A contribution of experimental economics toward characterization of the use of market power in oligopolisitc markets

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A CONTRIBUTION OF EXPERIMENTAL ECONOMICS TOWARD CHARACTERIZATION OF THE USE OF MARKET POWER IN OLIGOPOLISTIC ELECTRICITY MARKETS

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Abstract

Despite the numerous researches about imperfect competition, the market power remains difficult to quantify using traditional economics methods. In this paper, we propose an experimental economics design and outline some ways of analysis of its results toward characterization of the use of market power. A simple system with two regions and a limited interconnection transfer capacity allocated by an implicit auction is studied. Depending on the experiments two or three subjects share equitably the production capacity in one region, while the production capacity is equitably shared among 5 subjects leading to a more competitive situation in the second one. In both regions, we observe a market price that is different from the theoretical results allowing a quantification of the use of market power. Results are also analyzed based on a characterization of the subjects' behaviour. Further the impact of subjects' behaviour on the market price evolution is described.

1. Introduction

The ongoing liberalisation process of electricity markets has caused an important evolution of the industry structures over the world. A major goal of the reforms was to achieve economic efficiency and low electricity prices by introducing competition in former regional electricity markets. As way of example, a trend toward development of transmission interconnection capacities in order to reach a higher degree of competition in regional electricity markets [Boucher-Smeers (2002)] has been observed in Europe. In this context, interconnection capacities play not only the physical role of connector between regional transmission systems but also the role of threatening competitors and therefore promoting competition.

The electricity market integration requires well designed rules in order to allow efficiently scarce transmission capacities among economic agents. Two main methods have thus been applied in Europe to cope with limited interconnection capacities between countries: i) implicit auctions, where energy and transmission are priced together and ii) explicit auctions, where energy and transmission are priced separately [Ehrenman-Smeers (2005)]. These methods are efficient if the "perfect competition" assumption is respected. However, recent experience has shown that this prerequisite is usually not true.

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In fact the recent merging of generation utilities has reinforced the oligopolistic context remaining from former regional monopolies. Most of European regional electricity markets have thus reached a high level of market concentration with for instance monopoly in France, Belgium and Greece, duopoly in Spain, Finland, and Sweden or triopoly in United Kingdom [Glachant-Finon (2005), Newbery (2005), von der Fehr et al. (2005), Crampes-Fabra (2005)]. There is a large consensus among economists to state that these types of oligopoly induce an important market power for its participants. This notion of market power could be defined as the ability to alter profitably prices away from competitive levels [Mas Collel et al. (1995)]. The high market concentration is thus a characteristic of imperfect competition and a serious threat for the economic efficiency of electricity markets. There has been an increasing research activity to study the interaction between market power in national electricity market, limited interconnection capacities and allocation methods.

Numerous economic studies have already covered the theme of quantification of the use of market power in presence of transmission constraints. A traditional theoretical approach mainly based on Game Theory has been used to study imperfect competitive set up in electricity markets with transmission constraints [Cardell et al. (1997), Borenstein et al. (2000), Hobbs (2001), Ralph-Smeers (2006)]. According to most of game theory approaches, it is supposed that all market participants have perfect information and perfect rationality for computing the market (Nash) equilibrium and that they agree in playing it. However, there is still no satisfactory method for quantifying the exercise of market power in real systems, nor to evaluate the market power for any market designs. The main drawbacks of the theoretical approach are the lack of modelling bounded rationality and the lack of consideration of idiosyncrasies of market designs. A (fairly new) research method that solves these drawbacks is the experimental approach.

Experimental economics shows some properties that are decisive for a better understanding of the use of market power in electricity market. The experimental technique, which allows taking into account human decision making in a complex situation, is described in [Smith (1994)]. As long as a set of conditions is respected, for instance if the experiment is simple enough for players to understand their impact and for economists to analyze results properly, experimental economics can provide useful information in seven cases listed by Smith; two reasons out of the seven justify the use of this method in this study, namely to compare environments and to establish empirical regularities as a basis for a new theory.

In this paper an experimental approach is applied for measuring the exercise of market power in a simple system with two regions and a limited interconnection transfer capacity allocated by an implicit auction. Results from experiences are compared with theoretical results allowing a first quantification of the use of market power. Then, we propose a definition of some types of market behaviours, namely marginal-bidder, follower and leader, and we analyze the market price and its evolution depending on the behaviour of players. An accurate characterization of players' behaviour is indeed necessary for developing adequate regulation of new electricity markets, which could also be evaluated through experimental economics.

This paper is organized as follows: Section 2 describes the experimental design and the theoretical results that should be obtained according to classic game theory. Section 3 outlines the experimental process. A complete overview of the results is then presented in section 4. Finally conclusions and propositions for further works are presented in section 5.

2. Experimental design and assumptions

In this section, we set the characteristics of the particular case that was studied and experimented. We start by defining the market structure, then we draw up the market design and theoretical results are finally presented.

2.1 Market structure

The market structure is presented in Figure 1. Producers and consumers are located within two zones, which are most often linked by an interconnection[3]. Subjects control only producers, while consumers' actions are determined by a computer according to a predefined demand curve.

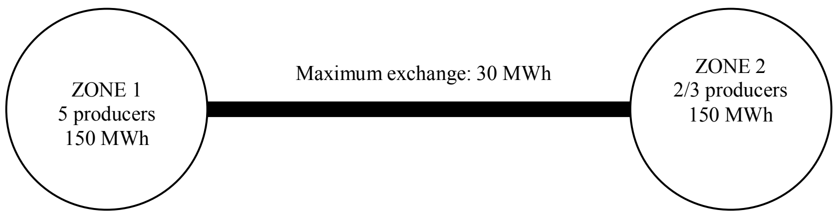

Figure 1: Market Structure

The available production is 150 MWh in each zone. This amount is equitably divided among 5 producers in the 1st zone and 2 (experimental design A) or 3 (experimental design B) producers in the 2nd zone. Production costs depend on the zone. For each producer, half of his production has a low marginal cost (10 and 15 €/MWh in zone 1 and 2, respectively) and the other half has a high marginal cost (20 and 25 €/MWh in zone 1 and 2, respectively). All numerical details are provided in Table I.

Zone	Experimental design	Unit type	Marginal production cost (€/MWh)	Available quantity (MWh)
1	A and B	Low cost	10	15
		High cost	20	15
2	A	Low cost	15	38
		High cost	25	37
	B	Low cost	15	25
		High cost	25	25

Table 1: Numerical data beside producers

Each experiment counts two or four phases; during which, the demand bids and the exchange capacity are maintained constant. These parameters are exposed in Table 2.

Experimental design reference	Phase	Duration (number of periods)	Demand curve	
			Zone 1	Zone 2
A and B	1	30	Base load	
	2	30	Peak load	

Table 2: Numerical data beside demands and interconnection

[3] The way this interconnection is run is described in part 2.2: Market design.

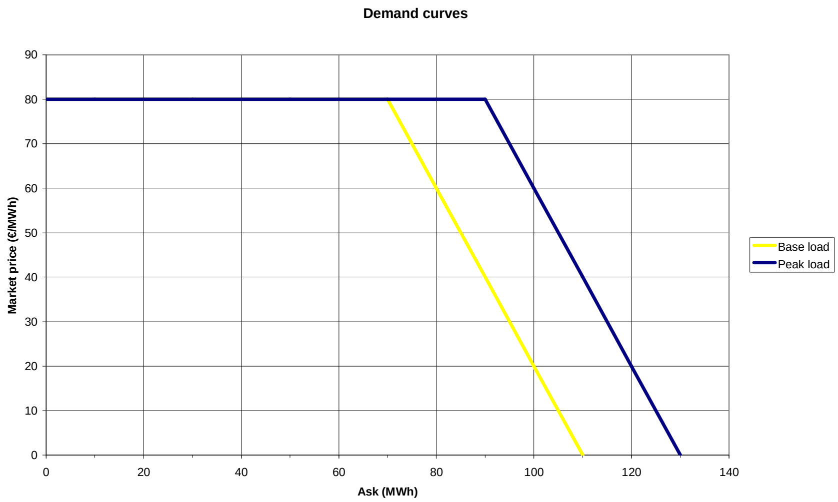

Figure 2: Demand profiles

The base case is experimental design A. It features a more competitive zone in which 5 producers own a production capacity of 30 MWh at a relatively low cost, and an oligopolistic zone in which only 2 producers can produce up to 75 MWh at a higher cost. Demand profiles are chosen in order to control the producers' ability to use market power unilaterally or not; additionally, they are drawn so that the line be congested under competitive assumption in phase 2, but not in phase 1. The ability to exercise market power is affected in the experimental design B by splitting of the 2 producers in zone 2 into 3.

2.2 Market design

The interconnection capacity is allocated following the method known as implicit auction (or market coupling mechanism [ETSO-EuroPEX (2004)]). In this context, each zone has a local market, where only producers that are physically located in the same zone can bid through a uniform price sealed auction.

Once offers have been submitted, aggregated bid and ask curves are computed on each market to calculate the two equilibrium prices PA and PB as represented in Figure 3

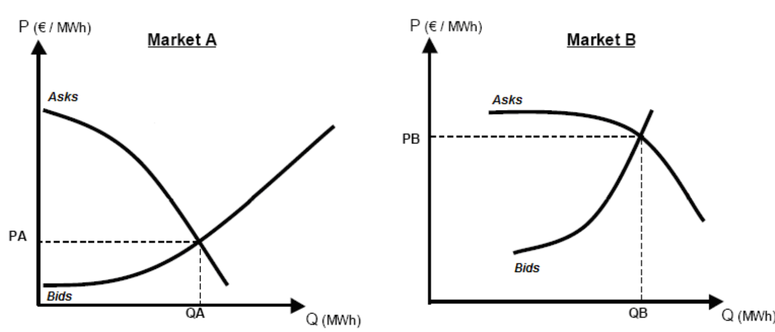

Figure 3: Market clearing mechanism

When the price PB is higher than PA, a quantity ΔQ is exchanged from zone A toward zone B. This export is equivalent to an additional ask ΔQ at any price in market A while the corresponding import is equivalent to an additional bid ΔQ at any price in market B. This quantity ΔQ is progressively raised from zero until one of the following cases is reached:

- 1st case: no congestion:

As we can see in figure 4, the quantity exchanged ΔQ = QA* - QA = QB* - QB is smaller than the Available Transfer Capacity of the interconnection A-B: there is thus only one price P* = PA* = PB* for both markets.

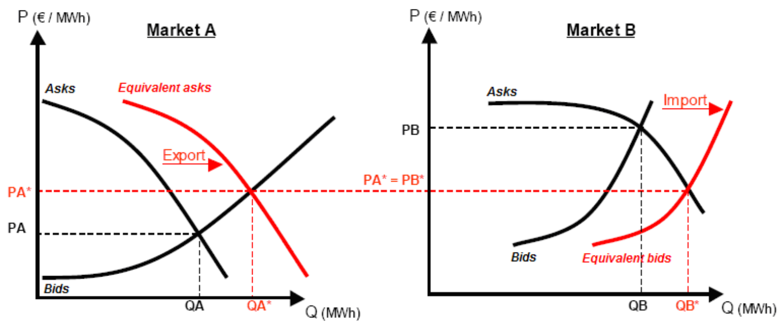

Figure 4: Market clearing by non congested interconnection

- 2nd case: congestion:

As presented in figure 5, the quantity exchanged ΔQ = QA* - QA = QB* - QB is equal to the Available Transfer Capacity of the A-B interconnection: there is one price for each market and (PB* - PA*) x ATC is the congestion rent.

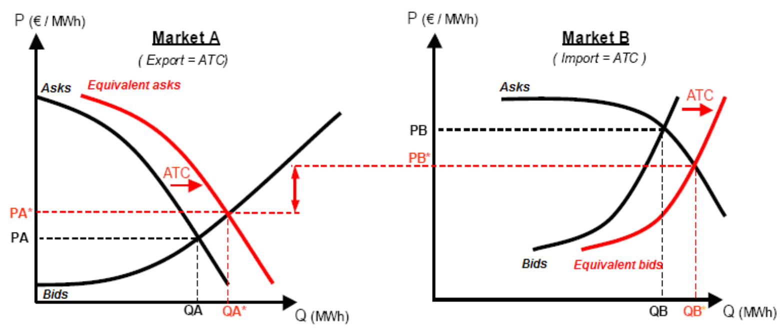

Figure 5: Market clearing by congested interconnection

In both cases, once equilibrium prices have been computed, bids submitted in market X are:

- fully accepted when the offered price is below PX*;

- fully rejected when the offered price is above PX*;

- partially accepted when the offered price equals PX*.

2.3 Theoretical results

Competitive and (static) Cournot equilibrium are computed for each experimental design and each phase following Hobbs (2001). Tables 3 and 4 show results corresponding to experimental designs A and B respectively. Given that the only difference between them is market structure ("concentration") in zone 2, results corresponding to the perfect competition case are equivalent. In these cases the difference between phase 1 and 2 is the occurrence of congestion. In phase 1, both zones have the same price as there is no congestion. In phase 2, price in zone 2 is higher than price in zone 1; the interconnection is congested.

In Cournot case, market structure is important and this can be seen comparing results from experimental design A and B[4]. Cournot prices of experimental design A corresponding to more concentrated market structure in zone 2 are higher than prices of experimental design B with a less concentrated market structure.

	Phase 1 (no congestion)		Phase 2 (congestion)	
	Price zone 1	Price zone 2	Price zone 1	Price zone 2
Perfect competition	20,0	20,0	20,0	25,0
Cournot	43,6	44,0	47,3	52,0
Unilateral market power	NP	25,0	25,0	NP

Table 3: Price equilibrium for experimental design A

	Phase 2 (no congestion)		Phase 2 (congestion)	
	Price zone 1	Price zone 2	Price zone 1	Price zone 2
Perfect Competition	20,0	20,0	20,0	25,0
Cournot	40,8	40,8	47,3	50,0
Unilateral market power	NP	25,0	25,0	NP

Table 4: Price equilibrium for experimental design B

Moreover, the price obtained when only one player exerts his market power is determined; "NP" means that no producer has market power on this zone, namely that no player can unilaterally and profitably raise the market price above the competitive one. It can be noticed that in phase 2, any producer in zone 1 is pivotal (as long as the market price is below 60 €/MWh): under these circumstances, unilateral exercise of market power in zone 1 leads to a leveling of prices in both zones.

3. Experimental process

9 experiences were run with different settings and subjects from various origins, as shown in Table 5.

[4] It is important to note that Cournot equilibrium computations have been done under the assumption that players do not try to "game" transmission pricing [Ralph-Smeers (2006)].

Designation	Experimental design	Subjects origin	Number of experiences led	Number of period per experience
A1, A2, A3	A	Students in engineering	3	60
A4		PhD students & faculty members (non-economists)	1	60
A5		PhD students (economists)	1	60
A6, A7		Students in engineering	2	40[5]
B1	B	Students in engineering	1	60
B2		PhD students & faculty members (non-economists)	1	60

Table 5: Distribution of subject by experimental design and by origins

3.1 The experimental economics laboratory

All experiments were led in the laboratory for experimental economics in Supelec, provided with fifteen isolated computers so that no subject can communicate with each other. Subjects pass their offers and receive results through a web interface represented in Figure 6. All computations and data storage are performed on a server, allowing any numerical analysis of the results ex-post.

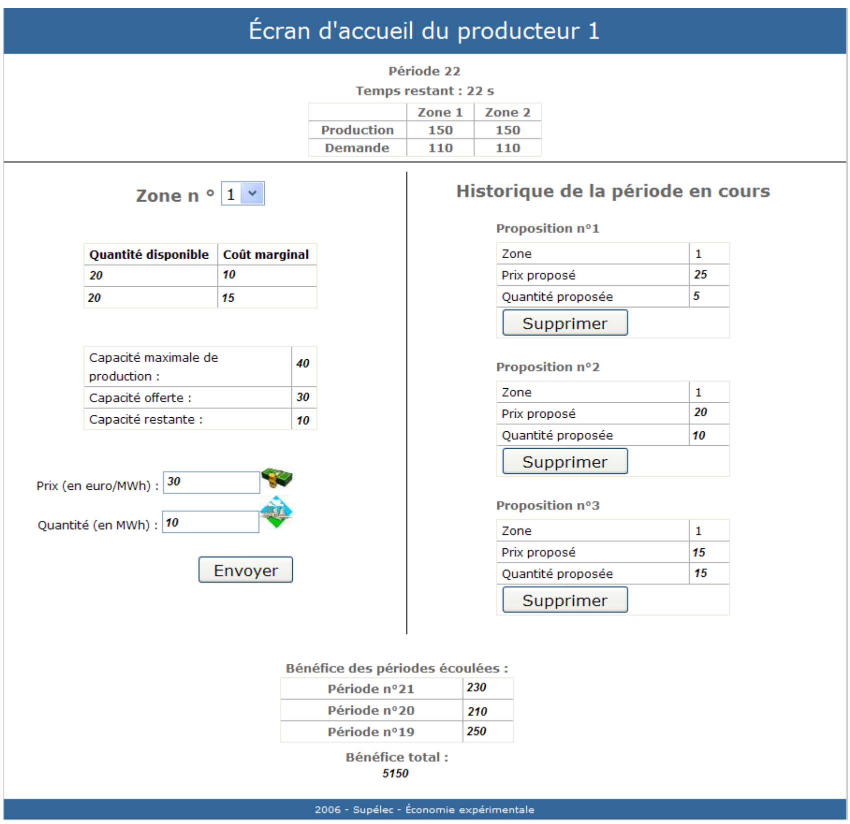

Figure 6: Web interface for experiment subjects

[5] Each phase lasts 20 periods but subjects had previously additional periods for training.

3.2 Instructions

Every experience is foregone by thirty minutes of instructions; the market structure is described and the market design is detailed. Subjects are also taught how to use the interface. Two demonstration periods close the instruction phase in order to ensure that subjects are familiar with the interface.

Subjects are given the phase parameters (demand curves and Available Transfer Capacities) and they are told when each phase begins. They know the total amount of production capacity available per zone (150 MWh) but they are not told others' costs and capacities.

3.3 Experimental progress

The experiment itself lasts from one hour to one hour and a half depending on the number of periods to run. During first periods, subjects have 60 seconds to submit their bids; this term is progressively decreased while subjects are getting trained; however time is never binding during the experience.

Subjects can submit and modify as many bids as many times as they want; nonetheless offered quantities and prices must be integers not only for computational purposes, but also to accelerate price convergence. In addition to information on the market structure, subjects have access to their last three periods' profits, their aggregated profits, results for each previous period bids (fully accepted, partially accepted or rejected) and the price evolution on each market (zone 1 or 2) from the beginning of the experience. There is no transaction cost and production costs are only due for sold units.

4. First results

4.1 Comparison of results with theory

The market price obtained in each zone at the end of each phase is reported in the tables below; when no convergence was reached, the price is the average of the last 20 periods and is indicated by a *.

	Phase 1 (no congestion)		Phase 2 (congestion)	
	Price zone 1	Price zone 2	Price zone 1	Price zone 2
Perfect competition	20,0	20,0	20,0	25,0
Cournot	43,6	44,0	47,3	52,0
Unilateral market power	20,0	25,0	25,0	25,0
A1	21	24,2*	24,7*	26,1*
A2	25,3*	25,6*	28,3*	28,9*
A3	21	21	25	25
A6	21	70	62*	80
A7	21	21	23,8*	28,8*

Table 6: Results for experimental design A

	Phase 1 (no congestion)		Phase 2 (congestion)	
	Price zone 1	Price zone 2	Price zone 1	Price zone 2
Perfect competition	20,0	20,0	20,0	25,0
Cournot	40,8	40,8	47,3	50,0
Unilateral market power	20,0	25,0	25,0	25,0
B1	21	21	31,9*	36,2*
B2	20,8*	20,9*	24,3*	25,6*

Table 7: Results for experimental design B

As it is explained in the following part, a market price of 21 instead of 20 €/MWh is still close to the competitive price. Thus, in the first phase, the market is often close to perfect competition; in the second phase, results are quite similar to the unilateral use of market power. In accordance with the results predicted in part *2.3*, market prices in both zones stay rather close, particularly in phase 2.

However, the market prices are far from (static) Cournot's model expectations, and it is necessary to study individual behaviours in order to understand this divergence.

4.2 A characterization of subjects' behaviour

In order to characterize subjects' behaviour, we propose a classification based on offer functions. Experimental economics offer the possibility to observe the exercise of market power by comparing bids with production costs. As way of example, figure 8 represents the percentage of quantity offered over all periods and experiences for a given markup (equals to offered price minus production cost); all withdrawn units are represented as having a markup of 100 €/MWh. This figure tends to show a massive exercise of market power.

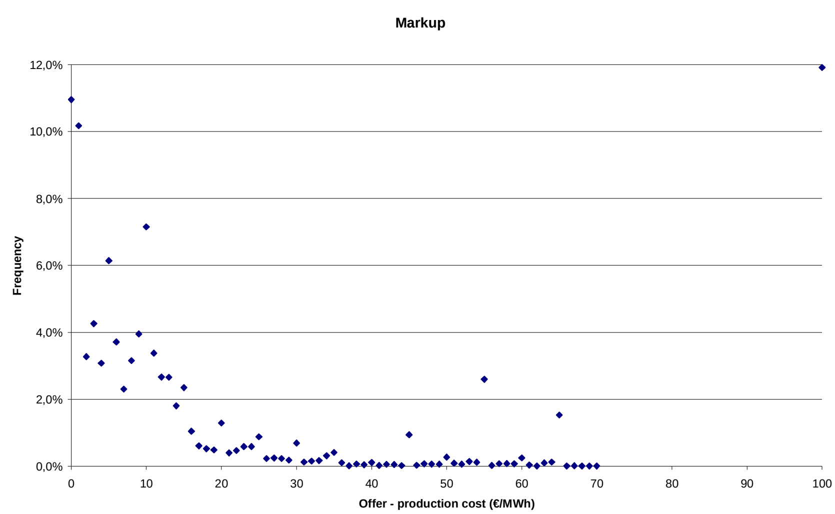

Figure 8: Price markup for all the experiences

However, a more accurate study of the way subjects bid indicates that, since the price can never be below 20 €/MWh, the bids associated with the cheaper part of their production is not significant as far as subjects' behaviour is concerned: the corresponding price can range from their production cost (10 or 15 €/MWh) to the competitive price (20 or 25 €/MWh) without any particular reason nor any consequence on the market price. Thus, only the second half of their available units has been taken into account in figure 9.

Since the offered price must be an integer, a markup equal to 1 is considered as a competitive behaviour linked to experimental design: the subject's profits are similar if his bid is accepted at a price of 20 €/MWh or if it is rejected, it would be zero in both cases. As a consequence he may bid just above his marginal cost. Even under this condition, hardly half of the more expensive units are offered at a competitive price on zone 1, and less than a third on zone 2.

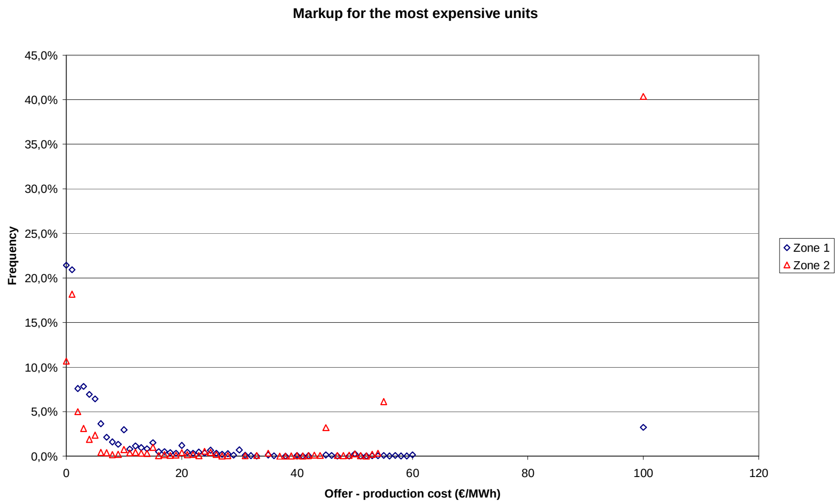

Figure 9: Price markup by zone

To build their offer functions, experiences show that subjects do not only refer to their marginal cost, but also to the previous period market price. Thus figure 10 represents the distribution function of the difference between the offered price and the previous market price, without taking into account competitive bids.

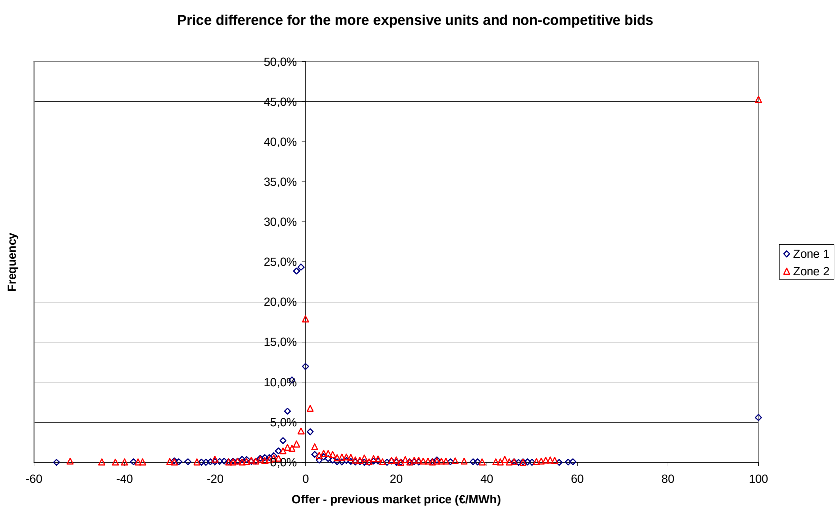

Figure 10: Difference between offered price and previous market price

This figure displays two different behaviours for bids which are not offered at their marginal cost. First, the price can be chosen above the previous market price, or even withdrawn as this is the case for almost half of the non-competitive bids on zone 2; this behaviour, and particularly capacity withdrawal, is an attempt to raise prices and is a feature of a price-marking, or leading, strategy.

Second, half of the non-competitive bids on zone 1 is offered at the previous market price minus 1 or 2 €/MWh. While the competitive behaviour is a price-taking strategy ensuring the player he will sell whenever it is profitable for him and the leader behaviour is a price-making strategy allowing the player to raise market price at a risk of not selling his power, this third one can be qualified as a follower behaviour: by bidding just below the previous price, the subject aims at preventing a price drop whilst limiting the risk for his offer to be rejected. This strategy is a clear incentive for a leader to raise the price punctually even if it is non-profitable in short term: the price decrease will be slow enough for him to earn more during the next periods than what he loses by exercising market power. Subjects can then reach an implicit collusion similar to the one observed in a repeated Stackelberg game, in which the follower plays functions of the leader's previous period decision. An even stronger implicit collusion was observed during the experiment A6 in which the two producers of the second zone implicitly agreed to bid at the monopoly price.

4.3 Impact of players' behaviour on the market price and its evolution

An experiment involving a leader and several followers results in prices significantly higher than the competitive price; moreover, price does not converge, but a dynamic equilibrium is found: price variation is a succession of peaks followed by slow decreases (over five to ten periods).

In particular, when the interconnection is such that all the excess production in zone 1 can be exported into zone 2, congestion leads to a raise of the market price in zone 1 up to its level in zone 2. Simultaneously, as soon as the interconnection is congested, a lack of competition on zone 2 results in a price increase, from which a vicious circle may ensue.

5. Conclusion

Although the experimental design that is presented in this paper is extremely simple, it contributes to a better understanding of the use of market power. This analysis is supported by a classification of the subjects' bids. Three main types of bids could indeed be clearly identified. This possible quantification of each type of bid is an interesting vector toward understanding the evolution of the market price. Future works are expected to depict more precisely the evolution of market price depending on the quantity of bids in each of the three classes.

As its results are significantly different than those obtained using more classical theories, experimental economics could also be useful in order to evaluate the real efficiency of regulation designs.

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