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

F. Petit, Y. Phulpin, M. Saguan and Ph. Dessante
Department of Power and Energy Systems, SUPELEC, 3 rue Joliot Curie, 91192 Gif sur Yvette, France
fabien.petit@supelec.fr, yannick.phulpin@supelec.fr,
marcelo.sanguan@supelec.fr, philippe.dessante@supelec.fr

Abstract

Despite the numerous researches about non perfect 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. The market structure is composed of two regions with a limited interconnection capacity. 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. The demand is controlled by computer. In the both regions, we observe a market price that is different than 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 European internal electricity market has been created through developing transmission interconnection capacities in order to reach a higher degree of competition in regional electricity markets [Boucher-Smeers (2002)]. 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 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.

More precisely, a common trend toward merging of generation utilities has been observed resulting in situations of oligopoly. Indeed, most of European regional electricity markets have 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)]. By 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 (je comprends pas!!!!!!). 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 of human beings 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. Smith… describes in [] this experimental technique, which allows taking into account human decision making in a complex situation. As long as the experiment is simple enough for players to understand their impact and for economists to analyze results properly, any market design can be evaluated.

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 among agents follow an implicit auction market design. We propose a definition of some types of market behaviours, namely ta soeur, follower, 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 back 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 interconnection1. Subjects control only producers, while consumers' actions are determined by a computer according to a predefined demand curve.

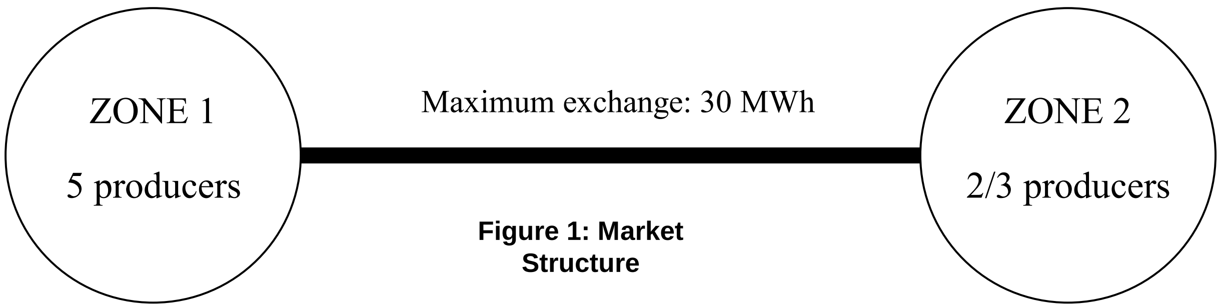


Figure 1: Market Structure

The available production is 150 MWh in each zone. This amount is equitably divided among 5 producers in the 1st zone and 2 (experimental designs A and C) 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	All	Low cost	10	15
		High cost	20	15
2	A and C	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 three or four phases; during which, the demand bids and the exchange capacity are maintained constant. These parameters are exposed in Table 2.

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

Experimental design reference	Phase	Duration (number of periods)	Demand curve		Interconnection
			Zone 1	Zone 2	
A and B	1	30	Profile 1	Profile 1	Yes
	2	30	Profile 2	Profile 2	
	3	30	Profile 2	Profile 1	
C	1	30	Profile 3	Profile 4	No
	2	20	Profile 1	Profile 1	Yes
	3	20	Profile 5	Profile 6	No
	4	20	Profile 2	Profile 2	Yes

Table 2: numerical data beside demands and interconnection

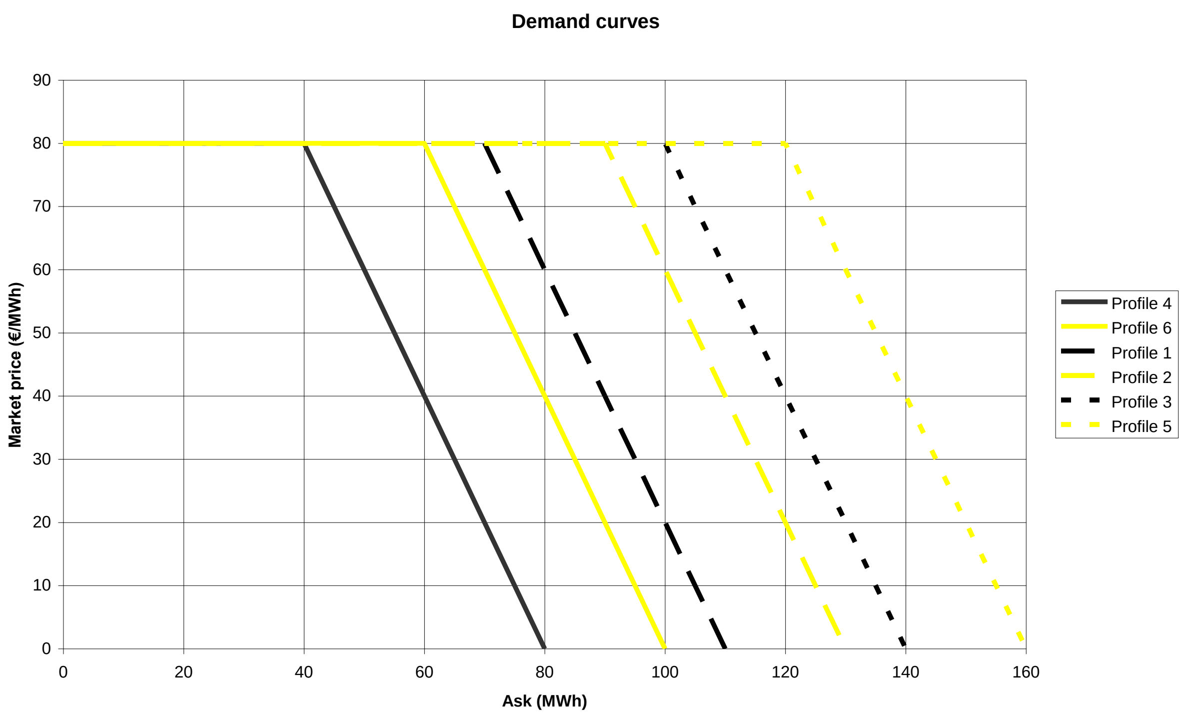


Figure 2: demand profiles (peut on mettre les profils dans l'ordre ?)

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 and so that the interconnection may be congested under competitive bidding. The ability to exercise market power is affected in the experimental design B by splitting of the 2 producers in zone 2 into 3.

In the experimental design C, phases 2 and 4 are similar to phases 1 and 2 from the base case design; in phases 1 and 3, zones are not linked and demand curves are determined from (respectively) profiles 1 and 2 under the assumption that the interconnection is congested from zone 1 to zone 2.

2.2 Market design

The interconnection is regulated with a market coupling mechanism [Référence à ETSO]. 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

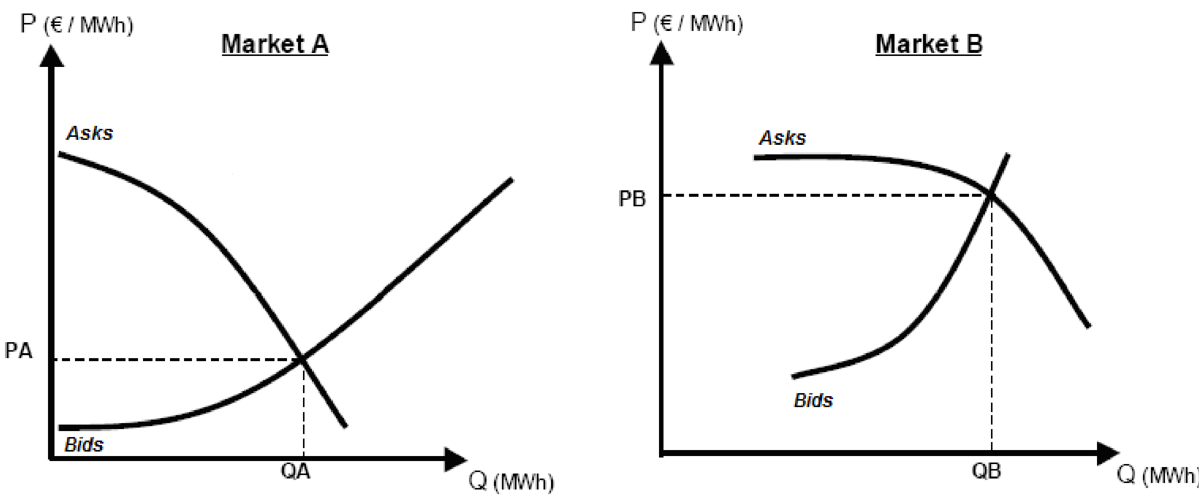


Figure 3: Market clearing mechanism

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.

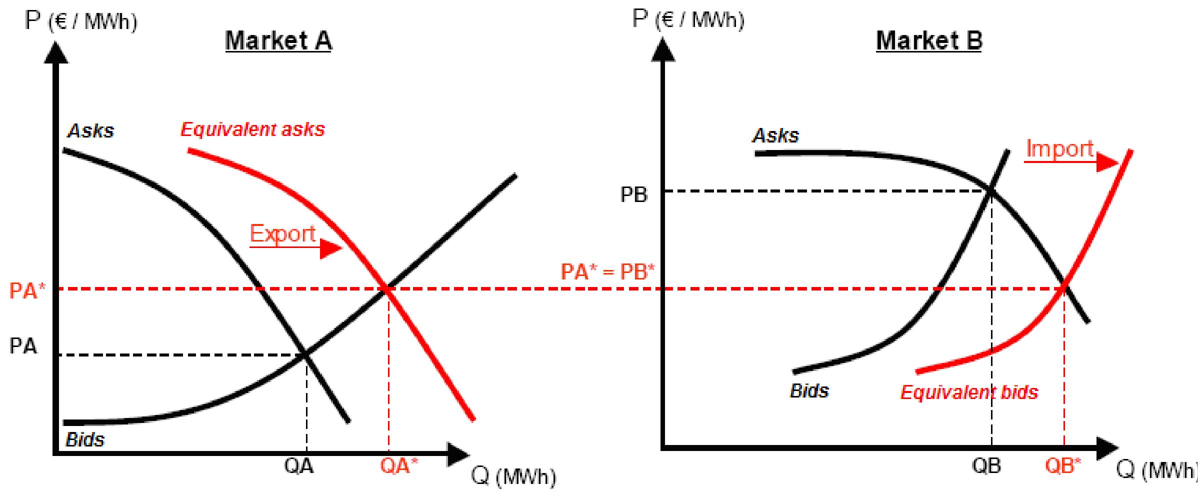


Figure 4: Market clearing by non congested interconnection

- 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.

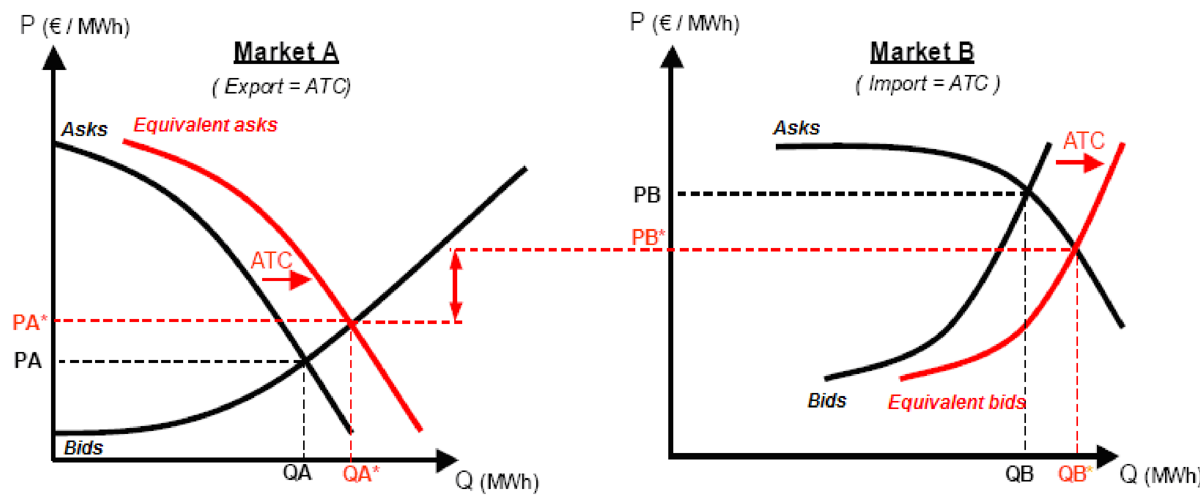


Figure 5: Market clearing by congested interconnection

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

3. Experimental process

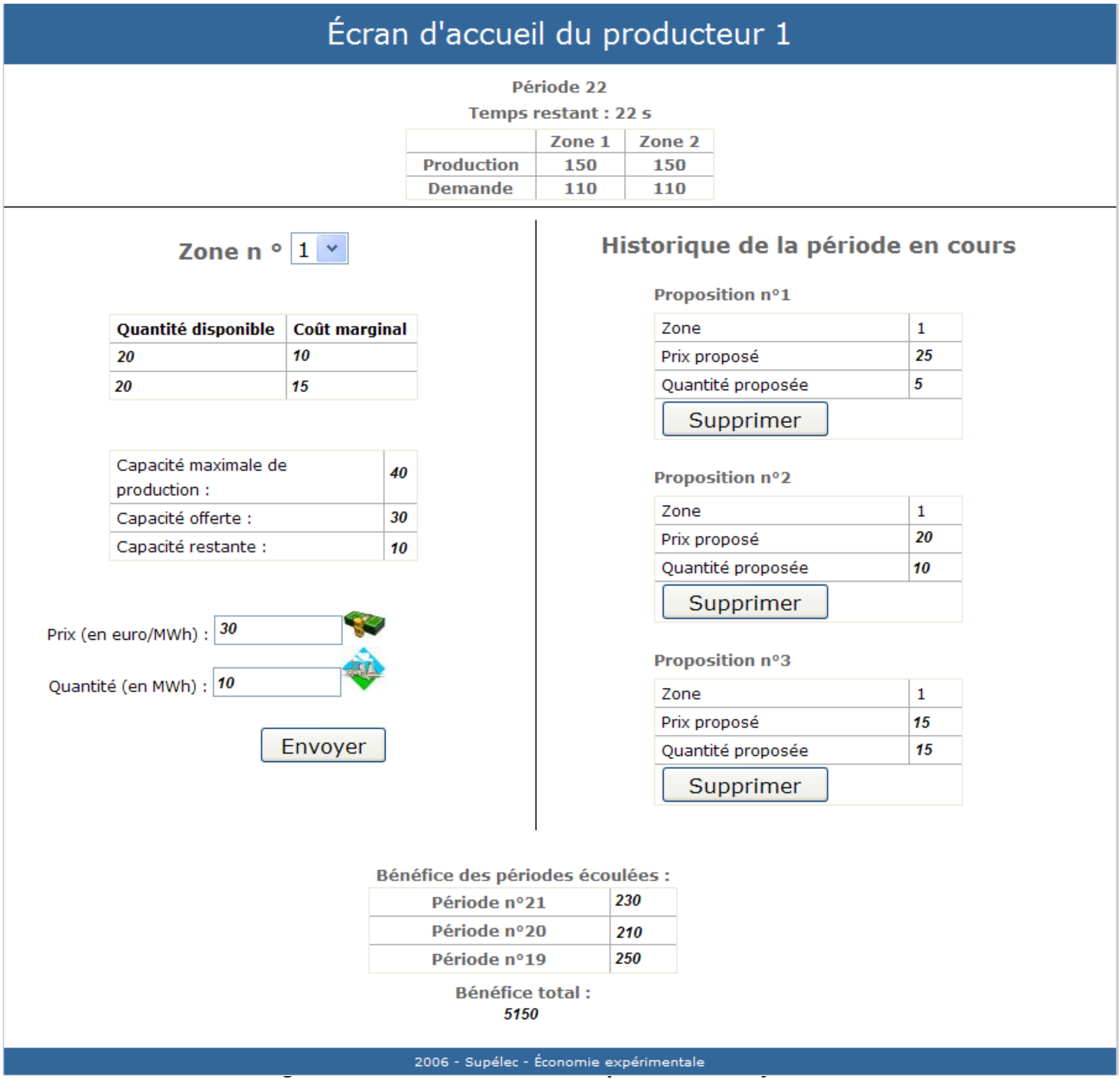
9 experiences were run with different settings and subjects from various origins, as shown in Table 3.

Designation	Experimental design	Subjects origin	Number of experiences led	Number of period per experience
A1, A2, A3	A	Students in engineering	3	90
A4		PhD students & faculty members (non-economists)	1	60
A5		PhD students (economists)	1	60
B1	B	Students in engineering	1	90
B2		PhD students & faculty members (non-economists)	1	60
C1, C2	C	Students in engineering	2	90

Table 3: 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 computers isolated from each other 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.



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 around 90 minutes 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. Results

4.1 Experiment outputs

4.2 Comparison of results with theory

4.3 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.

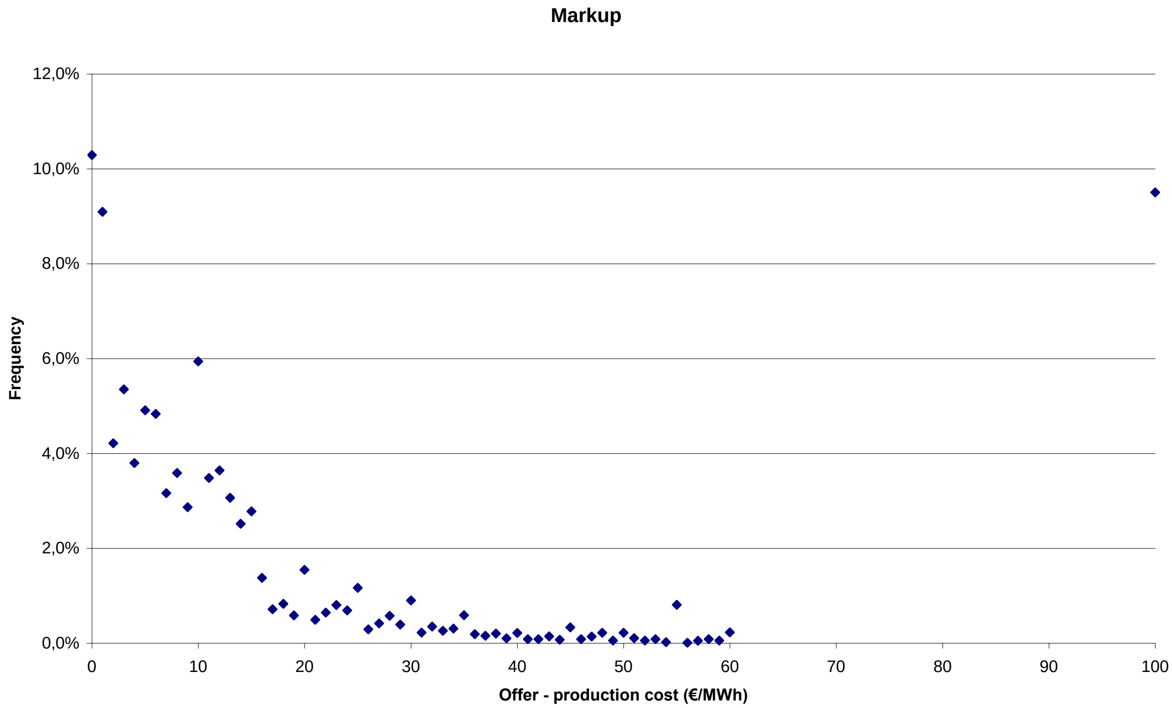


Figure 2: titre

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 2.

Since the offered price must be an integer, a markup equal to 1 is considered as a competitive behaviour linked to experimental design: the player is indifferent between being accepted at a price of 20 €/MWh or being rejected, because his profit would be zero in both cases; as a consequence he may bid just above his marginal cost. Even under this condition, only one third of the more expensive units are offered at a competitive price.

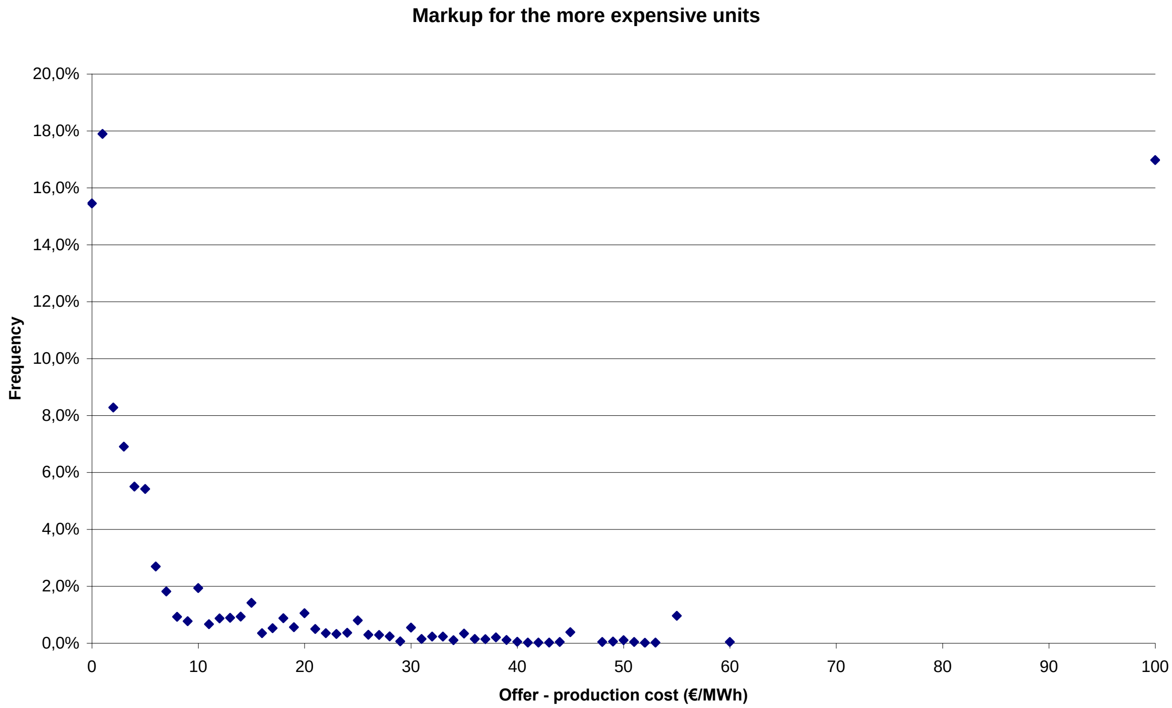


Figure 3

To construct 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 3 represents the distribution function of the difference between the offered price and the previous market price, without taking into account competitive bids.

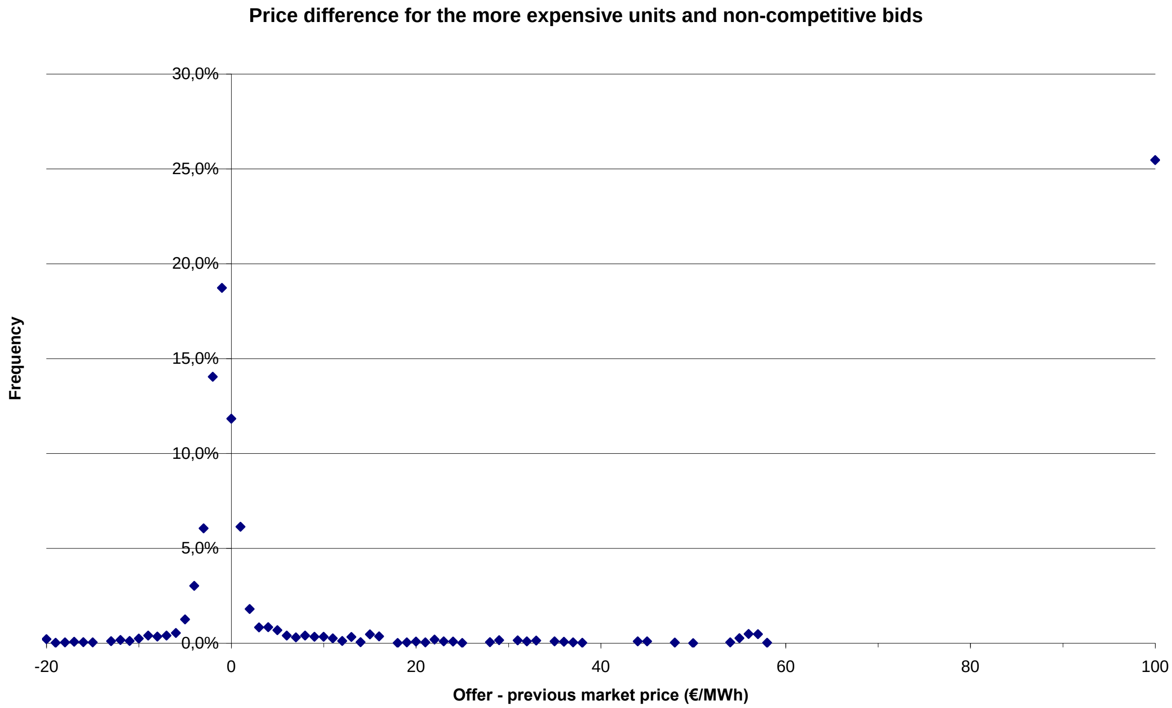


Figure 4

This figure displays two different behaviours. First, one third of the capacity is offered at a price equal to the previous market price minus 1 or 2 €/MWh

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

5. Conclusion

References

Borenstein, S., J. Bushnell and S. Stoft (2000), "The competitive effects of transmission capacity in a deregulated electricity industry", *Rand Journal of Economics* Vol. 31, No. 2, Summer 2000 pp. 294-325;

Boucher, J. and Y. Smeers (2002), "Towards a common European electricity market", *Journal of Network Industries*, vol.3, pp.375-424;

Cardell, J., C. Hilt and W. Hogan (1997), "Market Power and strategic Interaction in electricity networks", *Resource and Energy Economics*, Elsevier, vol. 19(1-2), pages 109-137;

Crampes, C. and N. Fabra (2005) "The Spanish Electricity Industry: Analysis and Prospects", *The Energy Journal Special Issue on European Electricity Liberalisation*, 127-154

Ehrenmann, A. and Y. Smeers (2005), "Inefficiencies in European congestion management proposals", *Utilities policy*, 13(2), 135-152;

Glachant, J-M and D. Finon (2005) "A Competitive Fringe in the Shadow of a State Monopoly: the Case of France", *The Energy Journal Special Issue on European Electricity Liberalisation*;

Hobbs, B. (2001), "Linear Complementarity Models of Nash–Cournot Competition in Bilateral and POOLCO Power Markets", *IEEE Transactions on Power Systems*, Vol. 16, N°. 2, May 2001;

Newbery, D. M. (2005) "Electricity liberalisation in Britain: the quest for a satisfactory wholesale market design", *The Energy Journal Special Issue on European Electricity Liberalisation*, 43-70;

Ralph, D. and Y. Smeers (2006), "EPECs as models for electricity markets", Invited Paper, *2006 Power System Conference and Exposition (PSCE)*, November 2006, Atlanta, USA;

von der Fehr, N-H, E. Amundsen and L. Bergman (2005) "The Nordic market: signs of Stress", *The Energy Journal Special Issue on European Electricity Liberalisation*, 71-98.