-c\right)\frac{\partial Q}{\partial n}d\varepsilon}{\int_0^{\bar{\varepsilon}} p_q \frac{\partial Q}{\partial n} d\varepsilon} + \dfrac{\int_{\bar{\varepsilon}}^1 \left(p-c\right) d\varepsilon}{\int_{\bar{\varepsilon}}^1 p_q d\varepsilon}\right]$ and using the fact that

$p - c = -p_q q \leq -p_q k$ in low demand states and $p - c \geq -p_q k$ in high demand states the sign of the right hand side is negative.

Q.E.D.

In high demand states there is a higher loss than in low demand states because of capacity constraint and despite the use of market power. The change in capacity expressed by (10) implies that prices effects are compensated, the overall effect on short term surplus is negative. It should be noticed that it is true as long as entry is deterred, if firms play the non cooperative game, (short term and long term) welfare increases with respect to the number of firms.

The long term effect of an increase of the number of firm is ambiguous because the positive effect mentioned above is partly compensated by the decrease of the long term cost $w_1\overline{K}(n)$. The derivation of welfare with respect to n is:

$$\frac{\partial W}{\partial n}=\int_0^a (p-c_1)\frac{\partial Q}{\partial n}d\varepsilon+\left[\int_a^1 (p-c_1)d\varepsilon-w_1\right]\frac{\partial \overline{K}}{\partial n} \tag{13}$$

If the second term is sufficiently important it could dominate the positive effect. Actually, from the proof of proposition 3, it is easily seen that if n is greater than $\overline{n}$ the long term welfare is strictly decreasing as n increases and firms choose the entry deterring capacity $\overline{K}$. And if we assume that the welfare is continuous with respect to the number of firms, there are n slightly below $\overline{n}$ such that even long term welfare is decreasing with respect to the number of firms. It should be mentioned, that entry deterrence is not equilibrium of non cooperative game in our setting. We analyse how welfare evolves along a pass of capacity and production that deters entry to stress that when uncertainty or variability is introduced the average price is not sufficient to determine welfare. For a constant average price, the repartition of production among the different demand states is relevant. And in our setting an increase of the number firms modifies this repartition in a way that could be welfare decreasing.

We conclude by a short analysis of a linear situation with two states. Marginal cost are normalized at zero, there are two equiprobable demand states with linear demand and additive uncertainty: $\varepsilon\in\{0,1\}$ and $p(Q,\varepsilon)=a+\varepsilon-Q$. The unconstrained Cournot aggregate output and prices are:

$$Q(n,\varepsilon)=\frac{n}{n+1}(a+\varepsilon) \text{ and } p(Q(n,\varepsilon),\varepsilon)=\frac{a+\varepsilon}{n+1}$$

The marginal cost of capacity should be low enough for capacity to be only used in high demand state: $w<\frac{1}{2}$, and sufficiently high to ensure that there exist entry deterring capacities: $\sum_{\varepsilon}\frac{1}{2}p\le w$. The former relation is equivalent to $a+\frac{1}{2}\le(n+1)w$.

The non-cooperative outcome is $K^N=\frac{n}{n+1}(a+1-2w)$ and the entry deterring capacity satisfies: $2(w+\delta)=\frac{a}{n+1}+\left(a+1-\overline{K}\right)$, hence $\overline{K}(n)=(a+1)+\frac{a}{n+1}-2(w+\delta)$.

Therefore, $\overline{K}(n)\ge K^N$ if and only if $a+\frac{1}{2}\ge w+(n+1)\delta$, the cost difference $(n+1)\delta$ has to be sufficiently small for that to be the case.

For small n this last inequality is satisfied and the influence of a change in n on $\overline{K}(n)$ is similar to its influence on $Q(n,0)$: $\frac{\partial \overline{K}}{\partial n} = -\frac{a}{(n+1)^2} = -\frac{\partial Q(n,0)}{\partial n}$. This greatly simplifies above calculations. Using expression(13), the sign of the long term effect of a change of the number of firms is the sign of $p(Q(n,0),0)-\delta$ which is negative if and only if $(n+1)\delta \geq a$. Therefore, when n increases the long term welfare is increasing for small n then there is a set where welfare decreases up to the point where entry is blockaded.

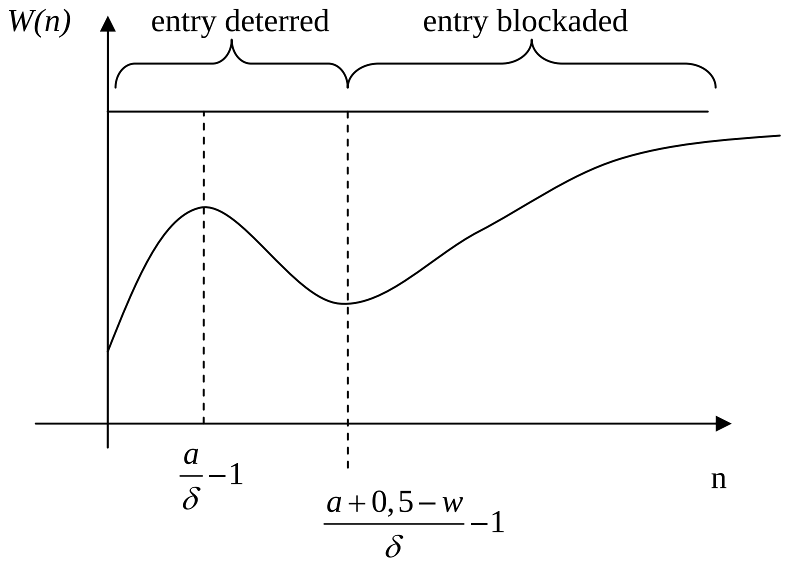

Figure 3: Welfare evolution with respect to n in a linear two states framework. When entry is deterred welfare could be decreasing with respect to n

5. Conclusion

Research works of game theory applied to market power on power markets do not take into account the entry possibilities. The threat of entry might discipline incumbents and softened the exercise of market power. In most analysis, firms are either price takers or strategic but without entry threat. The conclusion of all complex multi-stage models *à la Cournot* draw conclusions always in the same direction, with players controlling price up to very high levels and reducing capacities, which are far from the real world. To analyse the effects of concentration without taking into account entry threat is not satisfying.

This paper aims to complete the Newbery(1998)'s analysis of entry deterrence on power markets, with entry possibility acting as a threat. We analyse entry deterrence of an oligopoly of producers in a contestable market with uncertain demand. Entry deterrence is possible only if the entrant is less efficient than incumbents, but the reverse is not always true. We establish that first, there is not always a quantity of capacity that deters inefficient entrants and second, even if this quantity exists incumbents may not be able to get strictly positive by deterring entry. This is due to the lack of commitment ability of incumbents, which have incentives to raises prices on the short term, and this phenomenon is exacerbated by demand variability.

The introduction of a forward market increases the commitment ability of incumbents and could therefore increases welfare by increasing production efficiency.

Furthermore, with demand variability the number of incumbents influences the entry deterrence ability of the incumbent oligopoly. When the number of firms increases, competition is fiercer in low demand states and price lower. Hence, the entry deterring capacity decreases with respect to the number of firms.

For situation of entry deterrence, the evolution of welfare with respect to the number of firms is ambiguous. The consumers' surplus net of short term costs is decreasing, but this decrease is compensated by the decrease of long term capacity costs. We established in linear framework that welfare could be decreasing with respect to the number of firms in some situations.

The main drawback of our analysis is that we do not rationalize the entry deterrence by incumbents but only analyse whether it is possible or not to deter entry while earning positive profits. Our results suggest that, in many cases, entry deterrence is not profit maximising for incumbents when demand variability is introduced. The introduction of forward markets enables incumbents to commit their production and deter entry. Furthermore when a forward market is introduced, entry deterrence could be rationalised. Further analysis should be done on the relationship between market power, entry and market completeness to understand the long term efficiency of electricity markets and implications of the concentrations observed.

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