

Virtual Capacity and Competition

Christian Schultz[†]

Revised July 2009

Abstract

In several European merger cases competition authorities have required that the merging firm auctions off virtual capacity. The buyer of virtual capacity receives an option to buy an amount of output at a pre-specified price, typically equal to marginal cost. This output is sold in the market in competition with the merging firm.

We consider the case where contracts for virtual capacity with limited duration is sold repeatedly. It is shown that the merging firm, through the auction for virtual capacity, can extract the rent the virtual producer captures in the market and that there is a sequential equilibrium to the infinitely repeated game where the monopoly outcome results even though the virtual producers do not participate in tacit collusion.

Keywords: Virtual Capacity, Reputation, Tacit Collusion, Antitrust, Mergers, Competition Policy

JEL: L40, L41, D44

1 Introduction

It is common in merger cases that competition authorities require dominant firms to sell off capacity, so that their market shares do not grow (too much). Recently, several European electricity merger cases have resulted in the sale

*Department of Economics, University of Copenhagen, Studiestraede 6, DK 1455 Copenhagen K. e-mail: cs@econ.ku.dk, web: www.econ.ku.dk/cschultz, phone +4535323039

[†]I benefitted from comments from Svend Albæk, Kai-Uwe Kühn, Thomas Rønde, as well as seminar participants in Copenhagen and Reykjavik.

of virtual capacity in the form of so called Virtual Power Plants (VPP). The efficiency of VPP's to promote competitive outcomes has been a worry in several cases, see e.g. Glachant and Frion (2005), Barclays Capital (2005), and Energy Policy (2005) as well as the discussion below. The aim of this paper is to investigate the competitive effects of VPP's. In particular, we will be interested in the possibility of sustaining monopoly outcomes in the long run. Tacit collusion - or coordinated interaction - is a major worry in merger cases; see for instance the horizontal merger guidelines published by Department of Justice (1997) and the European Union (2004). As will become clear, in the case of Virtual Power Plants, prudent behavior by the incumbent, merging firm, can give monopoly outcomes even though the buyers of virtual capacity behave shortsighted and do not participate directly in tacit collusion.

Virtual capacity is by definition an option to buy (up to) a given amount output from the producer at a predetermined price per unit (typically equal to marginal cost), which the buyer then sells in the final product market in competition with the producer.

Virtual capacity is typically sold in auctions and the recipient of the auction revenue is the large merging firm - the incumbent. If the auction is competitive, the price for the virtual capacity will equal the expected profit - less perhaps a risk premium - from having access to the capacity. So, although the incumbent meets competition in the market from the virtual competitors, the incumbent extracts, through the auction, the rents the virtual competitors capture. This makes the incumbent internalize the industry profit under the virtual competition and, as will be shown, it enables him to sustain monopoly outcomes in the long run.

The paper provides a simple model of a market with one producing firm. The producing firm first auctions off virtual capacity and then it competes with the virtual producer(s) in the market. In a static market, the competitive effects of introducing virtual capacity are of a similar nature as those induced by a physical divestiture, where an independent producer acquires some of the incumbent's capital. The reason is simple. Once the auction for virtual capacity is held, the payment in the auction is sunk and everything is as if there are two independent firms in the market.

Typically, virtual capacity is not auctioned off once and for all, but a sequence of auctions is held. In the European electricity examples, auctions for virtual capacity are held several times a year. We consider the benchmark case where the auctions are competitive and the bidders are unable to coordinate and collude (e.g. because there are many potential bidders). The auction price of virtual capacity then reflects the expected profit to be earned from the virtual capacity, perhaps adjusted for some risk premium. This implies that a winner in the auction does not expect to earn any rents in future periods from virtual capacity. This has the important implication that there is no future punishment which can deter him from using the current amount of virtual capacity optimally, i.e. play a best response to whatever the other firms in the market do. This feature implies that winners of virtual capacity behave short sighted. In a standard setting, where firms owned their own capacity this would imply that tacit collusion is impossible: If all other firms play a best response, the best the incumbent can do is to play a best response and this results in the one shot Nash equilibrium. With virtual capacity this logic breaks down. Since the incumbent sells the virtual capacity, it is able to extract the rents the winners of virtual capacity capture in the market. The incumbent therefore internalizes all profit in the market.

For simplicity, we consider a Cournot market, where the firms choose production and the price is set in the market. However, the effect we identify is not special to a Cournot market it is a general effect depending on the fact that the incumbent internalizes all market profit, since it can extract the virtual competitors' profit¹. If the incumbent behaves prudent in the market it can induce the monopoly price by reducing its own sales to the monopoly output minus the virtual capacity it has sold off. The virtual producer will earn the monopoly price minus marginal (virtual) cost per unit. In a repeated game where this happens in each period, the bidders in the auction will realize it and bid accordingly. In this way, the incumbent can realize the whole monopoly profit (less perhaps a risk premium required by the virtual producers), partly earned in the auction partly earned though own

¹It is straightforward to replicate the analysis in the main body of the paper for the Bertrand case (with constant marginal costs).

sales. Of course, when it has auctioned off the virtual capacity in a period, there is an incentive to increase production above the low level inducing the monopoly price and earn more on the larger market share. However, there will be a future punishment as bidders in future auctions will then not expect monopoly outcomes and bid lower. We show that this punishment is sufficient to make it optimal for the incumbent to disregard the short run incentive to increase production if the discount factor is sufficiently high.

The analysis suggests that long run effects are something competition authorities should worry about. The analysis also shows that the duration of the contracts for virtual capacity is important. The longer the duration of a contract, the longer the incumbent can reap the benefits of increasing production before it is punished in the upcoming auctions and the more tempting such increases are. This incentive undermines the incentive to monopoly behavior. It is therefore advisable that the authorities make contracts for virtual capacity with a long duration. Similarly, the effects we identify are long run effects. The policy implication seems to be that it is not advisable to continue with auctions for a very long time, so that these long run effects become important. It is furthermore important to realize that the monopoly outcome under virtual capacity is possible *even though the virtual competitors behave short-sighted and do not participate in tacit collusion*. If instead a physical divestiture is required by the authorities, then the monopoly outcome requires that independent firms coordinate and tacitly collude. If one believes that there may be obstacles to coordination and collusion, physical divestiture seems like a better option for the authorities than virtual capacity.

When the duration of virtual capacity contracts are a quarter or a year, there is uncertainty about the profit which can be earned with the virtual capacity. We therefore explicitly consider the case where demand and costs are uncertain at the time of the auction. This does not affect the qualitative result. However, it is true that more uncertainty makes it more difficult to sustain the monopoly outcome, in the sense that it requires a higher discount factor.

As stated above, virtual capacity has been introduced in a number of recent European merger cases. In relation to Electricité de France's (EdF)

purchase of 34,5% of the German utility EnBW, EdF agreed to make 6.000 MW of virtual capacity available by November 2003. EdF was at the time selling to around 90% of the so-called free customers in the French market. The contracts for virtual capacity have durations of 3, 6, 12, 24 and 36 months. The auctions are organized as ascending clock auctions, conducted over the internet, and the first auction for 1.200 MW took place in September 2001. Typically, around 30 energy traders and suppliers have placed bids in the auctions, with approximately 20 bidders emerging as successful purchasers. EdF should provide virtual capacity for a period of five years, after which the French electricity market was expected to be sufficiently competitive without the virtual capacity (see Electricité de France, 2004). In 2005 EdF agreed to continue to offer VPP's on a voluntary basis until new arrangements are agreed.

The competitive effects of virtual capacity in the French market have been the subject of discussion. Glachant and Finon (2005) report that EdF seems to have countered the competitive effects of VPPs' by restricting supply in the market through buying up power from the VPP's. This is exactly the strategy we focus on in this paper. According to Glachant and Finon (2005), pages 15-16:

"This gap reveals that EDF competitors don't sell all their resources to French domestic demand or export, and that they thus finally resell all their surpluses to EDF. If this trend from the second quarter of 2003 and the first quarter of 2004 is to persist, questions will arise concerning the effectiveness of the VPP for creating an alternative competitive supply on the French market; as said –for the first time- a French official report in Fall 2004 (IGF-CGM 2004). In March of 2004, re-sales to EDF reached 1200 GWh, or over 30 per cent of the month's VPP resources. Furthermore, informal "not to be quoted and thus anonymous" sources suggested that actual resale to EDF by the competitive fringe is underestimated by the French regulator statistics."

Similarly, Energy Business Review (2006) writes:

"Having completed the virtual power plant (VPP) auctions deemed necessary by Brussels to permit its EnBW purchase, EdF has agreed to continue offering French power capacity on a voluntary basis until new arrangements are agreed. While regulatory body the CRE champions the continuation and expansion of such auctions, their effectiveness is highly questionable."

and

"These VPP auctions were essentially put in place to give third party access to its (EdF's, CS) massive nuclear fleet - the expectation being that increased availability of wholesale power would promote competition on EdF's home front. The realized price, however, must reflect available market prices, leading some observers to suggest the auction price can be artificially inflated ahead of the quarterly sale. An analyst with a leading Swiss energy trading firm has repeatedly noticed that "prices increased before VPP auctions," leading to the assumption "that prices had been influenced by the big market player."

The mechanism, the analyst alludes to, is exactly the mechanism, we focus on in this paper. The incumbent restricts supply in the spot market, so that the price is high. This induces a high auction price, and the incumbent captures the surplus of the virtual producers in this way.

The Dutch electricity producer Nuon agreed to auction off 900 MW virtual capacity in order to be allowed to buy Reliant and its 3500 MW capacity; the Dutch market size is approximately 20.000 MW. Again there was a five year limit on the requirement. See Van Damme (2005) for further details. Newbery (2006), page 20, notes that possible manipulation of the auction price and the potential relation to contract length became an issue in the Dutch case:

"The plan was to sell VPPs for five years in the first instance, but this was contested in the courts and reduced to one year at a time. One of the issues was whether an annually repeated

VPP auction would encourage the seller to bid up APX prices to make the auction price higher shortly before each auction, and if so this temptation would be reduced by infrequent auctions for longer periods. Action design is a technical matter not always wellunderstood by courts, but if VPPs are to be used as a method of mitigating market power this question is an important one to address".

The present paper exactly addresses this issue and the results indeed points to that more infrequent auctions are to be preferred, since it makes it harder for the incumbent to sustain non-competitive outcomes.

In March 2004 the Danish producer Elsam agreed to auction off 600 MW virtual capacity in order to be allowed to make an indirect purchase of 36% of the shares in E2, see Danish Competition Authority (2004). The total Danish market size is about 7000 MW. The auctions are to be held regularly and for varying durations all below three years. The virtual producer can buy electricity at the lowest marginal cost obtainable in the different plants owned by Elsam. Unlike in all other countries, the Danish Competition Authority (DCA) required that virtual capacity auctions should be held indefinitely. In view of the results of this paper, this seems like a questionable decision. The DCA expected in 2004 that:

"The sale of decentralized power and the release of virtual capacity will ensure that there continues to be competitors to Elsam at the production side and will - together with other remedies - have the same effect as divestiture of E2 shares. The sale of decentralized power and the release of virtual capacity in Jylland/Fyn (i.e. the West Danish market, CS) furthermore implies an improvement of the competition in Jylland/Fyn."²

However, in a later assessment in 2007 the DCA appeared less optimistic:

"The DCA has investigated to what extent the VPP-auctions have influenced Elsam's actual market strength in the West Danish market and found that the VPP-auctions only to a very

²See Danish Competition Authority (2004) page 12 (my translation from Danish).

limited extent has reduced Elsam's possibilities for determining the price..."³

VPP's have been required by several other European Competition Authorities: Due to ESB's dominance in the Irish power market, the Irish government initiated the Virtual Independent Power Producer Auction (see European Commission, 2002). In 2003, the Belgian Competition Council approved that a subsidiary of Electrabel became the default supplier for the customers of several inter-municipal distribution companies conditional on Electrabel offering up to 1200 MW VPP capacity in Belgium for a period of five years (see Belpex, 2007). In Spain, the big producers Endesa and Iberdrola have been required to hold a series of five auctions offering VPP capacity (see Endessa, 2007). Similarly, VPP auctions are launched in Portugal in 2007 (see REN, 2007). Interestingly, the large German producer eon has decided to launch virtual capacity as from September 2007 although not required to do so by the authorities (see eon 2007).

There is a long literature on tacit collusion, see Tirole (1991) for an overview. The detection of tacit collusion in electricity markets have been the subject of a number of papers including Green and Newbery (1992), von der Fehr and Harbord (1993), Borenstein and Bushnell (1999), Wolfram (1999), and Fabra and Toro (2004). A literature studies the effects of forward contracts in markets in general and electricity markets in particular, both in a static setting, see Allaz and Vila (1993), as well in a long run setting, see Ferreira (2003), Liski and Montero (2006) and Zhang and Zwart (2006). This literature differs in (at least) two respects from the issue we consider: Where virtual capacity is an option to buy output (typically) at the incumbent's marginal cost, a forward contract is on delivery of a given amount of physical output at a particular price. Secondly, the amount a firm decides to sell forward is endogenous and chosen by the firm, while the amount of virtual capacity a firm is forced to provide is exogenously specified by the competition authority. An interesting contribution to the literature on forward contracts is Frutos and Fabra (2008) who consider a

³See Danish Competition Authority (2007) paragraph 299 (my translation from Danish).

static model, where the amount of forward trading is exogenously stipulated before spot trading takes place through auctions. A related literature concerns capacity-sharing or cotenancy, which has been used as an anti-trust remedy in the US. Under capacity sharing, a firm may use unused capacity held by other firms. As with virtual capacity, this has the advantage that it combines the benefits of single plant production with competition at the marketing stage. Again the amount of co-shared capacity is endogenously chosen by the firms. See, e.g. Baseman (1988) for an interesting description of a newspaper case. Gale (1994) considers optimal pricing by firms in a one-shot game and Rassenti et al (1994) present experimental results. None of the papers consider long run effects similar to the one highlighted in this paper. To the best of my knowledge the issue of virtual capacity and long run effects has not been considered in the literature.

The organization of the paper is as follows. Section 2 describes the basic model and derives the static solution. Section 3 considers the long run effects of repeated auctions, while some concluding remarks are offered in Section 4. Some proofs are in Appendix.

2 Basics: The static market

There are potentially $n + 1$ firms in the final market. Firm 0 is the large firm, which has been created in the merger, we will denote it the incumbent in the following. Firms $i = 1, \dots, n$ are bidders in the auction for virtual capacity.

Firm 0 is the sole producer. Its costs are stochastic, the cost function is $c(q, \psi)$, where q is the total production and ψ is a stochastic disturbance. The cost is assumed to fulfill $c_q \geq 0$, i.e. marginal costs are non-negative, and a high ψ implies high costs, $c_\psi > 0$, and high marginal costs, $c_{q\psi} > 0$. The disturbance ψ is distributed according to the cumulative distribution Ψ on the support $[\underline{\psi}, \bar{\psi}]$. The expected cost is denoted $c(q)$

$$c(q) = \int_{\underline{\psi}}^{\bar{\psi}} c(q, \psi) d\Psi(\psi).$$

Demand for the final product is stochastic and if q units are sold in the market, the market price is $p(q, \varepsilon)$. The disturbance ε is distributed

according to the cumulative distribution function F on the support $[\underline{\varepsilon}, \bar{\varepsilon}]$. The inverse demand curve is downward sloping, $p_q < 0$, and high ε denotes high demand, $p_\varepsilon > 0$. We also assume that $p_{q\varepsilon} > 0$, this ensures that the marginal revenue of a monopolist increases when ε increases. Furthermore, for all realizations of $\varepsilon, \psi : p(0, \varepsilon) > c(0, \psi)$, i.e. the "choke" price is above the fixed cost. This implies that the market is viable for all realizations of ε, ψ . Throughout the paper, we will make two weak standard assumptions ensuring that second order conditions are fulfilled and the reaction functions slope downward and are flat:

$$p_q(q, \varepsilon) + p_{qq}(q, \varepsilon)q < 0 \text{ and } c_{qq}(q, \psi) \geq p_q(q, \varepsilon). \quad (1)$$

They mean that an increase in the other firms' output lowers a firm's marginal revenue, and secondly that the demand curve intersects the large firm's marginal cost curve from above. The conditions are among the weak stability conditions for Cournot equilibrium, see Dixit (1986) or Farrell and Shapiro (1990).

The auction is over k different amounts of virtual capacity, $q_j, j = 1, \dots, k$. The total amount of virtual capacity is $q_v = \sum_{j=1}^k q_j$. Let n_1 be the number of winning firms in the auction, i.e. bidders who actually win a positive amount of virtual capacity. Let q_i be the capacity of winning firm i . We will call winning firm i for virtual producer i .

In the examples mentioned in the Introduction, the competition authorities have specified the price owners of virtual capacity could buy electricity for. Typically, this price has been equal to the per unit cost of the most effective units of the incumbent⁴. If the incumbent is required to deliver q_v units and they are produced at the most efficient units the cost to the incumbent is $c(q_v)$. We therefore assume that the per unit price of output for a holder of virtual capacity is

$$\sigma(q_v, \psi) = \frac{c(q_v, \psi)}{q_v}.$$

It should be noted that virtual capacity has the virtue that it furthers productive efficiency. It ensures that costs are internalized by one player

⁴This is, for instance, directly stipulated in the Danish case, while in the French the price is set at the marginal cost of a nuclear plant.

and production will be efficiently distributed on the available plants. Furthermore, since we assume a convex cost function, the initial merger is only justified if there are large fixed costs. A physical divestiture may therefore cause economies of scale to be lost. This also points at an advantage for virtual capacity over physical divestiture.

We assume that the stochastic elements to demand and cost are observed before the firms make the actual decision about how much to sell. This is motivated by the conditions on electricity markets, where the most important stochastic elements typically are weather, seasonal variations, the amount of water in water basins for hydro power, fuel prices, and variations over the day. These are features which to a large extent can be predicted days in advance. However, at the time of the auction they are uncertain. Evidently, there is some uncertainty, which is not resolved before the time of production, but we will abstract from this and focus on the more important uncertainty which is not resolved before the auction, but is resolved before the production decisions are taken.

As a benchmark, consider the situation where the incumbent is monopolist in the market. In this case, its profit is

$$\pi(q, \varepsilon, \psi) = p(q, \varepsilon)q - c(q, \psi).$$

Let the profit maximizing quantity given the realization of the uncertainty be denoted $q^m(\varepsilon, \psi)$ and the associated price and profit be $p^m(\varepsilon, \psi)$ and $\pi^m(\varepsilon, \psi)$, respectively. The first order condition for maximum is

$$p_q(q, \varepsilon)q + p(q, \varepsilon) = c_q(q, \psi),$$

so that

$$\frac{dq^m(\varepsilon, \psi)}{d\varepsilon} = -\frac{p_{q\varepsilon}(q, \varepsilon)q + p_\varepsilon(q, \varepsilon)}{p_{qq}(q, \varepsilon)q + 2p_q(q, \varepsilon) - c_{qq}(q, \psi)}.$$

This is positive since $p_{q\varepsilon}(q, \varepsilon) > 0$. Under the regularity assumptions made here, the monopoly quantity, price and profit all are increasing in ε . Similarly, a higher ψ gives a lower monopoly quantity and profit and a higher monopoly price.

Let the expected monopoly profit be denoted π^m , then

$$\pi^m = \int_{\underline{\psi}}^{\bar{\psi}} \int_{\underline{\varepsilon}}^{\bar{\varepsilon}} \pi^m(\varepsilon, \psi) dF(\varepsilon) d\Psi(\psi).$$

We will assume that the virtual producers are so small, that the optimal strategy of the virtual producers consists in marketing their whole capacity, q_v . Below we will give conditions under which this is indeed the case. In the examples of virtual capacity seen hitherto, discussed in the Introduction, the market shares of virtual producers have all been below ten percent, and the assumption appears eminently plausible for these cases. Furthermore, the evidence points to that indeed all capacity is used, see Barclays Capital (2005) and the discussion after Theorem 2 below.

When the total production of the virtual producers is q_v and the incumbent chooses to market q units by himself, the incumbent's cost for the q units is $c(q + q_v, \psi) - c(q_v, \psi)$, since the virtual producers get their quantity, q_v , for $c(q_v, \psi)$. The incumbent's profit from his own sales in the market is

$$\pi(q, q_v, \varepsilon, \psi) = p(q + q_v, \varepsilon)q - (c(q + q_v, \psi) - c(q_v, \psi)).$$

The incumbent's best reply to q_v , $q(q_v, \varepsilon, \psi)$, fulfills the first order condition

$$p_q(q + q_v, \varepsilon)q + p(q + q_v, \varepsilon) = c_q(q + q_v, \psi). \quad (2)$$

Let q_{-i} denote the total production of all other firms than firm i . For virtual producer i the maximization problem is:

$$\max_{q \leq q_i} p(q_{-i} + q, \varepsilon)q - \sigma(q_v, \psi)q.$$

If

$$p_q(q(q_v, \varepsilon) + q_v, \varepsilon)q_i + p(q(q_v, \varepsilon) + q_v, \varepsilon) \geq \sigma(q_v, \psi),$$

then the solution is $q = q_v$. This condition is fulfilled for all virtual producers, regardless of the distribution of the virtual capacity if

$$p_q(q(q_v, \varepsilon) + q_v, \varepsilon)q_v + p(q(q_v, \varepsilon) + q_v, \varepsilon) \geq \sigma(q_v, \psi). \quad (3)$$

The condition implies that if all virtual capacity is held by one virtual producer, then in equilibrium, he wishes to use it all. In the special case, where marginal cost is constant, the condition is fulfilled if and only if the amount of virtual capacity is less than half of the total production in the Cournot duopoly equilibrium among two firms who are not capacity constrained. We will assume that condition (3) is fulfilled for all realizations of ε and

ψ . Under our assumption $p(0, \varepsilon) > c(0, \psi)$ for all ε, ψ , (3) is fulfilled if q_v is sufficiently small. Then, in equilibrium, each virtual producer markets all his capacity regardless of the demand state and the large firm chooses $q(q_v, \varepsilon, \psi)$.

When (1) and (3) are fulfilled, more virtual capacity is pro-competitive in the sense that a larger virtual capacity increases the total production in the market, so the price is lowered. To see this notice that more virtual capacity is pro-competitive if $q(q_v, \varepsilon, \psi) + q_v$ increases in q_v , i.e. if

$$\frac{dq}{dq_v} + 1 > 0 \Leftrightarrow \frac{dq}{dq_v} > -1.$$

From (2), we obtain

$$\frac{dq}{dq_v} = -\frac{p_{qq}(q + q_v, \varepsilon)q + p_q(q + q_v, \varepsilon) - c_{qq}(q + q_v, \psi)}{p_{qq}(q + q_v, \varepsilon)q + 2p_q(q + q_v, \varepsilon) - c_{qq}(q + q_v, \psi)},$$

which is larger than -1 when (1) is fulfilled.

The market price will be $p(q(q_v, \varepsilon, \psi) + q_v, \varepsilon, \psi)$ and the expected price is

$$p(q_v) = \int_{\underline{\psi}}^{\bar{\psi}} \int_{\underline{\varepsilon}}^{\bar{\varepsilon}} p(q(q_v, \varepsilon, \psi) + q_v, \varepsilon, \psi) dF(\varepsilon) d\Psi(\psi).$$

The profit to the incumbent from its own sales in the market in state ε, ψ , when virtual capacity is q_v , is

$$\pi_0(q_v, \varepsilon, \psi) = p(q(q_v, \varepsilon, \psi) + q_v, \varepsilon)q(q_v, \varepsilon, \psi) - (c(q(q_v, \varepsilon, \psi) + q_v, \psi) - c(q_v, \psi)),$$

and the corresponding expected profit is

$$\pi_0(q_v) = \int_{\underline{\psi}}^{\bar{\psi}} \int_{\underline{\varepsilon}}^{\bar{\varepsilon}} \pi_0(q_v, \varepsilon, \psi) dF(\varepsilon) d\Psi(\psi).$$

The profit to a virtual producer with capacity q_i in state ε, ψ is

$$\pi_v(q_i, q_v, \varepsilon, \psi) = (p(q(q_v, \varepsilon, \psi) + q_v, \varepsilon) - \sigma(q_v, \psi))q_i,$$

and the corresponding expected profit is

$$\pi_v(q_i, q_v) = (p(q_v) - \sigma(q_v))q_i.$$

where $\sigma(q_v) = c(q_v)/q_v$. Notice that this expected profit is linear in the capacity. Hence the total expected profit to the virtual producers does not depend on how the virtual capacity is distributed. Summarizing the discussion:

Proposition 1 *Assume (1) and (3). A larger virtual capacity makes the static market more competitive. Furthermore, the virtual producers use all their capacity and their total expected profit is independent of how the virtual capacity is distributed.*

In the auction for virtual capacity, the participating firms realize that the expected profit from winning a unit of virtual capacity is $p(q_v) - \sigma(q_v)$. We will assume that *the auction is competitive*. The reason could be that there are so many participants that they are not able to coordinate their behavior. The bidders have an outside option, so they will only bid in the auction for virtual capacity if they can get a return $r \geq 0$. A positive r may reflect a positive outside option or that the bidders demand a risk premium, due to the uncertainty. If the bidders are risk neutral and their outside option has zero value, then the auction price for one unit of virtual capacity will equal $p(q_v) - \sigma(q_v)$. More generally, the winning bid(s) for a unit of virtual capacity in the auction equal(s)

$$b(q_v, r) = \frac{p(q_v) - \sigma(q_v)}{1 + r}.$$

Evidence from the French VPP auctions actually suggests that they are competitive and the price of virtual capacity reflects the future profits from the capacity. Armstrong, Galli & Kapoor (2007, p. 10) conclude in a study of the French VPP auctions that "*the premiums paid to acquire this capacity reached the point where the successful bidders could not necessarily make a profit by reselling the power on Powernext*⁵. *In fact in many cases, it would have been less expensive for them to have purchased the capacity at the prevailing market clearing price.*"

The incumbent gets the proceeds from the auction, so its earnings from the auction are

$$\alpha(q_v, r) = \frac{p(q_v) - \sigma(q_v)}{1 + r} q_v.$$

The total expected profit to the incumbent consists of the proceeds from the auction plus the earnings in the market and equals

$$\Pi_0(q_v, r) = \pi_0(q_v) + \alpha(q_v, r). \quad (4)$$

⁵The French spot market, CS

In the sequel we will assume that the incumbent is risk neutral and his outside option is zero. However, if the incumbent is risk averse, the proceeds from the auction have the virtue that they are not uncertain⁶. It follows directly from Proposition 1, that more virtual capacity lowers the total earnings of the large firm.

The analysis of this section shows that from a static perspective virtual capacity seems like a good merger remedy. It works just as physical divestiture at the marketing stage and it may even ensure productive efficiency.

3 Repeated auctions for virtual capacity

In this section we consider the case where the incumbent auctions off virtual capacity repeatedly. There are infinitely many periods $t = 0, \dots, \infty$. Each period is as described above. The stochastic shocks to demand and cost are identically and independently distributed over time. All firms discount expected future profits with the discount factor δ , where $0 < \delta < 1$.

We will now show that if the incumbent is sufficiently patient, there exists a sequential equilibrium to the repeated game, where the incumbent's total profits (almost) equals the monopoly profit. The "almost" comes from the fact that buyers of virtual capacity demand a return equal to r . If r equals zero, the incumbent can realize the whole monopoly profit. In this equilibrium, the incumbent makes sure that in each period the total production equals the monopoly production, so that the market price equals the monopoly price. This makes virtual capacity valuable, and the auction price for the virtual capacity reflects this.

We claim the following constitutes a sequential equilibrium of the repeated game. There is a *normal* and a *punishment* phase. In each period t of the *normal* phase, the incumbent chooses a quantity so small that the total quantity sold equals the monopoly quantity, given the realization of cost and demand, i.e.

$$\tilde{q}(q_v, \varepsilon, \psi) = q^m(q_v, \varepsilon, \psi) - q_v.$$

⁶ Although the exact formulas in the sequel depend on the assumption that the incumbent firm is risk neutral, the qualitative results do not.

This implies that the price will equal the monopoly price $p^m(\varepsilon, \psi)$ and the total profit in the market will equal the monopoly profit $\pi^m(\varepsilon, \psi)$ ⁷.

In each period of the *punishment* phase, the incumbent chooses the Cournot quantity $q(q_v, \varepsilon, \psi)$. A period is normal if either $t = 0$ or the incumbent has chosen $\tilde{q}(q_v, \varepsilon_\tau, \psi_\tau)$ in all periods $\tau < t$. Otherwise, it is a punishment period.

Let p^m be the expected monopoly price, i.e.

$$p^m = \int_{\underline{\psi}}^{\bar{\psi}} \int_{\underline{\varepsilon}}^{\bar{\varepsilon}} p^m(\varepsilon, \psi) dF(\varepsilon) d\Psi(\psi).$$

If the period is normal, the expected value of a unit of virtual capacity will be $p^m - \sigma(q_v)$, and bidders in the auction for virtual capacity bid

$$\tilde{b}(q_v, r) = \frac{p^m - \sigma(q_v)}{1 + r},$$

per unit of virtual capacity, while if it is a punishment period, the expected value of a unit of virtual capacity is $p(q_v) - \sigma(q_v)$ and they bid

$$b(q_v, r) = \frac{p(q_v) - \sigma(q_v)}{1 + r},$$

per unit of virtual capacity. In either kind of period they choose to use all the virtual capacity they won in the auction.

The bidders' strategy is sequentially optimal, a higher bid would give negative expected profits both in the normal and in the punishment phase, while a lower bid would be a losing bid and not increase profits. Since all firms' strategies only depend on whether the period is normal or not, and the virtual producers cannot affect this, it is optimal for the virtual producers to maximize profits and use all capacity in a single period. Notice, that as long as the auctions are competitive, winners of virtual capacity will not expect to earn any rents in future periods, and they can therefore not be punished by lower rents in the future (it is always an option for the bidders to stay out of the auction). In *any* sequential equilibrium, where the auctions are competitive, they will therefore use all their virtual capacity. They behave as if they are shortsighted.

⁷Where no confusion is possible we will not give the variables a time-index, so we write ε for ε_t etc.

In a normal period, the incumbent sells $\tilde{q}(q_v, \varepsilon, \psi)$ in the market, and the profit from the sales is

$$\tilde{\pi}(q_v, \varepsilon, \psi) = p^m(\varepsilon, \psi)(q^m(\varepsilon, \psi) - q_v) - (c(q^m(\varepsilon, \psi), \psi) - c(q_v, \psi)).$$

The corresponding expected profit is

$$\tilde{\pi}(q_v) = \pi^m - (p^m q_v - c(q_v)).$$

The proceeds from the auction are

$$\alpha^m(q_v, r) = \frac{p^m q_v - c(q_v)}{1 + r}.$$

Hence, in such a period the total expected earnings of the incumbent equal

$$\tilde{\Pi}_0^m(q_v, r) = \pi^m - r(p^m q_v - c(q_v)),$$

i.e. the expected monopoly profit minus return on virtual capacity required by the bidders. If the incumbent chooses $\tilde{q}(q_v, \varepsilon)$, the next period will be a normal period, and this will continue as long as $\tilde{q}(q_v, \varepsilon)$ is chosen.

The best one shot deviation from the equilibrium strategy is to $q(q_v, \varepsilon, \psi)$, which gives $\pi_0(q_v, \varepsilon, \psi)$. The future periods will then be punishment periods. The proceeds from the auctions will be $\alpha(q_v, r)$ in all periods regardless of what the incumbent does, so it is optimal to choose the Cournot quantity, $q(q_v, \varepsilon, \psi)$ and the incumbent will earn $\Pi_0(q_v, r)$ in each period. Hence, the gain from a deviation equals $\pi_0(q_v, \varepsilon, \psi) - \tilde{\pi}(q_v, \varepsilon, \psi)$ and the expected future loss from a deviation equals

$$\frac{\delta}{1 - \delta} \left(\tilde{\Pi}_0^m(q_v, r) - \Pi_0(q_v, r) \right). \quad (5)$$

As the monopoly profit exceeds the sum of the Cournot profits, this expression is positive for $r = 0$ and for sufficiently low r . We assume this is the case (otherwise it would be optimal for the incumbent just to choose the Cournot-production in each period). A deviation is not worthwhile if the future loss exceeds the immediate gain, which we can rewrite as

$$\frac{\pi_0(q_v, \varepsilon, \psi) - \tilde{\pi}(q_v, \varepsilon, \psi)}{\tilde{\Pi}_0^m(q_v, r) - \Pi_0(q_v, r) + \pi_0(q_v, \varepsilon, \psi) - \tilde{\pi}(q_v, \varepsilon, \psi)} \equiv \delta(\varepsilon, \psi) < \delta. \quad (6)$$

Since (5) is positive, it follows that $\delta(\varepsilon, \psi) \in]0, 1[$ for all ε, ψ .

The gain from a deviation $\pi_0(q_v, \varepsilon, \psi) - \tilde{\pi}(q_v, \varepsilon, \psi)$ is increasing in ε and decreasing in ψ . To see this use the envelope theorem to get

$$\begin{aligned} \frac{d(\pi_0(q_v, \varepsilon, \psi) - \tilde{\pi}(q_v, \varepsilon, \psi))}{d\varepsilon} &= \frac{\partial \pi_0(q_v, \varepsilon, \psi)}{\partial \varepsilon} - \left(\frac{\partial \pi^m(\varepsilon, \psi)}{\partial \varepsilon} - \frac{\partial p^m(\varepsilon, \psi)}{\partial \varepsilon} q_v \right) \\ &= p_\varepsilon(q(q_v, \varepsilon, \psi) + q_v, \varepsilon, \psi) q(q_v, \varepsilon, \psi) - p_\varepsilon^m(\varepsilon, \psi) (q^m(\varepsilon, \psi) - q_v). \end{aligned}$$

This is positive as $p_{\varepsilon q} > 0$ and $q(q_v, \varepsilon, \psi) > q^m(\varepsilon, \psi) - q_v$. In the same way it can be seen that the gain is decreasing in ψ . Since the gain from deviation $\pi_0(q_v, \varepsilon, \psi) - \tilde{\pi}(q_v, \varepsilon, \psi)$ is increasing in ε and decreasing in ψ it follows that condition (6) is fulfilled for all ε, ψ if $\delta(\bar{\varepsilon}, \underline{\psi}) < \delta$.

The following Theorem summarizes the above

Theorem 2 *If $\delta \geq \delta(\bar{\varepsilon}, \underline{\psi})$, there exists a sequential equilibrium, where in each period the market price and quantity are at the monopoly levels and the incumbent's expected total earnings equal $\tilde{\Pi}_0(q_v, r)$, i.e. the expected monopoly profit less the bidders required return on virtual capacity. If $r = 0$, then in this equilibrium the incumbent's expected earnings equal the expected monopoly profit, π^m .*

The Theorem shows that the incumbent can maintain the monopoly outcome by being prudent and withhold production from the market so that the total production equals the monopoly production. This leaves some of the monopoly rent to the virtual producers, but (most of) this rent is collected by the incumbent in the auctions. The incumbent has a short run incentive to cheat the virtual producers and produce more, but refrains from this since it would spoil the reputation for monopoly behavior.

In the sequential equilibrium of Theorem 2, the incumbent rightly foresee that the virtual producers use all of their capacity and chooses an optimal strategy given this behavior. Barclay Capital (2005), p 26, found in a report on the European Electricity Markets to the EU Commission that indeed virtual producers use all of their capacity, and thus are very predictable:

"To provide effective competition, VPP positions must translate into active participation in setting wholesale prices. This requires VPP holders to have the option to "generate" or "not

to generate” at or around the prevailing market price. However, our experience is that the strike prices of VPP offerings place them deeply in the money. While putatively based on the marginal costs of production, the strike prices are often so low as to make it virtually impossible for the option to “generate” not to be exercised.”

If there is no uncertainty and the virtual producers’ outside option equals zero, $r = 0$, then condition (6) reduces to

$$\delta > \delta|_{r=0} \equiv \frac{\pi_0(q_v) - \tilde{\pi}(q_v)}{(p^m - p(q_v))q_v}. \quad (7)$$

Here the denominator is extra value of virtual capacity under monopoly pricing compared with the Cournot outcome, while the numerator is the incumbent’s gain from deviation.

The duration of a period equals the duration of the contract for the virtual capacity. For given time preferences, discount rate ρ , and duration of contract for virtual capacity, Δt , the relevant discount factor is

$$\delta = \exp(-\rho\Delta t).$$

This is smaller, the longer duration of the contract. A longer contract therefore makes it more difficult to fulfill the requirement that the discount factor exceeds the crucial discount factor $\hat{\delta}$. Hence, a longer contract makes it more difficult to sustain the monopoly outcome.

As discussed in the Introduction, the length of (some) of the contracts for Dutch VPPs were initially set at five years, but the Dutch incumbent, Nuon, appealed this and the court ruled in an interim judgement that the contracts should be shortened to one year (see van Damme, 2005 and Newbury, 2006). The result here shows that this decision favors the incumbent’s chance of softening competition.

When the auctions are competitive, virtual producers will bid up the price of virtual capacity to its expected value in the market. This implies that the incumbent cannot be punished harder than in the Cournot equilibrium. Virtual producers are unable to produce more than their capacity allows, so if the incumbent should be punished, it should be through a low

auction price. Hence, the punishment phase in the equilibrium above is the toughest possible for the incumbent provided the auctions are competitive.

The monopoly outcome under virtual capacity is possible even though the virtual competitors behave short-sighted and do not participate in tacit collusion. If instead a physical divestiture is required by the authorities, then the monopoly outcome requires that independent firms coordinate and tacitly collude. If one believes that there may be obstacles to coordination and collusion, physical divestiture seems like a better option for the authorities than virtual capacity. Nevertheless, it is an interesting question, which we have left for further research, whether the smallest discount factor compatible with the monopoly outcome under virtual competition is smaller or larger than the smallest discount factor compatible with the monopoly outcome under tacit collusion. The analysis here is complicated by the fact that we are considering an asymmetric Cournot market with a large and a small (or more small) producers. Characterizing the lowest discount factor compatible with tacit collusion on the monopoly outcome - for optimal punishments - is not straightforward. In a previous working paper version of this paper (Schultz, 2004) a comparison was made in a linear, quadratic example where punishments under tacit collusion consisted of reversion to the Cournot equilibrium. In this case the total profits made in the market in the punishment phases are the same under virtual capacity and tacit collusion. Then the lowest discount factor is lower under virtual capacity.

The no deviation constraint is most difficult to fulfill when there are large positive shocks to demand or very low relations of the cost and the gains from a deviation therefore are large. If condition (6) cannot be fulfilled for large ε and small ψ , the incumbent will have to settle for lower profits in such periods. This is as in Rotemberg and Saloner's (1986) analysis of tacit collusion under fluctuating demand.

Now assume that $\delta(\underline{\varepsilon}, \bar{\psi}) < \delta < \delta(\bar{\varepsilon}, \underline{\psi})$, so that if the incumbent chooses $\tilde{q}(q_v, \varepsilon, \psi)$ in each period, (6) cannot be fulfilled in periods with high demand and or low cost. The incumbent then has to settle for lower profits in such periods by choosing a larger quantity $q > \tilde{q}(q_v, \varepsilon, \psi)$. In periods with lower demand/higher cost it may choose $\tilde{q}(q_v, \varepsilon, \psi)$ without violating the no deviation constraint. We now demonstrate the existence

of an equilibrium with this feature. In order to avoid that the exposition becomes extremely cumbersome, we will assume that there is no stochastic element in the cost function in the following. This is purely for expositional reasons. The crucial feature is that profit is stochastic and there are periods where the temptation to deviate becomes too strong. Since we assume that cost is not stochastic, we abuse notation by not conditioning on ψ from now on.

Let ε^* be the highest state, where the gain from a deviation does not exceed the punishment if the incumbent's strategy prescribes $\tilde{q}(q_v, \varepsilon^*)$ in that state. In higher states, the incumbent chooses $\hat{q}(q_v, \varepsilon, \varepsilon^*) > \tilde{q}(q_v, \varepsilon)$, which ensures that the gain from a deviation is not larger than in state ε^* , so $\hat{q}(q_v, \varepsilon, \varepsilon^*)$ is given as the solution in \hat{q} to

$$\pi_0(q_v, \varepsilon) - \pi(\hat{q}, q_v, \varepsilon) = \pi_0(q_v, \varepsilon^*) - \tilde{\pi}(q_v, \varepsilon^*). \quad (8)$$

Let

$$\hat{\delta} \equiv \frac{\pi_0(q_v, \underline{\varepsilon}) - \tilde{\pi}(q_v, \underline{\varepsilon})}{\hat{\alpha}(q_v, \underline{\varepsilon}, r) - \alpha(q_v, r)}. \quad (9)$$

In the Appendix, we show

Theorem 3 *Assume that $\hat{\delta} < \delta < \delta(\bar{\varepsilon})$. Then there exists ε^* , where $\underline{\varepsilon} < \varepsilon^* < \bar{\varepsilon}$, such that the best sequential equilibrium for the incumbent involves*

$$\begin{aligned} \hat{q}(q_v, \varepsilon, \varepsilon^*) & \text{ for } \varepsilon \geq \varepsilon^* \\ \tilde{q}(q_v, \varepsilon) & \text{ for } \varepsilon \leq \varepsilon^* \end{aligned}$$

The requirement that a δ exists fulfilling $\hat{\delta} < \delta < \delta(\bar{\varepsilon})$ evidently takes that $\hat{\delta} < \delta(\bar{\varepsilon})$. This condition can be rewritten

$$\begin{aligned} & \frac{\pi_0(q_v, \underline{\varepsilon}) - \tilde{\pi}(q_v, \underline{\varepsilon})}{\pi_0(q_v, \bar{\varepsilon}) - \tilde{\pi}(q_v, \bar{\varepsilon})} \\ < & \frac{\hat{\alpha}(q_v, \underline{\varepsilon}, r) - \alpha(q_v, r)}{\tilde{\pi}(q_v) + \alpha^m(q_v, r) - (\pi_0(q_v) + \alpha(q_v, r)) + \pi_0(q_v, \bar{\varepsilon}) - \tilde{\pi}(q_v, \bar{\varepsilon})} \end{aligned}$$

This condition will be fulfilled if the gain from a deviation in the bad state $\underline{\varepsilon}$ is sufficiently much smaller than in the good state $\bar{\varepsilon}$.

The uncertainty makes it impossible for the incumbent to sustain the monopoly profit in the good states and the average profit is lowered. Hence,

the profit from reputation building is less for the incumbent. Still, the general result is unaffected, the incumbent can sustain a higher profit by behaving prudent and reducing production.

4 Concluding remarks

Virtual capacity has been a new and interesting feature in major merger cases on electricity markets. Competition authorities have tried to mitigate the anti-competitive effects of mergers by requiring that the merging firm auctions off virtual capacity to prospective competitors in the final market. We have shown that indeed in a static setting this has the expected competitive effects. As regards the longer run effects the picture is more blurred. The fact that the incumbent can acquire the rent captured by the virtual competitors through the auctions, makes the incumbent internalize all profit in the market and gives incentives to reduce total production to the monopoly level. The analysis points out that a long duration for the contract for virtual capacity increases competitiveness and it points to that it would be good to limit the time period for which the competitive remedies rely on virtual capacity. It is also important to notice that virtual capacity gives possibilities for the incumbent to realize the monopoly outcome even though the virtual competitors behave short sighted and do not participate in tacit collusion. This would not be possible if a physical divestiture was required by the competition authorities.

If the competition authority mandates an amount of virtual capacity so high that the incumbent cannot withhold a sufficient amount of production so that the monopoly price is realized even though the virtual producers use all their capacity, the equilibrium we have focussed on breaks down. However, this is not likely to happen. Competition law in most countries - including the EU - stipulates that merger remedies should be proportional to the anti-competitive effects of the merger. It is difficult to imagine that courts will uphold decisions where the amount of virtual capacity is significantly higher than the market shares involved in the merger. Still, the results of this paper point out that authorities - and courts - should probably be less optimistic about virtual capacity as a remedy.

5 Appendix

Proof of Theorem 3:

From equation (8) we have that

$$\pi(\hat{q}(q_v, \varepsilon, \varepsilon^*), q_v, \varepsilon) = \pi_0(q_v, \varepsilon) - (\pi_0(q_v, \varepsilon^*) - \tilde{\pi}(q_v, \varepsilon^*)). \quad (10)$$

The implicit function theorem gives $\frac{d\hat{q}(q_v, \varepsilon, \varepsilon^*)}{d\varepsilon^*} < 0$. The price in state $\varepsilon > \varepsilon^*$ is $p(\hat{q}(q_v, \varepsilon, \varepsilon^*) + q_v, \varepsilon) < p^m(\varepsilon)$.

The expected price then becomes

$$\hat{p}(q_v, \varepsilon^*) = \int_{\underline{\varepsilon}}^{\varepsilon^*} p^m(\varepsilon) dF(\varepsilon) + \int_{\varepsilon^*}^{\bar{\varepsilon}} p(\hat{q}(q_v, \varepsilon, \varepsilon^*) + q_v, \varepsilon) dF(\varepsilon) < p^m, \quad (11)$$

and the proceeds in the auction from virtual capacity is

$$\hat{\alpha}(q_v, \varepsilon^*, r) = \frac{\hat{p}(q_v, \varepsilon^*) - \sigma(q_v)}{1+r} q_v < \alpha^m(q_v, r).$$

The expected per period profit for the incumbent in such an equilibrium is

$$\hat{\Pi}(q_v, \varepsilon^*, r) = \int_{\underline{\varepsilon}}^{\varepsilon^*} \tilde{\pi}(q_v, \varepsilon) dF(\varepsilon) + \int_{\varepsilon^*}^{\bar{\varepsilon}} \pi(\hat{q}(q_v, \varepsilon, \varepsilon^*), q_v, \varepsilon) dF(\varepsilon) + \hat{\alpha}(q_v, \varepsilon^*, r).$$

Using (8) we get

$$\begin{aligned} \hat{\Pi}(q_v, \varepsilon^*, r) &= \int_{\underline{\varepsilon}}^{\varepsilon^*} \tilde{\pi}(q_v, \varepsilon) dF(\varepsilon) + \int_{\varepsilon^*}^{\bar{\varepsilon}} \pi_0(q_v, \varepsilon) dF(\varepsilon) \\ &\quad - (1 - F(\varepsilon^*)) (\pi_0(q_v, \varepsilon^*) - \tilde{\pi}(q_v, \varepsilon^*)) + \hat{\alpha}(q_v, \varepsilon^*, r). \end{aligned}$$

Hence,

$$\hat{\Pi}(q_v, \underline{\varepsilon}, r) = \pi_0(q_v) + \tilde{\pi}(q_v, \underline{\varepsilon}) - \pi_0(q_v, \underline{\varepsilon}) + \hat{\alpha}(q_v, \underline{\varepsilon}, r), \quad (12)$$

and

$$\hat{\Pi}(q_v, \bar{\varepsilon}, r) = \tilde{\pi}(q_v) + \hat{\alpha}(q_v, \bar{\varepsilon}, r).$$

Furthermore, $\frac{d\hat{\Pi}(q_v, \varepsilon^*, r)}{d\varepsilon^*} > 0$.

The total discounted loss of profit associated with the punishment phase equals

$$\frac{\delta}{1-\delta} \left(\hat{\Pi}(q_v, \varepsilon^*, r) - \Pi_0(q_v, r) \right).$$

An equilibrium stipulated in the Theorem exists if there exists an $\varepsilon^* \in]\underline{\varepsilon}, \bar{\varepsilon}[$ such that

$$\pi_0(q_v, \varepsilon^*) - \tilde{\pi}(q_v, \varepsilon^*) = \frac{\delta}{1 - \delta} \left(\hat{\Pi}(q_v, \varepsilon^*, r) - \Pi_0(q_v, r) \right).$$

By assumption, the left hand side exceeds the right hand side at $\varepsilon^* = \bar{\varepsilon}$ (otherwise the best equilibrium involves the monopoly outcome each period). Consider $\varepsilon^* = \underline{\varepsilon}$, if

$$\pi_0(q_v, \underline{\varepsilon}) - \tilde{\pi}(q_v, \underline{\varepsilon}) < \frac{\delta}{1 - \delta} \left(\hat{\Pi}(q_v, \underline{\varepsilon}, r) - \Pi_0(q_v, r) \right). \quad (13)$$

then, by continuity of the involved functions, an equilibrium exists. Use (4) and (12) to rewrite (13)

$$\pi_0(q_v, \underline{\varepsilon}) - \tilde{\pi}(q_v, \underline{\varepsilon}) < \frac{\delta}{1 - \delta} (\tilde{\pi}(q_v, \underline{\varepsilon}) - \pi_0(q_v, \underline{\varepsilon}) + \hat{\alpha}(q_v, \underline{\varepsilon}, r) - \alpha(q_v, r)),$$

which is fulfilled if $\delta > \hat{\delta}$. This proves the Theorem.

References

- [1] Abreu, D. (1988), On the Theory of Infinitely Repeated Games with Discounting, *Econometrica*, 56(2): 383-96.
- [2] Allaz B. and J.-L. Vila (1993), Cournot Competition, Forward Markets and Efficiency, *Journal of Economic Theory*, 59, 1993.
- [3] Armstrong, M., A. Galli and A. Kapoor (2007), French VPP: Are buyers making a profit?, *mimeo*, Cerna, Ecole des Mines de Paris.
- [4] Baseman, K. (1998) "Partial Consolidation: The Detroit Newspaper Joint Operating Agreement" in J. Kwoka and L. White, eds., *The Antitrust Revolution*. Oxford University Press
- [5] Barclays Capital (2005), *Competition in EU Electricity Markets*, Submission by Barclays Capital to DG Energy and Transport, 29 July 2005, http://ec.europa.eu/energy/electricity/report_2005/doc/market_operators/24_barclays_capital.pdf.
- [6] Belpex (2007), <http://www.belpexvpp.be/>.

- [7] Borenstein, S. and J. Bushnell (1999), An empirical analysis of the potential for market power in California's electricity industry, *Journal of Industrial Economics*, XLVII, 3, 285-323.
- [8] Danish Competition Authority (2004): *Fusionen mellem Elsam og Nesa*, (in Danish, The Elsam Nesa merger).
- [9] Danish Competition Authority (2007), *Elsams elpriser i 2005 og 2006*, (in Danish: Elsam's Power Prices in 2005 and 2006).
- [10] Electricite de France (2004), http://www.edf.fr/index.php4?coe_i_id=346.
- [11] Endessa (2007), <https://www.endesa-iberdrola-vpp.com/en/public/about-the-vppa>.
- [12] Energy Business Review (2006), French wholesale power: are more virtual auctions the answer? *Energy Business Review*, 5th April 2006.
- [13] eon (2007), http://www.eon-sales-and-trading.com/_pdf/_produkte/_vpp/pim_engl.pdf.
- [14] Fabra, N. and J. Toro (2004), Price Wars and Collusion in the Spanish Electricity Market, *Oxford University Working Paper* 136.
- [15] Ferreira, J. L. (2003), Strategic interaction between futures and spot markets. *Journal of Economic Theory*, 108, 2003.
- [16] von der Fehr, N.H. and D. Harbord (1993), Spot market competition in the UK electricity industry, *Economic Journal*, 103, 531-460.
- [17] de Frutos M.-A. and N. Fabra (2008) On the Impact of Forward Contract Obligations in Multi-Unit Auctions, *mimeo*, Universidad Carlos III de Madrid.
- [18] Glachant, J.M., and D. Finon (2005), A Competitive Fringe in the Shadow of a State Owned Incumbent: The Case of France , *Adis Working Paper 2005-09*, University de Paris, Sud.
- [19] Gale, I. (1994), Price competition in noncooperative joint ventures, *International Journal of Industrial Organization*, 12, 53-69.

- [20] Green, R. and D. Newbury (1992), Competition in the British electricity spot market, *Journal of Political Economy*, 100, 929-53.
- [21] Department of Justice (1997): "*Horisontal Merger Guidelines*", revised version (to be found at http://www.usdoj.gov/atr/public/guidelines/horiz_book/21.html).
- [22] European Commission, (2002): Madrid Forum ,see <http://europa.eu.int/comm/energy/gas/madrid/doc-5/long-term-contracts-gas-release-22-01-2002-draft.pdf>.
- [23] Fudenberg, D., D. Kreps, and E.S. Maskin (1990): Repeated Games with Long-run and Short-run Players, *Review of Economic Studies*, 57(4): 555-73.
- [24] Liski, M. and J.-P. Montero (2006), Forward trading and collusion in oligopoly, *Journal of Economic Theory*, 131, 212-230.
- [25] Newbery, D. (2006), Market Design, *CWPE 0615*, Cambridge University.
- [26] Rassenti, S.J., , Reynolds, S.S and Smith, V.L, (1994), Cotenancy and competition in an experimental auction market for natural gas pipeline networks, *Economic Theory*, 4, 41-65
- [27] REN (2007), http://www.ren.pt/portal/resourcesuser/leilao/EN/REN-VPP%2021_Sep_2007%20Auction%20-%20Test%20Guide.pdf.
- [28] Schultz, C. (2004), Virtual Capacity and Tacit Collusion, *CIE-working paper 2004-5*, University of Copenhagen.
- [29] Selten, R. and R. Stoecker (1986) "End Behaviour in Sequences of Finite Prisoner's Dilemma Supergames" A Learning Theory Approach," *Journal of Economic Behaviour and Organisation*, 7, 47-70.
- [30] Tirole, J. (1990): "*The Theory of Industrial Organization*", MIT press.
- [31] Zhang Y. and G. Zwart (2006), Market Power Mitigation Contracts and Contract Duration, *mimeo*, University of Tilburg.

- [32] Wolfram, C. (1999), Measuring duopoly power in the British spot market, *American Economic Review*, 89, 805-826.