INSTITUT NATIONAL DE LA STATISTIQUE ET DES ETUDES ECONOMIQUES
Série des Documents de Travail du CREST
(Centre de Recherche en Economie et Statistique)

n° 2007-27

Bidder Behavior in Multi-Unit Ascending Auctions : Evidence from Cross-Border Capacity Auctions*

L. LAMY [1]

* I thank the Commission de Régulation de l’Energie (CRE) and especially Christophe Gence-Creux for providing the data.

[1] Laboratoire d’Economie Industrielle, CREST-INSEE, 28 Rue des Saints-Pères, 75007 PARIS, France. laurent.lamy@ensae.fr

Bidder Behavior in Multi-unit Ascending Auctions: Evidence from Cross-border Capacity Auctions*

Laurent Lamy†

*I thank the Commission de Régulation de l'Energie (CRE) and especially Christophe Gence-Creux for providing the data.

†Laboratoire d'Economie Industrielle, CREST-INSEE, 28 rue des Saints-Pères 75007 Paris. e-mail: laurent.lamy@ensae.fr

Abstract

We analyse a unique data set on multi-unit ascending auctions, which contains the whole dynamic of bidders' behavior in the IFA-auctions selling the right to use the electric transmission capacity between France and England. First, we document that daily auctions suffer from a great extent of underpricing and that the winning price and the award concentration are varying a lot across time periods. Second, we fail to explain this evidence by winner's curse-driven arguments. The time periods, which are proxying for small changes in the bidding rules, seem to play a significant role in the extent of underpricing. Our empirical findings are consistent with the view that daily multi-unit ascending auctions among a small number of potential bidders allow a large panel of outcomes, in particular very collusive ones.

Keywords: multi-unit auctions, Ascending auctions, Demand reduction, Transmission, Power Markets
JEL classification: D44, L13, L94, G14

Abstract

Nous analysons des données sur des enchères multi-unitaires ascendantes, qui contiennent la dynamique des enchères pour la mise en vente des capacités de transmission électrique entre la France et le Royaume-Uni. D'une part, nous montrons que le prix des enchères journalières est très faible au regard du différentiel des prix entre les marchés correspondants et que les performances des enchères varient considérablement dans le temps. D'autre part, nous ne parvenons pas à expliquer les faits empiriques vis-à-vis des théories relatives au biens à valeur commune. Certaines périodes, susceptibles d'être un proxy par rapport à des modifications des règles des enchères, semblent jouer un role important par rapport à la formation des prix. Nos résultats empiriques sont cohérents avec la perspective que les enchères multi-unitaires journalières au sein d'un faible nombre d'acteurs peuvent soutenir un large spectre d'équilibres, en particulier des équilibres collusifs.

Mots-clés: Enchères multi-unitaires, Enchères ascendantes, Réduction de la demande, Transmission, Marchés de l'électricité
Classification JEL: D44, L13, L94, G14

1 Introduction

The use of multi-unit sealed-bid auctions is widespread for a long time. Examples include financial and monetary instruments, as the treasury debt or foreign currency, and wholesale power markets as in the British Pool from 1990 to 2001. The simultaneous ascending auction was first introduced in 1994 for radio spectrum licences in the U.S.. In some European countries as U.K. and Germany, it has been used to auction licences for third generation spectrum (UMTS). Evidence on this format is scarce and mixed: its performance remains largely to be discussed. We analyse the performance of multi-unit auctions for transmission capacity in Power Markets using a unique data set provided by the Commission de Regulation de l'Energie (CRE), the french regulator of electricity and natural gas markets. The data set contains the chronology of the actual bids submitted by each bidder as well as the auction awards to the bidders in over 1500 IFA-auctions that were held during the period 2001-2005 for the France-England Interconnector.[1] Our data set consists of multi-unit ascending auctions for which the complete set of submitted bids (about 40,000) is available.

IFA-auctions sell the rights to use the transmission capacity in one given direction. IFA products are then essentially financial options that are valuable to use if the price differential has the suitable sign. From the perspective of small pure financial traders, it can be viewed as a pure common value auction. In a similar framework, studies of securities markets have found that new issues of debt or equity tend to be underpriced in primary markets relative to its underlying 'true' value [9, 36, 37, 30, 29]. From a theoretical point of view, this gap has been modelled as an equilibrium behavior by Milgrom and Weber [28]. With a large number of bidders, Pesendorfer and Swinkels [33] show however that the price converges in probability to the true value of the object in a uniform sealed bid auction, which is consistent with the empirical evidence that underpricing remains small in security primary markets. On the contrary, the distribution of the number of bidders in IFA auctions is much tighter: the average number of participants is 4 in daily auctions. Bidders are also interacting repeatedly on a daily basis. Furthermore, the ascending multi-unit auction also seems to be more prone to collusion than the uniform sealed bid auction as suggested by the very uncompetitive equilibria derived by Ausubel and Schwartz [5] and Bruso and Lopomo [8]. The GSM spectrum auction analyzed by Grimm et al [18] is a clear cut example of a low price outcome in a multi-unit ascending auction, whereas similar incidents were observed in the FCC spectrum auctions in the US [10]. Finally, prices in power markets are much more volatile which suggests a greater importance of the winner's curse. Altogether, opportunities

[1] The term IFA corresponds to the abbreviation for France-England Interconnector in French.

for tacit collusion are large in IFA-auctions.

There is a huge empirical literature on auction data. Since the pioneering work of Donald and Paarsch [12], a new strand identifies and estimates the Bayes-Nash equilibria derived from the auction theory literature. In most sealed-bid formats, the distribution of bidders' types can be recovered from the auction data under weak assumptions, allowing therefore counterfactuals and thus comparisons between different possible auctions formats.[2] This approach has been very fruitful for single-item auctions. In multi-unit auctions, identification first comes up against the existence and uniqueness of equilibria. Nevertheless, for uniform and discriminatory multi-unit auctions, some methods have been developed from the share auction model of Wilson [38]: structural elements are estimated from the Euler-Lagrange necessary condition from bidders' optimization problem in Hortaçsu [19] and Février, Préget and Visser [15]. For electricity markets, Wolak [39] develops a similar methodology for the supply function equilibrium concept of Klemperer and Meyer [24]. On the other hand, auction theory does not provide any solvable equilibrium predictions nor first order conditions leading to exploitable moment restrictions for the multi-unit simultaneous ascending auction. The non-stationary nature of this dynamic auction game prevents any structural approach as in Jofre-Bonnet and Pesendorfer [21] where bidders are assumed to adopt markovian strategies. In some application, it could be reasonable to reduce the set of strategies used by the bidders in the multi-unit simultaneous ascending auction, e.g. by restricting attention to proxy-bidding (also called straightforward bidding, see Milgrom [27]) where strategies are isomorphic to a decreasing demand curve as in the uniform price auction. Nevertheless, the quantities demanded by the bidders are not generally a decreasing function of the price in the IFA-auctions excluding thus any structural analysis where the ascending auction is considered as strategically equivalent to the uniform price sealed-bid auction.

For those reasons, we adopt a reduced form approach where our objective is to provide a descriptive analysis of the auction data and to discuss whether the regularities match with the intuitions provided by auction theory. Our aim is to shed some light on the striking features of the data: first, the gap between the final prices for daily and long term contracts, the average prices in the former being about 30% smaller than in the latter ; second, the great variability across periods of time of the average theoretical profit per MW made by the winning arbitrageurs.

The paper is organized as follows. Section 2 describes the IFA products, how they are sold and their position in the french and british power markets. In section 3 we provide a description of the data set and some

[2]See the survey of Athey and Haile [3] about structural econometrics of auction data using nonparametric approaches that do not impose any structure on the distribution of types.

summary statistics. Section 4 presents some intriguing evidence. Long-term auctions considerably outperform daily auctions in term of revenue. Furthermore, daily auctions present a great inter-temporal instability in term of profitability but also in the way the price differentials explain the winning price. Section 5 reviews various theoretical scenarii that may explain the data. Section 6 provides descriptive statics of the data. We break the time period studied into two categories that proxy for the changes in the bidding rules. We analyse separately six endogenous variables: four concern the outcome of the auction (the weighted average winning price, the winning prices' spread, the number of winners and the HHI index) and two concern the dynamic of the auction (the average number of bids submitted per participant and the average number of bids whose last digit is zero or five). We then run regressions of these endogenous variables on the exogenous variables -consisting of price differentials, a corresponding volatility measure, the quantity auctioned and time dummies- and also on the participation decisions. The total number of participants and more generally each individual participation decisions are arguably endogenous. Lagged values of these regressors are employed as instruments in two-stage least squares estimation. We test whether time period classifications have a significant impact on the endogenous variables after having controlled not only for the exogenous variables (in particular the ex-post theoretical value of the capacity) but also for the heterogenous participation's decisions of the bidders across time periods, our data set allowing us to follow a bidder not only within an auction but also from auction to auction. The results are broadly consistent with switches in the bidders behaviors that could be rationalized by tacit collusion and by small changes of the bidding rules. Section 7 discusses the links with the previous literature on the role of interconnectors in power markets and the empirical and experimental literature on multi-unit ascending auctions. Section 8 concludes.

2 Auctions Rules and Institutional Details

The economic and finance literature is not familiar with the auctions for interconnector capacity. We then present in details the institutional setting.

The IFA is a 2,000 MW high voltage interconnector connecting the French and British transmission systems. It is jointly operated by National Grid and RTE (Réseau de Transport d'Electricité), respectively the English and the French Transmission System Operator. Historically, interconnectors in Europe have been build for reliability reasons: an unforeseen shock in one country could be absorbed by his neighbors. However, the IFA has been the first interconnector that has been used to exploit the price differential between both countries: due to an overcapacity in nuclear energy, the marginal cost in France was traditionally lower than in the rest of Europe, making thus

France a natural exporter all over Europe and so in England. Historically, the transmission capacity was attributed through a long term contract that gave EDF exclusive rights over export to the UK. This contract expired in March 2001. RTE and National Grid have opened the interconnector to third parties by auctioning rights to use the interconnector from April 01 of 2001. The capacity is sold simultaneously but separately in the directions 'England to France' and 'France to England' under different contracts covering different durations: tri-annual, annual, seasonal, quarterly, monthly, two days (for the weekend) and daily. The two latter are referred to as short-term auctions, whereas annual, seasonal, quarterly and monthly auctions are referred to as long-term auctions. Table 1 reports the number of auctions held for each duration and both directions. We also report the number of strategies and the number of bids observed for each category. For example, the 73 monthly auctions in our database correspond to the observation of 480 bidding dynamics and 7,419 bids. The amount to be sold, the date of auctions and the planned outages are announced each year. The availability has consistently exceeded 95% per year. Two open and non-discriminatory processes are used to sell capacity right: "tenders" and auctions. "Tenders" are what is referred to as the first price sealed bid auction in the economic literature. The first and unique tri-annual contract is the only contract that has been auctioned in this way. "Auctions" are a multi-unit ascending share auction that is described below in more details. Participation is restricted to eligible users that have signed the IFA User Agreement. Eligibility basically requires that the user has arranged access to the respective transmission system of UK and France. Up to June 2005, 21 different users have participated in IFA auctions in the 1,581 auctions recorded in our database.[3] Participants include firms with generation capacity, distributors and pure traders.

The purchaser of 1MW of transmission capacity for one day and a given direction owns the right to use the capacity in this direction according to the load profile he wants for that day provided that the power transmitted never exceed 1MW. Thus capacity rights are essentially a bundle of options for each time increment of the load profile. Those rights are subject to a "use-it-or-lose-it" rule: by 07:00 a.m. France local time[4] on the day of the daily auction selling the rights for the contract day, owners of units for that contract day (previously sold in the various periodic auctions) announce whether they intend to use the capacity and lose their rights if they indicate that the capacity will be unused. Nevertheless, the IFA access rules do not

[3] The original users 18 and 19 in the database have been bundled together as a single user identified below as user 18*. The reason is that those users are belonging to a common consortium since april 2000 and that their participation decisions in the IFA-auctions seem to be coordinated: user 18 has participated in the auctions from february 2002 to december 2005, whereas user 19 participates from january 2005. Moreover, the bidding statistics of those users are very similar.

[4] Henceforth, all time reference are expressed in France local time.

include any provisions intended to ensure that actual use reflects the notified level of use.[5] Consequently, the actual rules seem to leave some room for capacity preemption as in Joskow and Tirole [22]. Unfortunately, the usage of the purchased capacity is not recorded in the data. Owners of rights for long-term capacity are able to resell some part of it either through a reassignment procedure (a subletting contract that should be notified not later than 05:00 p.m. the day before the daily auction) or a reallocation procedure. In this latter, the owner of a contract that covers the duration contract that will be sold can reallocate some of his units at the auction and receive the prices achieved in the auction.[6] Nevertheless, for the years 2003 and 2004, only a total negligible amount of 500MW has been reauctioned in this way in the direction France to England.

[5]see the IFA User Guide, Issue 5, December 2005.

[6]e.g. the owner of an annual contract can reauction his rights in monthly or daily auctions

Table 1: IFA Auctions for the period April 01 of 2001 to July 01 of 2005

	France to England			**England to France**			**Subtotal**		
	Auctions	Participants	Bids	Auctions	Participants	Bids	Auctions	Participants	Bids
Daily	899	3,841	17,138	489	1,513	6,055	1,388	5,354	23,193
Weekend	61	293	2138	1	1	1	62	294	2,139
Monthly	36	247	2,694	37	233	4,725	73	480	7,419
Quarterly	14	105	1,700	14	95	1,287	28	200	2,987
Seasonal	4	27	415	4	23	497	8	50	912
Annual	10	68	1,360	10	62	1,177	20	130	2,537
Tri-annual	1	2	2		0		1	2	2
Subtotal	1,026	4,583	27,478	555	1,927	11,711	1,581	6,510	39,189

Note.-The columns Auctions, Participants and Bids are reporting respectively the total number of Auctions, Participants and Bids in the database.

2.1 Chronology of the IFA-Auctions in the French and the British Power Markets

Each weekday, an auction is held for the capacity available for the following day, simultaneously for each direction. No auction is held on weekends. On Friday, three auctions take place sequentially for capacity available for the following Saturday, Sunday and Monday. By 08:00 a.m. on the day of a daily auction, information on interconnection capacities for the day to be contracted are published. In particular, the capacity sold in previous long term auctions and that is not used is made available for the daily auction process. Then the auction takes place between 08:45 and 09:15 a.m.. The results of the auction are published within 30 minutes of the close of the auction. Contrary to the former English Pool (1990-2001), there is no mandatory market in France and UK nowadays: bilateral contracts can be freely signed. On such a liberalized market, participants can act on a variety of markets. The bulk of the transactions comes from the over-the-counter (OTC) market (about 20,000 MWh per month in the first quarter of 2006 for France). Due to this high volume of transactions, prices data are supposed to be more accurate in those markets and it is those utilized by the CRE from the cotation agency Platts. The alternative is the organized markets or Power Exchanges that have been build in some countries to promote competition. In this perspective, Powernext has been launched in 2001: a day in advance, electricity is traded according to a uniform double-auction. In 2006, Powernext Day-ahead and Futures exceed 50 traders and the traded volumes are increasing steadily (about 2,000 MWh per month in the first quarter of 2006). The fixing of the Day-ahead market is at 11:00 a.m., i.e. after the disclosure of IFA auctions results. In the same way, APX UK is an organized market providing a continuous trading system which closes at 10:30 a.m.. Finally, from 12:00 am to 02:00 p.m., interconnector's users submit and revise their nomination for the IFA capacity.

2.2 The value of the Interconnector's capacity: a call option on price differentials

In this subsection, we present a simple theory of the value of the Interconnector in term of price differentials. The naive approach, that has been used in the first studies of the European Interconnectors as in Boisseleau [6] (pp. 275-286), considers that the value of capacity rights corresponds to a call option on the differential of average daily prices. This approach leaves out the fact that a capacity buyer is free to use it according to his desired intra-day profile and that the price differential fluctuates deeply intra-day. Actually there are large intra-day fluctuations between imports and exports as shown in Figure 1 where a typical business day transfer is depicted. In the same way, it would be absurd to gauge the price of monthly auctions with the monthly average price differentials. Indeed, in the explicit auctions organized by RTE at the other french interconnections, daily capacities are put up for auction per hourly period, whereas Power Exchanges (e.g. Powernext, APX UK) are organized on a 24 or 48 daily slots basis.[7]

Daily capacity rights are essentially a bundle of (European) call options on the hourly price differentials between France and England for a given day and with a null strike price. In the following, we consider that the day is fixed and we drop any reference to it in the notation. Denote by $(p_t^i)_{1 \leq t \leq 24}$ the vector of hourly prices per MWh in zone i where i equals to E and F respectively for England and France. Let $d_t^{i \Rightarrow j} = p_t^j - p_t^i$ be the price differential between zone i and zone j. The expected payoff for a daily right on 1MW of transmission capacity from zone i to zone j is:[8]

$$\Delta^{i \Rightarrow j} = \mathbb{E}[\sum_{t=1}^{24} (d_t^{i \Rightarrow j})^+]$$

Without information asymmetry between bidders and if the explicit auctions were competitive, then the winning price, denoted by $P^{i \Rightarrow j}$, should be equal to the theoretical value of the Interconnector $\Delta^{i \Rightarrow j}$.

A monthly capacity right for 1MW is formally equivalent to the bundle of the daily capacity rights for 1MW for each day. Thus, if daily and monthly capacity rights were sold simultaneously, then the arbitrage condition would imply that the price for the monthly auction should be equal to the sum of the prices for the daily auctions. The same applies for the other long term auctions.

2.3 The Auction mechanism

The auction mechanism is an ascending auction through a screen-based system that guarantees the anonymity of the bids submitted. At any time, a bidder is free to submit any price-quantity pair. Those offers are unconditional and irrevocable offers among which the auctioneer selects the best competing ones: the provisional winning allocation is such that capacity is awarded to the bidder offering the highest price, then to the bidder offering the next highest price, and so on until the quantity offered is fully subscribed. Moreover, each successful bidder pays the price he has bid. Note that the seller may select several offers from the same bidder as it happens in about 10% of the daily auctions. This winning bidder has then to pay a different price for each of his selected offers. Thus the provisional allocation rule corresponds to a pay-as-bid pricing rule. Nevertheless, it is a bit misleading since the dynamic structure of the mechanism makes it correspond

[7] See the various capacity access rules for the France-Belgium, France-Spain, France-Italy and French-German interconnections published by RTE (Réseau de Transport d'Electricité).

[8] For a real number x, x^+ designates the maximum between 0 and x.

to a uniform pricing rule. As regularly as possible, the auctioneer publicly reveals the prices and volumes submitted by all parties and the provisional allocation. Then the bidders are permitted to submit new bids at any time provided that the auction is not closed. A bidder is allowed to resubmit a bid not only because one of his previous offers has been outbid but also because he wishes to bid for more units. Thus bidders can submit any demand schedule.

Various rules have been experimented for the closing rules for the long and short-term auctions whose closing rules may have differed in some periods. At the beginning, the end of the auction was fixed in time. Since March 2002, long term auctions last 30 minutes and continue as long as bids are placed every two minutes. For daily auctions, a random closing rule has also been used.[9] The last bid to be accepted may receive only a part of the quantity demanded. In the case of a tie between several offers at the lowest price, then the allocation is made according to a first-come-first-served basis, the time at which each bid is submitted being recorded.[10] Each bid submitted is published anonymously in the electronic system and the new selected allocation is computed. The quantities are expressed in MW with the increment of 1MW. The prices are submitted in Euros per MW for the length of the contract and must be to a maximum of two decimal places. In the daily auctions, a reserve price of 3 Euros per MW applies.

We emphasize that the ascending multi-unit auctions analysed previously in the empirical and experimental literatures are differing from the IFA auctions in an important way. In the latter, bidders are not constrained to submit nondecreasing demand schedule. On the contrary, the experimental literature [2, 13, 23] implements clock auctions for homogenous items where bidders should reduce their demand as the price raises. Similarly, in FCC or UMTS spectrum auctions, some 'activity rules' are prevailing which are roughly imposing that as the price raises the demand of a buyer should fall, as it is also usually imposed in multi-unit sealed-bid uniform auction.

3 Data

3.1 Bid Distribution Data

For this study, the auction data set has been obtained from the CRE under a confidentiality clause. The raw data set contains 39,189 bids that have been submitted for the period April 01 of 2001 to July 01 of 2005. Thus our database contains the whole dynamic of each auction. For example, 2,987

[9] We have tried unsuccessfully to obtain the precise dates where closing rules have changed.

[10] Unfortunatly, our database does not contain the time stamp of the bids. This dimension of the auction dynamic may reveal interesting patterns as in Roth and Ockenfels [35, 31].

bids have been submitted in the 28 quarterly auctions, which also correspond to 200 bidding strategies. The number of participants and the number of bids in the various durations are reported in Table 1 which shows a clear gap between long- and short-term auctions: there are much more participants in long-term auctions and bidders submit more bids. Each auction is characterized by the period of validity of the contract and its direction and also the date on which the auction was issued (this information is provided at least in the case where the same contract was sold sequentially at different dates). Each bid is characterized by the identity of the bidder, the price offered in Euro per MW, the quantity demanded in MW, the quantity obtained and also the rank of the time stamp of the bid. The bidder identifier remains constant not only within the auction but also from auction to auction. The two-digit bidder identifier from 1 to 22, denoted by ID, protects the identity of the bidder.

We then construct variables that characterizes the bidding dynamics and its outcome. For each auction, we construct the variables PRICE and QUANTITY which are respectively the average winning price and the total quantity sold. The average winning price PRICE is the average price of the highest offers of each winning bidder.[11]

Our data set is a record of all bids submitted and not of the IFA auctions themselves. In particular, for some directions and some days, no bids have been submitted and we can not distinguish whether the auction has been cancelled (e.g. due to a planned outage) or the reserve price has been actually binding. Since an outage involves a cancellation of the auction in both directions whereas a binding reserve price in one direction is related to a low price differential in that direction and thus a high differential in the opposite direction since price differentials are inversely correlated, we decide to classify the data in a way such that: the event "no bids in both directions" for one day corresponds to a period of REPAIR. This case corresponds to 222 days for the period from February 02 of 2002 to May 31 of 2006. On the contrary, if the auction in the opposite direction is held then we consider that the event "no bids submitted" corresponds to a null participation.[12]

The number of participants in the auction is measured by PARTICIPANTS which reports the number of different IDs that have submitted bids if the auction has been held.[13] We should be cautious with this measure since a bidder can participate in the auction without submitting any bid

[11]Thus it is not weighted by the quantity obtained by each bidder. Specifications with PRICE being equal to the lowest or the highest winning offers are leading to similar results.

[12]The 222 days with REPAIR equal to 1 may seem to raise a contradiction with the claimed level of availability of the link. Nevertheless, the link comprises of four individual cables of 500MW such that the cancellation of a daily auctions does not mean that the whole link is unavailable. See the appendix C for more details.

[13]If the identity of some bidders is missing, we assume that it corresponds to a unique bidder that has not been previously identified in the auction.

since no activity rules have been set as in the FCC auctions. As an example of an erratic bidding activity, in the annual auction held November 03 of 2004 for the capacity from France to England, bidder 14 has submited the price-quantity offer $(700, 100)$ and then has stopped to bid until 57 bids have been submitted and finally has re-entered the auction as an active bidder between 102,000 and 108,460 where he has submitted 5 bids for the quantity 40 MW. This is a low bidding activity for an annual auction where the average number of bids per participants is above 16.

The aggregate auction purchases in the daily auctions for the direction France to England correspond to 15 Millions of Euros for the period in our data set. As shown in Table 2 at a disaggregate level, the total amount paid and quantity purchased by each bidder in daily auctions are very concentrated: about three quarter of the market both in terms of prices and quantities are in the hand of four bidders 5, 8, 13 and 18. This asymmetry will lead us to test in section 6 whether each of these bidders has an influence on the final outcome.

Table 2 reports additional aggregate information for each bidder. The date of entry and the date of exit -left empty if the bidder has participated to an IFA auction in june 2006- are given. The column 'proportion won conditional on participation' gives the ratio of the auctions where a given bidder has purchased some capacity among the auctions he has submitted an offer. The broad pattern is a ratio in the range 30-50% and such that 'big purchasers' have a higher probability to purchase capacity conditional on participation.

Table 2: IFA Auctions April 2001-May 2005, France to England

ID	Number of Competitive Auctions	Proportion won conditional on participation	Aggregate auction purchases (Euros)	Aggregate quantities (MW)	Weighted average estimated profit	Date of Entry	Date of Exit
18*=18+19	559	0.419	4,588,912	50,347	42.8	02/02/2002	
8	424	0.441	2,782,807	33,212	61.1	02/02/2002	
13	636	0.601	2,386,200	64,398	47.4	01/04/2003	
5	424	0.474	1,917,982	22,192	58.2	01/01/2003	
7	272	0.290	482,746.9	7,739	91.9	05/02/2004	
11	94	0.319	418,140.2	4,492	54.4	02/02/2002	01/01/2004
10	144	0.222	408,226.9	3,564	46.4	24/10/2002	
3	123	0.309	368,833	3,412	43.8	23/04/2004	
2	133	0.376	338,678.4	6,620	58.2	02/02/2002	
12	232	0.220	292,548.3	3,748	80.3	20/04/2002	
9	40	0.375	224,111.9	2,345	74.2	03/02/2002	23/10/2002
16	75	0.44	180,202.3	3,008	65.1	17/12/2004	
1	145	0.221	77,116.36	2,513	41.6	05/03/2004	
4	208	0.139	46,107.26	2,022	61.4	03/02/2002	
17	20	0.75	32,582.22	2,890	25.0	16/02/2002	01/07/2002
21	27	0.556	22,894.61	970	31.2	15/03/2002	01/07/2002
20	16	0.25	20,264.46	248	48.0	16/03/2002	01/04/2005
22	1	1	63	1	771.9	24/03/2005	
6	2	0.5	3.5	1	103.3	26/02/2005	
14	3	0	0	0	.	01/04/2002	
15	0	.	0	0	.	01/06/2004	
missing	263	0.293	336,471.8	4,715	37.7		
TOTAL			14,924,936	218,737			

Note.-Bidders are ranked according to their total purchases in the daily auctions. However that it does not correspond to the rank of their total purchase in all IFA auctions: some of the largest bidders in the long-term auctions, as bidder 2, are “small” in the daily auctions.

3.2 Ex-post Profit Estimation from Market Prices

Since the markets are decentralized, there is no single measure for the prices. In a preliminary step, we have used the hourly prices from Powernext and APX UK corresponding respectively to the 11 a.m. fixing and the closing price at 10 p.m..[14] The ex-post theoretical profits based on those prices were a bad predictor for the auction price. We then decide to use the prices from the cotation agency Platts that are considered as being more accurate and thus used by the CRE. Nevertheless, it means that we give up the use of hourly prices.

Let us introduce a proxy for $\Delta^{i\Rightarrow j}$ that we will use in the regressions. Denote respectively by $\overline{p}^i_{Peak}$ and $\overline{p}^i_{OffPeak}$ the average prices in the Peak and Off-Peak period in zone i where the Peak period designates the period from 08:00 a.m. to 08:00 p.m. and the OffPeak period designates the complementary period. If the sign of the price differential remains constant intra-period then the following equalities would be satisfied:

$$\Delta^{i\Rightarrow j} = 12 \cdot \left((\overline{p}^j_{Peak} - \overline{p}^i_{Peak})^+ + (\overline{p}^j_{OffPeak} - \overline{p}^i_{OffPeak})^+ \right)$$

In general the sign of the price differential may change intra-period. Indeed, the sign of the price differential changes between Peak and OffPeak periods in 30.4% of the days in our data set. From the convexity of the function $x \to x^+$, the following inequality is satisfied very generally:

$$\Delta^{i\Rightarrow j} \geq 12 \cdot \left((\overline{p}^j_{Peak} - \overline{p}^i_{Peak})^+ + (\overline{p}^j_{OffPeak} - \overline{p}^i_{OffPeak})^+ \right)$$

In particular, the difference of the average daily prices is a lower bound for the value of the interconnector. In this study, we report the results with the proxy $12 \cdot \left((\overline{p}^j_{Peak} - \overline{p}^i_{Peak})^+ + (\overline{p}^j_{OffPeak} - \overline{p}^i_{OffPeak})^+ \right)$ which is from now on referred to as VALUE. The daily price differential from zone i to j is defined as $\frac{\left((\overline{p}^j_{Peak} - \overline{p}^i_{Peak})^+ + (\overline{p}^j_{OffPeak} - \overline{p}^i_{OffPeak})^+ \right)}{2}$: it corresponds to the average value in Euros per MWh of transfers from zone i to zone j.

VALUE is estimated from the indicative quotes of OTC transactions reported from Platts. Those quotes are provided to us by the CRE: for each weekday we have the prices in Euros per MWh of a Base contract and a Peak contract for both France and England. For saturday and sunday, only the base contract prices are available: we then set $\overline{p}^i_{Peak} = \overline{p}^i_{OffPeak} = \overline{p}^i_{Base}$ for greater convenience. The base contract (respectively the peak contract) corresponds to a constant profile over the whole day (from 08:00 am to 08:00 pm). In France, the transmission use of system charge is a postage charge for the whole network. Thus the available prices correspond to 1MWh anywhere in the network. On the other hand, the transmission use of system

[14] We would have preferred to use hourly prices fixed just after the closure of the IFA auction for both countries. Such data is not available.

Table 3: Day ahead prices from Platts, price differentials

	2001	2002	2003	2004	2005	2002/ 2005	Std. Dev.	Min.	Max.
Daily Price (MWh):									
England	30.4	25.1	28.7	32.8	44.6	30.8	11.3	9.84	149.1
France	29.1	21.5	29.4	28.3	39.8	28.0	11.8	6.25	150
Price differential (Euros/MWh):									
France to England	4.47	4.64	2.86	5.01	5.77	4.1	5.1	0	40.0
England to France	3.37	1.08	3.54	0.49	0.94	1.4	3.5	0	56.7

charges under the NETA (New Electricity Trading Arangements since 2001) contains a locational varying element supposed to reflect the marginal costs of investments in the transmission system and contributing to 25% of the total use of system charge. This gap between the price cotations and the price at the end of the Interconnector may introduce some bias in some of our regressions if it is not constant over time. We neglect this aspect in our analysis.

Table 3 reports summary statistics of the daily prices and the price differentials between both countries. In the period 2001-2005, the average price in England exceeds the one in France expect in the year 2003 due to an exceptional hot summer in France. The price differential is then greater in the direction from France to England (4.1 Euros per MWh for the period 2002-2005) than from England to France (1.4 Euros per MWh).

We define the variable PROFIT as the ex-post estimated profit due to the acquisition of 1MW of capacity, i.e. $PROFIT = VALUE - PRICE$. The fifth column of table 2 reports for each bidder the average profit he makes per MW purchased in the daily auctions. The huge heterogeneity of this variable among bidders even for bidders of the same size is a striking feature. As an example, in the 272 auctions he participated, bidder 7 bought 7,739 MW, his total theoretical profit is 710,000 Euros which corresponds to an average profit of 92 Euros per MW. On the other hand, bidder 18* participated in 559 auctions and bought 4,273 MW. His theoretical profit is 2,2 Millions of Euros, which corresponds to an average profit of 43 Euros per MW. There is no clear pattern between average profits and the sizes of the bidders. Altogether, the stakes at hand in the daily auctions are small, especially compared to the 90 Millions bid of bidder 18* in the tri-annual auction.

4 Intriguing Evidence about Prices and ex-post Profits

4.1 Failure of the arbitrage condition

Table 4 provides a raw data summary for each duration and both directions. A clear pattern emerges: short-term auctions raise a much lower revenue for the seller or equivalently a much higher profit for the bidders than the long-term ones. Recall that it is exactly the same capacity rights that are sold at long and short term auctions. A mild difference could come from the payment dates. Nevertheless, long term auctions are payable in equal monthly instalments. Such 'yield curve' effect would have then a very mild impact on the outcomes. It means that the arbitrage condition equation fails: it costs less to buy capacity at short-term auction and the Operator seems to have interest to sell only through long-term contracts.

The average price received by the seller for 1MW per day was respectively 172.5, 96.0 and 59.6 Euros in the (single) tri-annual auction, the long-term auctions and daily auctions for the direction "France to England". This represents a difference in term of revenue between long-term and daily auctions of 61%. The corresponding difference equals to 33% for the direction "England to France". In the same way, the number of participants, the number of submitted bids and also the performance measures as the number of winners and the HHI index strongly differ in long-term and daily auctions.[15, 16]

We consider the average profits per day of the winning bidders. Apart from the seasonal auctions, the average profits are inversely related to the

[15]Note that the average of the ex-post value differ between long-term and daily auctions. In a stationary auction timetable, as the one prevailing at the first years on the IFA auctions where there is for example one daily auction and one monthly auction, the average ex-post values should be exactly the same. Nevertheless, the auction timetable has changed from October 2004 where, instead of one monthly auction, two different sequential monthly auctions are run the month before the month to be contracted. The other long-term contracts are been sold with this sequential pattern. Then in the 35 monthly auctions for the direction "France to England" present in our database, months after November 2004 are represented by two points whereas months before November 2004 are represented by a single point. Since the price differential from England to France was higher than usual, then the average ex-post value is higher from monthly auctions and more generally for long-term auctions than the daily auctions that are uniformly captured by a point. Since the price differential from France to England was lower than usual from November 2004, the same argument implies that the average ex-post value is higher in daily-auctions than in long-term auctions.

[16]Note also that the difference between the ex-post value of rows Daily and All Day, REPAIR=0 is significantly positive. A nonparametric Wilcoxon (Mann-Whitney) rank-sum test indicates that the distributions are different at the $p < 0.0001$ level for both directions. As expected, the days where no bids have been submitted and where we presume that an auction has been held according to the classification REPAIR are corresponding to a lower expected value, which gives more support to the classification REPAIR detailed in the appendix C.

duration of the contract auctioned, ranging from 47.9 Euro for a daily auctions[17] to -80.7 Euro for the tri-annual auction. The difference of 128.6 Euro is bigger than the average value of the capacity. On the one hand, we can not reject the null hypothesis that the profits of a winner in the monthly, quarterly, seasonal and annual auctions are drawn from the same population in the direction France to England (a Kruskal-Wallis test yields $p = 0.92$). On the other hand, we can reject the null-hypothesis that the profits from the duration above are drawn from the same distribution as the ones from the daily auctions (a Kruskal-Wallis test yields $p < 0.001$). On the whole, we can not reject that the arbitrage condition equation holds between long-term auctions, but we can reject that it holds between daily and long-term auctions.

[17] The profit of a day without repair and a null participation is assumed to be null.

Table 4: Descriptive Statistics of the IFA Auctions

	Exogenous		Bidding Variables		Performance			
	Ex-post value per day	Quantity sold	# of Participants	# of bids	Price per day	Profit per day	# of winners	HHI
France to England								
Daily (882)	121	244	4.2	19	67.0	53.9	1.6	0.77
All Day, REPAIR=0 (994)	109				59.6	47.9		
Monthly (35)	118	277	8.7	133	89.3	29.3	3.9	0.33
Quarterly (13)	116	192	8.5	121	96.7	24.2	3.4	0.31
Seasonal (4)	135	175	8.8	104	85.3	49.9	3.3	0.36
Annual (9)	117	267	9.3	151	120.4	-9.4	4.4	0.29
Tri-annual (1)	91.8	650	2	2	172.5	-80.7	2	0.86
England to France								
Daily (482)	71.6	482	3.1	12.4	27.5	43.4	2.0	0.68
All Day, REPAIR=0 (978)	37.5				13.5	21.8		
Monthly (36)	33.7	299	7.3	72.6	18.5	15.5	3.9	0.33
Quarterly (13)	32.6	281	7.6	89.1	16.3	16.9	3.4	0.42
Seasonal (4)	12.6	175	7	124	21.1	-8.5	4	0.32
Annual (9)	32.5	310	8.3	131	17.7	14.4	4.4	0.32

4.2 Time Instability of the Margins

A first sign of instability appears roughly in the first sequential auctions that have been held for annual contracts. Those auctions took place November 03 and 30 of 2005 for a contract covering the year 2005. On the one hand, the (average) price for the direction "France to England" was 108,500 Euros/MW (4,500 for the opposite direction) in the first auction. On the other hand, those prices falls respectively to 65,800 and 3,900 Euros in the second auction. We may doubt that the fall of about 2% of the annual contract for the year 2005 in Powernext Futures in November 2005 is the single cause of the fall of 66% in the price of the transmission capacity from France to England especially since the fall concerns also the opposite direction. Furthermore, the fall is also surprising since more bidders have participated in the second auction (14) than in the first (10). The pattern of the price dynamics depicted in Figure 3 suggests that the ascending nature of the auction may play a key role. In both cases, we can observe two phases in the dynamic. In a first phase of about 100 offers, the bidders are using big increments. In particular, there is a jump bid from 57,500 to 75,000 in the first auction whereas, few weeks later, in the second auction for the same good, nearly 300 offers have been needed to raise the price from 60,000 to 66,001 the highest winning offer. It seems that those jump bids are used because it is common knowledge that the value of the capacity is much higher than the current price since we do not observe any exit of participants in this phase. Nevertheless, we can not view this phase as totally uninformative since some bidders reduce the quantities in their offer. The second phase corresponds much more with the button auction formalization of the English auction with small bid increment (see Figure 3).

The main sign of instability that will be carefully analyzed in section 6 concerns the link between the price and the theoretical ex-post value. Let us define the average profit ratio $APV(t,T)$ in period t over $T+1$ auctions as the percentage of the profit captured by the bidders in the period $[t-\frac{T}{2};t+\frac{T}{2}]$:

$$APV(t,T) = 1 - \frac{\sum_{i=t-\frac{T}{2}}^{t+\frac{T}{2}} PRICE_i}{\sum_{i=t-\frac{T}{2}}^{t+\frac{T}{2}} VALUE_i}.$$

In the exploratory phase of the data, we run regressions of the price on our exogenous variables (especially the value) and on the participation and asked whether those relations were robust by running them on different time periods and with different models (OLS, 2SLS, autoregressive time series). What has emerged is a great instability of the estimated coefficients and in particular of the one corresponding to the profit which explains the main part of the variability in our data. As an illustration, consider the simple regression model:

$$PRICE_i = \alpha + \beta \cdot VALUE_i + \epsilon_i \quad (1)$$

The time-series distribution of the variables $APV(t, 90)$ and the $\beta(t)$ and $R^2(t)$ coefficients obtained from a 180-days rolling-window regression of the model above are shown in Figure 2. The difference between those estimations in the summers 2002 and 2003 is spectacular: in September 2002, β is around 0.9 whereas it nearly reaches 0.1 in August 2003 with a standard deviation around 0.04.[18] The coefficient R^2 follows the same pattern as β ranging from 10% to 88% and APV follows an opposite pattern. On the whole, periods where bidders capture a small (respectively big) part of the potential profits, i.e. periods that can be qualified as competitive (collusive), are characterized by highly (less) predictable prices given the ex-post value and the price is (not) very responsive to the expected value. We will see next that this kind of instability goes much beyond the specification (1).

5 Various Theoretical Scenarii of Bidders Behavior

There are several possible explanations why the average profits differ in the different auctions, i.e. the arbitrage condition fails. Risk aversion is one but it would imply that the premium is in favor a long term contracts since they involve more risk due to the huge stakes at work and the incertainty of future prices. Anyway, we doubt that risk aversion plays a role in this market: the aggregate auction purchases of the more active bidders are about 10 millions Euros per year which represents 2% of EDF Trading's annual turn-over (408 Millions in 2004), the department of EDF (Electricité de France) for Energy Trading, the French historic public utility operator which has an annual turn-over of 47 Billions (2004). Five main determinants may predict the pattern of the expected profits: volatility of the underlying asset, asymmetric information, transaction costs, collusion and differences in the auction mechanism. Let us consider the different predictions implied by those theories.

5.1 Volatility of the underlying asset

Capacity rights are a specific financial instrument, a European call option, and the insights of the finance literature thus apply (see Demange and

[18] France experienced an unusual spike in the summer 2003 making electricity flows from England to France much more profitable than usual. Nevertheless, this spike had much less impact on the value of the interconnector from England to France. The time-series distribution of the 180-day moving average of this price differential is shown in Figure 4. Anyway, by adding the square of the profit in the regression, we have controlled that the robustness of the instability of the coefficient β is not linked to the union of nonlinearities in the relation between PRICE and PROFIT and different distribution of PROFIT across time.

Laroque [11] for an introduction). From the Black-Scholes formula, the value of an option is increasing in the volatility of the underlying assets for a given expected value of the underlying assets. At first glance, it does not matter here since we compare directly winning prices with ex post realizations of the profits. Nevertheless, the bias of our estimator of the ex-post value of the option may depend on the intra-day volatility. In more volatile periods, the sign of the price differential is more likely to switch inside the peak or the off-peak periods and our proxy may underestimate the real value of the capacity rights. It could give some rational for the instability of the margins across time periods. However, it is not clear in practice whether the buyers benefits from such switches, the market of base and peak contract being much more liquid than the market for hourly contracts. The goodness of fit coefficient of our unreported regressions with ex post values based on hourly prices was reduced by half compared with our proxy.

5.2 Asymmetric Information

As formalized by the pioneering work of Milgrom and Weber [28], in a common value auction, asymmetric information creates a gap between the winning price and the expected value. The more a bidder cares about his opponents information, the more he shades his bids to avoid the winner's curse, i.e. he bids less than the expected value conditional on his own signal by taking into account the fact that winning the good means that the opponents received low signals. In the literature, e.g. Nyborg et al [29], the volatility is supposed to proxy the precision of bidders' signals. The idea is that a high volatility is indicative of a large winner's curse and should be associated with cautious bidding. The failure of the arbitrage condition could be rationalized by more asymmetric information in daily auctions.

5.3 Transaction Costs

Contrary to asymmetric information which is probably highly volatile as suggested by the high volatility of the electricity prices, transaction costs should rather be constant over time. For a participant in this market, it should be related to the cost of employing a trader that participates at the IFA auctions and at the Power Exchanges in France and UK. Note that the dynamic nature of the ascending auction make it more time consuming (between 15 and 30 minutes per Day for a Daily auction and 1 and 2 hours one a year for an annual auction) and thus involves at least higher transaction costs than standard sealed bids.

As shown in Table 4, the arbitrage between monthly and daily auctions involves a total arbitrage of 25 Euros per MW and per day (18.6 Euros for the direction France to England and 6.3 Euros from England to France). With the average quantity of 150 MW obtained by a winning bidder, it corresponds to a benefit of 3,750 Euros per day.

Anyway, transaction costs can not be the whole story. In that case, it would mean that bidders are making profit when there is a single participant in the auction whereas the auction is competitive and leads to a null profit when there are at least two participants. It stands in contradiction with the evidence that the benefit of a winning bidder is much bigger when there are at least two participants.

5.4 Collusion

A game that is repeated on a daily basis is prone to collusion. Strategies that depend not only on the current game but also on the past outcomes are likely to be played, even if past actions are imperfectly observed as it is the case here due to the anonymous nature of the auction. Folk theorems (see Fudenberg and Tirole [14]) establish that the set of equilibrium outcomes is very rich. In repeated game with imperfect public information, the pioneering work of Porter [34], that has been generalized by Abreu et al [1], has introduced trigger-price strategies for a model where price cuts are secret. It leads to switching regimes models where, at equilibrium, the competition alternates between collusive periods and price wars. It could give some rationale from the instability of the margins across time.

5.5 Small changes of the Bidding Rules

The literature insists on the fact that seemingly innocuous changes of the bidding rules may have a huge impact on the outcome: the different rules for ending an auction may leave more or less scope for some "collusive" equilibria as in the theory of late bidding developed by Ockenfels and Roth [31].[19] They compare the closing rules in the second price Internet auctions on eBay and Amazon. In the former, a fixed end time is used, as in the earliest days of IFA-auctions. In the latter, the auction extends automatically 10 minutes after the last submitted bid whereas a 2-minutes automatic extension rule applies nowadays in the long-term IFA-auctions. They state that under a fixed time closing rule where last-minute bids may be lost, late bidding lowers prices in particular through collusive equilibria that avoid bidding wars. Here, the effect of a fixed time closing rule is different: bidders are submitting bids at the last minute, which makes the ascending auction more similar to the standard sealed-bid discriminatory auction.

Another closing rules has been used in the IFA-auctions: a random closing time, which is now the rule for the daily auctions. We claim that this rule opens the door to seemingly collusive equilibria where participants are

[19] On the contrary, results as the Revenue Equivalence Theorem insists on the fact that seemly big changes of the bidding rules may have not impact on the outcome

bidding very slowly by adding only the price increment to the current winning bid and where they alternately hold the highest bid that could win if the auction closes immediately.[20] Otherwise, whenever some bidders deviate from this equilibrium strategy, bidders are returning to a less profitable equilibrium with high increments. Thus the random and the automatically extended closing rule suggest different predictions in term of the final price. Nevertheless, the multi-unit and repeated nature of the interaction in the IFA auctions leaves scope for collusive equilibria under each closing rules.

In the following, to capture the changes in the closing rules, we divide the data in two periods: the year 2002, where it is supposed that a fixed time closing rule was prevailing and the period from the beginning of the year 2003, where it is supposed that the daily auctions are actually a real dynamic auction.[21]

6 Empirical Findings on Bidder Behavior and Auction Performance

In this section, we report on the broad patterns in bidder behavior and, in particular, how bidders respond to, and how auction performance is related to the value of the interconnector, the volatility of the underlying value, the auction size and the participation decisions. We first present the differences between the year 2002 and the period from the beginning of 2003 with descriptive statistics. A more rigorous analysis of those differences is made in the regression part of this section.

6.1 Descriptive Statistics

Tables 5 and 6 report summary statistics on the bidding variables and the auction performance in the sample as a whole and according to our proxy for the changes in the closing rules. Summary statistics on the value of the interconnector, the uncertainty of this value and the auction size are also reported.

Added to PRICE and PARTICIPANTS, three additional variables are characterizing the strategy profile of the bidders. The aggressiveness of the bidding profile is captured by the variable SPREAD which is equal to the difference between the highest accepted bid and the lowest best offer of a bidder that wins some items. Thus SPREAD is null if there is only one winning bidder. In the sub-sample of auctions with at least two winning bidders, the average SPREAD equals 2.8 Euros from 2003 to 2005 which should be compared to the average winning price 55.9 Euros. On the other hand, this

[20] A formal statement as in [31] is left to the reader.

[21] The choice of the beginning of the year 2003 is consistent with our discussions with IFA-experts and what we observe from the dynamic of the auctions.

average is equal to 26.3 Euros in the year 2002, i.e. about one third of the average winning price. SPREAD is very high in 2002 consistent with the view that the dynamic nature of the auction is canceled by the closing rule. On the contrary, the low values for SPREAD from 2003 are consistent with a dynamic auction. In this last case, it is a measure of the pace of the auction or the aggressiveness of the bidders. The drawback of a alternative measure of aggressiveness that considers the average of the submitted increments is that it would take account of the early bids in the auction which may not be very meaningful. On the contrary, with our measure, a high SPREAD reflects for example jump bids, a sign of competitiveness. On the other hand, collusive bidders may prefer to push the price at a slow pace such that the spread remains low. The average number of bids submitted by each participating bidder is captured by the variable NUMBER OF BIDS PER PART, which has an average of 3.89 and a maximum of 29. The difference is striking between the two periods: in 2002, the average number of submitted bids per bidders is 1.44 in auctions with one participant and 1.66 in auctions with at least two participants. From 2003, those figures are equal respectively to 1.15 and 4.89. A standard two sample mean comparaison test with unequal variance reveals that all those means are statistically different at the p=0.01 level. This evidence is again consistent with our proxy for the change in the closing rules.

Under an ascending auction -the average winning price is 3.4 Euros - bidders are submitting roughly only one bid at the reserve price when there is only one participant.[22] However, if bidders are entering the auction at the last moment, they bid a demand curve with several bids and with offers strictly above the reserve price -the average winning price is 22.4 Euros in auctions with only one bidder. When there are several bidders, the difference is striking before and after 2003: the average number of bids per participants is about three times higher in the later period, confirming again its dynamic nature. The extent to which a bidder uses the ascending nature of the auction to communicate is measured by DIGIT, the proportion of bids submitted whose last digit is neither 0 nor 5. Cramton and Schwartz [10] have shown how the simultaneous ascending auction used by the FCC to sell the spectrum has been vulnerable to signaling techniques by the bidders through the trailing digits of their bids. Indeed, more than a communicating device for collusive behavior as in [10], the last digit of a bid may be a proxy for the pace of the auction: digits like 0 and 5 are reflecting a more aggressive strategy profile using possibly jump bids.

The auction performance is first measured by the variable PROFIT

[22] Submitting more than one bid is rational if the first bid covers less than the quantity offered at the auction, which happens in two auctions where the second bid were also at the reserve price. Nevertheless, in six auctions, bidder 18* outbids itself slightly though there was no other bidder which explains why the winning price is not stuck at the reserve price.

equal to the difference between the VALUE and the PRICE of the capacity. PROFIT is large compared to VALUE: its average is 53.9 Euros which roughly corresponds to the half of the VALUE of the capacity. The cross-section variation is large going from -300 to 807.8 Euros with a standard deviation of 74.5 Euros. The difference of PROFIT of 3.4 Euros between the period after 2003 and the earliest days of the IFA-auctions is not statistically significant (p=0.51 in a t-test with unequal variance). Moreover, it remains true if we condition on the number of participants. It is not clear how to interpret that pattern. First, the average number of participants widely differs between the two periods, rising from 3.2 to 4.56. Thus, since the quantity sold has not changed much, the average profit per participants has clearly dropped. It means that it should not be interpreted as an auction with endogenous entry where bidders are making a constant profit to compensate their participation costs. Second, since the theoretical value of the capacity rights has fallen over time, the share of the VALUE converted into PROFIT falls meaning that the auction price was more competitive under the fixed time closing rule though there were less participants at that time. The variables VALUE and then PRICE are increasing in the number of participants, which confirms the endogenous nature of the participation decisions. On the contrary, PROFIT displays no clear participation pattern, except that the average profit of the winning bidders is much lower in the case where there is a single participant.

WINNING is equal to the number of winning bidders. Its average is equal to 1.68, i.e. 40% of the average number of participants, and increases with the number of participants. HHI is the Herfindahl-Hirschman Index relative to the capacity allocated in the daily auction.

Tables 5 and 6 exhibits three exogenous variables: VALUE, VOLATILITY and QUANTITY. We measure uncertainty as the differential price volatility using an ARCH-in-mean process.[23] The one-day volatility has an average of 14.1, which corresponds to 11.6% of the average value of the interconnector, and a maximum of 330.3, which is thus 23.4 standard deviations larger than the mean. The auction size, QUANTITY, has an average of 245.4 MW and is a little higher than the minimal quantity (200MW) that has to be available in daily auctions.

[23]The details of the time-series modelling are in the Appendix A

Table 5: Descriptive Statistics of the IFA Daily Auctions, France to England

Period	Total Sample				YEAR 2002		YEAR $\geq$ 2003	
	Mean	Stand. Dev.	Minimum	Maximum	Mean	Stand. Dev.	Mean	Stand. Dev.
Exogenous Variables								
VALUE	121.5	124.8	0	959.8	146.2	140.6	114.2	118.9
VOLATILITY	14.1	25.1	.39	330.3	16.0	31.7	13.5	22.8
QUANTITY	245.4	100.1	5	650	255.2	94.1	242.5	101.7
Participation Decisions								
PARTICIPANTS	4.25	2.17	1	10	3.20	2.0	4.56	2.1
PART5	0.47	0.50	0	1	0	0	0.61	0.49
PART8	0.48	0.50	0	1	0.52	0.50	0.46	0.50
PART13	0.71	0.45	0	1	0	0	0.92	0.27
PART18*	0.55	0.55	0	1	0.69	0.46	0.60	0.49
PART OTHER	2.05	1.65	0	8	1.99	1.66	1.97	1.57
Bidding Variables								
PRICE	67.5	95.8	3	1000	94.9	131	59.4	80.9
SPREAD	2.74	11.64	0	196.7	7.2	22	1.4	5.0
DIGIT	.78	.20	0	1	.75	0.28	.78	0.17
NUMBER OF BIDS PER PART	3.89	3.14	1	29	1.6	1.5	4.6	3.2
Performance								
PROFIT	53.9	74.5	-300	807.8	51.3	60.3	54.7	78.3
WINNING	1.68	.89	1	5	1.4	0.69	1.8	0.92
HHI	.78	.26	.22	1	0.88	0.21	.74	.27
Observations	877				200		677	

Table 6: Descriptive Statistics of the IFA Daily Auctions, France to England

Period	All periods							YEAR = 2002		YEAR $\geq$ 2003	
Observed Number of Participants	1	2	3	4	5	6	$\geq$7	1	$\geq$2	1	$\geq$2
Exogenous											
VALUE	37.9	76.9	90.5	140.6	143.1	163.1	173.6	49.2	176.9	28.8	122.4
VOLATILITY	10.5	11.0	12.3	15.7	17.7	15.5	14.9	11.4	17.5	9.9	13.9
QUANTITY	187.6	260.6	244.5	257.4	255.1	252.5	250.6	194.9	274.3	181.7	248.3
Bidding Variables											
PRICE	11.9	26.8	38.2	70.8	84.3	103.4	117.5	22.4	117.8	3.4	64.7
SPREAD	0	1.14	2.23	2.76	3.50	5.70	3.44	0	9.5	0	1.5
DIGIT	.88	.85	.81	.75	.74	.73	.71	0.84	.72	.92	.77
NUMBER OF BIDS PER PART	1.28	2.89	3.52	4.21	4.73	4.85	5.09	1.44	1.66	1.15	4.89
Performance											
PROFIT	26.0	50.1	52.0	69.8	58.8	59.7	56.0	26.8	59.1	25.4	57.5
WINNING	1	1.48	1.59	1.65	1.84	2.05	1.98	1	1.49	1	1.84
HHI	1	.79	.79	.78	.74	.69	.69	1	.85	1	.72
Observations	107	119	123	131	130	112	155	48	152	59	618

6.2 Regression Analysis

Our empirical approach is fairly straightforward. For a given outcome variable Y, such as the PRICE or the award concentration measures, we suppose that:

$$Y = f(RULES, EXO, PART, \epsilon)$$

where f is an unknown function, $RULES$ is a discrete variable capturing the auction rules, EXO is a vector of exogenous variables, $PART$ is the vector characterizing the participation decisions of the potential bidders, and ϵ is an unobservable white noise.

In our regression, the main explicative variable is the estimated ex-post value of the transmission capacity VALUE. Following the aforementioned empirical finance literature, we include in our regressors the volatility of the underlying asset VOLATILITY and the quantity sold QUANTITY. If bidders are neither risk-averse nor capacity constrained, then the auction should be invariant to QUANTITY after having controlled for the set of participants. The variable QUANTITY should only affect the participation decisions since higher quantities involve higher potential benefits in play. The remaining endogenous variables are time dummies capturing the seasonal effects: we only control for the day of the week.

The number of participants and more generally the participation decisions of each potential bidder are arguably endogenous. Thus the vector PART should be instrumented. The first lag of these regressors are employed as instrument in a two-stage least squares estimation.[24] The inclusion of the whole participation vector leads to insignificant results. Thus we decide to include only the four biggest bidders - PART5, PART8, PART13, PART18- and to aggregate the participation decision of the remaining bidders (PART OTHER).

Our regressions are reported in Tables 7-10. They have three purposes: first, the estimation of the impact of the exogenous variables ; second, the estimation bidders-specific effects and third the identification of the effect of the auction rules. Under the assumption that the unobserved component ϵ is independent of the time period, this last effect is equal to:

$$\tau = \mathbb{E}_{EXO,PART,\epsilon}[f(1, EXO, PART, \epsilon) - f(0, EXO, PART, \epsilon)].$$

Then the most obvious approach is to consider a linear specification when restricting to auctions with at least two participants:

$$Y = \alpha \cdot RULES + EXO \cdot \beta + PART \cdot \gamma + \epsilon \qquad (2)$$

[24] We do not include additional lags as instruments because the time series contains some gaps.

At this point, this approach has some caveats. It does not allow the effect of the auction rules -proxied by the time period- to vary as a function of the profitability of the capacity. To remedy this, we first perform separate regressions for each auction rules that are reported in Table 7. Next, in the nested regression displayed in Table 8, we also report estimates from specifications where we interact RULES with the exogenous variables VALUE, VOLATILITY and QUANTITY and also the participation decisions.

We first comment the effect of the exogenous variables on the price formation. The results are quite different according to the auction rules. In 2002, both VOLATILITY and QUANTITY have not significant effect on the final price. From 2003, those variables have a significant effect at the 1% level and with the predicted sign: an increase in VOLATILITY (resp. QUANTITY) by a one standard deviation results in a typical decrease of 10.0 Euros (6.2 Euros) in the final price, which corresponds to less than 10% of the price's standard deviation. Those results are robust to several specifications: OLS, 2SLS and ARIMA. We reject exogeneity of the variable NUMBER OF PARTICIPANTS with a Davidson-MacKinnon test for misspecification ($p<0.0001$) for both periods. In the following, our analysis is devoted then to the 2SLS regressions.

Table 8 reports the results for the nested regression for both time periods. It allows us to test whether the small changes in the auction rules had a significant impact in the formation of the price. In the first column, we interact RULES with the exogenous variables. The variable RULES has a significant effect on the way the exogenous variables influence the price. We can reject that the slopes for VALUE and VOLATILITY and also the intercept are equal for both periods: the p-values are respectively equal to 0.0007, 0.0222 and 0.0007. From the year 2003, the price appears to be much more reactive to a change in VALUE: a 1 Euro's increase in VALUE translates in a 0.83 Euro's increase in 2002 and only a 0.49 Euro's increase from 2003. It stands in contradiction with the intuition of the linkage principle which suggests a better aggregation of bidders' private information in a dynamic format than in a sealed bid format. Since the auction rules make it closer to an ascending auction from 2003, we should expect that the relation between the final price and VALUE would be flatter in 2002 than from 2003. Nevertheless, this informational linkage is valid for single-unit auction and is not longer true in multi-unit auctions (see Perry and Reny [32]). In particular, the above intuition does not hold for seemingly collusive equilibria.

The significant effect of VOLATILITY from 2003 gives some support to the asymmetric information story with bidders shading their bid to avoid the winner's curse, which is coherent with the low slope (0.487) for VALUE relative to the slope equal to 1 in the theoretical benchmark. Table 9 displays the regression with another time period classification: we consider the years 2003 and 2005 versus the year 2004. The slope on VALUE and on VOLATILITY is significantly different in the 2004 at the 1% level, giving support to the changes of regimes hypothesis. In particular, the estimated slope for VOLATILITY is positive in 2004. In all those regressions, note that we control for the participation decisions, i.e. that bidders' probability of participation are varying differently in the different periods.

One of the main issues raised by the descriptive statistics is the discrepancy of 53.1 Euros per MW between the average price in 2002 and the average price in the period from 2003. In the same spirit, there is a discrepancy of 30.7 Euros per MW between the average price in 2004 and the one for the years 2003 and 2005 tough the exogenous variables were quite similar in these two panels. It is not clear wether the price formation is more competitive in 2002 and 2004 than in 2003 and 2005, whether it is due to differences in the identities of the participants or finally to changes in the exogenous variables. The regression in the first column of Table 8 leads to the following decomposition: 51 Euros are due to bidder heterogeneity, namely more aggressive bidders are bidding more in 2002, 26 Euros are due to the higher value of the interconnector in 2002, the effect of the changes in VOLATILITY and QUANTITY are negligible, the residual is the effect of the period 2002, which comes from the changes in the intercept and in the slopes on the exogenous variables, and is thus negative. Thus we find that, having fixed the number of participants and the set of exogenous variables, then the modification of the closing rules seems to have a positive effect on the price. Nevertheless, if we fix only the set of exogenous variables, then the modification of the closing rules τ has a negative effect on the price. In the second column of Table 8, we also interact the variable RULES with the participation decisions to test whether some bidders are bidding differently according to the time period: we can not reject that the coefficients on PART8*YEAR02, PART18**YEAR02 and PART OTHER*YEAR02 are jointly equal to zero (Wald test, p= 0.7038).

Next, we comment the effect of the participation variables on price formation and on the other endogenous variables from 2003. The results are reported in Table 10. The issue is whether some bidders have a specific impact on the price formation, e.g. by means of specific strategies. We can not reject that the coefficient on the participation decisions are jointly equal for the variables PRICE, SPREAD and NUMBER PER PART. The p-values of the corresponding Wald test are respectively equal to 0.26,0.44 and 0.21. Nevertheless for the variables DIGIT and WINNING, identity-specific effects are highly significant. Bidder 18* seems to play a bit differently in the auction: he raises more bids with less digits which leads to a more concentrated outcome. Nevertheless, his effect on the price is not significant. We run the various regressions on the endogenous variables separately though a game-theoretic model of the ascending auction should involve interactions between those variables. We test whether the residuals of the above regressions are correlated. As it was conjectured, most of the coefficient of correlation between the residuals are significantly different from zero. As an example, the coefficient of correlation between the residuals of the regressions for PRICE and DIGIT is equal to -0.1957. It means that an auction dynamic with more digits is positively correlated with a lower price after having controlled for the exogenous and participation variables.

Table 7: Regression Analysis of the winning price

Period	YEAR 2002				YEAR ≥ 2003			
	OLS	**2SLS**		**ARIMA**	**OLS**	**2SLS**		**ARIMA**
		PRICE	NUMBER OF PARTICIPANTS			PRICE	NUMBER OF PARTICIPANTS	
VALUE	0.799**	0.837**	0.003**	0.777**	0.473**	0.478**	0.005**	0.435**
	(0.088)	(0.093)	(0.001)	(0.089)	(0.057)	(0.066)	(0.001)	(0.057)
VOLATILITY	0.149	0.022	0.009†	-0.004	-0.417**	-0.402**	-0.008*	-0.336**
	(0.227)	(0.241)	(0.004)	(0.124)	(0.147)	(0.155)	(0.004)	(0.124)
QUANTITY	0.087	0.088	-0.003†	0.080	-0.058**	-0.062*	0.002**	-0.057**
	(0.077)	(0.092)	(0.002)	(0.092)	(0.022)	(0.024)	(0.001)	(0.022)
NUMBER OF PARTICIPANTS	9.504**	13.735*		8.557**	9.165**	9.881†		8.423**
	(3.037)	(6.101)		(3.155)	(1.465)	(3.318)		(1.311)
FIRST LAG OF THE NUMBER OF PARTICIPANTS			0.426**				0.416**	
			(0.073)				(0.034)	
N	152	127	127	152	621	587	587	621
R^2	0.824	0.836	0.405		0.643	0.644	0.35	

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%. Robust standard errors are in parentheses. The regressions are run for observations with at least two participants. The coefficients for time dummies and the intercept are not reported.

Table 8: Regression Analysis of the price: YEAR 2002 versus YEAR $\geq$ 2003

	PRICE	PRICE
PART8	28.478**	28.468*
	(10.887)	(12.247)
PART8*YEAR02		-24.427
		(36.030)
PART13	-61.914†	-60.625†
	(34.419)	(35.424)
PART5	21.940	23.634†
	(13.904)	(14.177)
PART18*	6.634	13.215
	(15.823)	(16.525)
PART18**YEAR02		-88.210
		(78.473)
PART OTHER	9.306**	9.040*
	(3.430)	(4.275)
PART OTHER*YEAR02		4.189
		(8.141)
YEAR02	-122.179**	-83.539
	(36.022)	(54.659)
VALUE*YEAR02	0.827**	0.876**
	(0.092)	(0.105)
VALUE*(1-YEAR02)	0.487**	0.478**
	(0.060)	(0.064)
VOLATILITY*YEAR02	0.069	0.051
	(0.212)	(0.216)
VOLATILITY*(1-YEAR02)	-0.504**	-0.452**
	(0.148)	(0.157)
QUANTITY* YEAR02	0.070	0.171
	(0.084)	(0.124)
QUANTITY* (1- YEAR02)	-0.044	-0.047
	(0.035)	(0.035)
N	738	738
R^2	0.711	0.700

Significance levels : † : 10% $*$: 5% $**$: 1%. Robust standard errors are in parentheses.
The regressions are run for observations with at least two participants.
The coefficients for time dummies and the intercept are not reported.

Table 9: Regression Analysis of the price: YEAR 2004 versus YEAR 2003 and 2005

	PRICE
PART8	13.680
	(12.562)
PART13	-36.207
	(31.907)
PART5	10.798
	(17.552)
PART18*	-4.323
	(16.978)
PART OTHER	5.021
	(4.070)
YEAR04	-37.476
	(24.460)
VALUE*YEAR04	0.275**
	(0.080)
VALUE	0.388**
	(0.073)
VOLATILITY*YEAR04	0.607**
	(0.217)
VOLATILITY	-0.497**
	(0.142)
QUANTITY* YEAR04	0.047
	(0.075)
QUANTITY	-0.042
	(0.031)
N	604
R^2	0.67

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%. Robust standard errors are in parentheses. The regressions are run for observations with at least two participants. The coefficients for time dummies and the intercept are not reported.

Table 10: Regression Analysis of the endogenous variables, YEAR $\geq$ 2003

	PRICE	SPREAD	DIGIT	NUMBER PER PART	WINNING	HHI
PART8	27.596*	1.555†	-0.059*	0.189	-0.097	0.045
	(12.135)	(0.920)	(0.029)	(0.645)	(0.202)	(0.058)
PART13	-59.638†	-3.670	-0.036	2.589	0.455	-0.143
	(35.336)	(3.012)	(0.086)	(1.760)	(0.585)	(0.180)
PART5	23.197	0.820	0.059	-0.707	-0.168	0.050
	(14.165)	(1.260)	(0.041)	(0.916)	(0.232)	(0.072)
PART18*	14.135	-0.590	-0.151**	1.892*	-0.637*	0.146†
	(16.380)	(1.723)	(0.043)	(0.955)	(0.270)	(0.081)
PART OTHER	8.830*	0.405	-0.042**	0.321	0.118†	-0.025
	(4.326)	(0.323)	(0.010)	(0.225)	(0.066)	(0.019)
VALUE	0.482**	0.008†	0.000†	0.000	0.000	0.000
	(0.067)	(0.005)	(0.000)	(0.002)	(0.001)	(0.000)
VOLATILITY	-0.492**	-0.016	0.000	-0.007	-0.001	0.001
	(0.152)	(0.012)	(0.000)	(0.006)	(0.002)	(0.000)
QUANTITY	-0.051	0.002	0.000	-0.004*	0.003**	-0.001**
	(0.034)	(0.003)	(0.000)	(0.002)	(0.001)	(0.000)
R^2	0.61	0.05	0.22	0.04	0.081	0.026

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%. Robust standard errors are in parentheses. The regressions are run for observations with at least two participants. The coefficients for time dummies and the intercept are not reported.

6.3 Check of robustness

VALUE is the main variable that drives about 90% of the explained variance for PRICE in our regression. Since there is no particular reason for the relationship between the endogenous variables and VALUE to be linear, we have included the square of VALUE in the regressions as a check of robustness and we have estimated the model without the 10 and 40 observations with the highest VALUE. The results are similar though the squared terms differs significantly from zero in both periods (p<0.0001). The coefficients on VALUE are modified significantly relative to the original regression. However, the impact on the other covariates are similar and the same comments apply.

All our regressions can be criticized as been driven by the fact that VALUE may be an imperfect proxy of the ex-post value of the Interconnector. In particular, the relationship between those two values may depend on the day of the week (e.g. the profiles of the export and import flows depend on the weekday) or may experience large fluctuations across years. We have run some complementary regressions to check the robustness of our results relative to this issue. We run 2SLS regressions with a specific slope for VALUE for each day of the week. For the full sample, the estimated slopes are lying between 0.35 and 0.72 and we can not reject that the slopes are jointly equal (Wald-test, $p = 0.1829$). Nevertheless, in some specific periods, it is no longer the case and it seems that the measurement error problem matters though it does not induce strong bias in the broad pattern of estimated coefficients. E.g., for the years 2003 and 2005, we can reject that the slopes are equal (Wald-test, $p < 0.0001$). Moreover, for friday, the slope is not statistically different to zero at the 10% level.

7 Discussion

7.1 Theoretical literature on the allocation of transmission capacity

One of the main assumptions of the literature on the allocation of transmission capacity (Joskow and Tirole [22], Gilbert et al. [16]) is that efficient arbitrage forces the price paid for transmission contracts to equal the spot price difference between the nodes. On the contrary, our empirical analysis shows that the price paid for transmission is very significantly below spot price differences. We also show that the auction mechanism itself seems to play a role: the closing rule (fixed time versus random) or the frequency of the auction (daily versus long term).

A second important aspect of this literature are the different incentives of the actors in this market relative to their respective market power in the importing and the exporting markets. Furthermore, this literature does not consider the additional motive for market manipulation resulting from the coincidence that half of the auction revenue goes to RTE, whereas EDF, her parent company, participates in the auction. Our analysis finds that bidders may have identity-specific effects on the concentration outcome and on the auction dynamic. Nevertheless, we do not find evidence that specific bidders influence significantly the final price. Thus our analysis gives no support to the view that bidders may have heterogenous motives for capacity rights.

7.2 The Empirical and Experimental Evidence on multi-unit Ascending Auctions

The empirical analyses of simultaneous ascending auctions are scarce. The European UMTS auctions happen only once preventing any statistical inference. Jehiel and Moldovanu [20] discuss the auction results across different countries in the light of their theories of auctions with externalities. Considering the whole dynamic of the auction in the U.K., Börgers and Dustmann [7] are trying to elucidate why several bidding behaviors deviate strongly from straightforward bidding with private values. Cramton and Schwartz [10] analyse some revenue-reducing strategies that are specific to simultaneous ascending auctions by means of code bids or retaliating bids. They find evidence that those signalling techniques were effective.

The experimental literature on auctions has asked whether the ascending multi-unit auction outperforms its sealed-bid counterparts. More precisely, in [2, 13, 23], the ascending multi-unit auction studied is a clock auction which implements dynamically the traditional uniform-price auction. As the price is increasing, a bidder may drop out on some units he has bid for. Furthermore, dropping out is irrevocable: there is no room for re-entry. In a private-value framework with two units demand, all those experiments show that demand reduction is stronger in the ascending format. As a consequence, both efficiency and revenue are substantially lower than in other auctions. What kind of conjectures give those experiments for the IFA auctions? There are numerous differences between those experiments and the environment in the IFA-auctions. First, transmission capacity entails an important common-value component, which is supposed to benefit to ascending formats. With flat multi-unit demand and with informational externalities, Ausubel [4] has proved that the Ausubel auction outperforms the Vickrey auction in term of revenue. Nevertheless, the hypothetic theoretical gains from the linkage principle may overestimate the practical benefits of open formats as shown in Kagel, Levin and Richard [26] for a single object, where the English auction outperforms the first price auction only for super experienced bidders and on a much smaller scope. Second the lack of any activity rules leaves more scope for collusion: it costs nothing to a bidder to reduce temporally his demand and see how his opponents react because he can increase his demand again if they do not play the "demand reduction equilibrium". The early phases of the auction can then be used as a room for cheap talk. In the same spirit, Goswami et al [17] have shown how preplay communication facilitates the adoption of low price equilibria in uniform-price share auctions. Thus, apart from the possibility of intertemporal strategies, the daily repetition gives time to learn how to play low price equilibria. Finally instead of two bidders and two units auctions as in [13, 23], IFA-auctions are share auctions with more participants. On the one hand, the extreme divisibility of IFA-auctions suggests strong underpricing may happen.[25] On the other hand, the number of participants is greater but not that much in daily auctions. The number of units is thus much larger than the number of bidders.

On the whole, the previous points suggest that the gap between the ascending and the sealed bid uniform-price auctions should be worse in the IFA-auctions than in the multi-unit ascending uniform-price auction experimented in the lab.

8 Conclusion

The simultaneous ascending auction has been proposed to auction items that are very sensitive to the winner's curse for long-term licences. Anyway, the main drawback of this format is that it is more prone to seemingly collusive low price equilibria especially if it is played on a daily basis as in the IFA-auctions. Moreover, the specific details of the ascending auction in IFA daily auctions - the absence of any activity rules and the closing rules - are making this ascending format less prone to competitive equilibria.

Our results are not clear-cut. On the one hand, the winner's curse may play some role since the volatility of the underlying market - our proxy for the precision of bidders' signals- has a significant negative effect on the price from 2003. Nevertheless, its influence is positive and not significant at the 10% level in 2002. Moreover, the effects on the other endogenous variables are not significant. On the contrary, studies as Nyborg et al [29] have found a statistically negative effect of the volatility on the award concentration. On the other hand, the IFA daily auctions seem to experience different regimes with a significant effect on the endogenous variables as the price or the award concentration. The effect of the period is significant after having controlled for the identity of the participants in the auction.

We have tried to analyse the factors and the path that drive the bidders to a low price equilibrium. In particular, we consider several endogenous variables relative to the dynamic of the auction as the last digits of the bids. It appears that some of the big bidders have a significant influence on those variables. Nevertheless, the heterogeneity in the bidders' strategies and their

[25] See Kremer and Nyborg [25] for an analysis of the impact of price and quantity tick size.

Table 11: Volatility Coefficients

	Main Equation			Volatility Equation			
	β_0	β_1	σ^2	γ_1	γ_2	γ_3	γ_7
	France to England						
Mean	.112	.710	-.050	.375	.157	.040	.046
Standard deviation	.071	.023	.006	.031	.027	.008	.016
	England to France						
Mean	.207	.752	-.046	.132	.111	.244	.259
Standard deviation	.026	.014	.003	.017	.017	.019	0.023

identity-dependent influences on the outcome of the auction deserves more attention, especially in a more controlled framework as a lab experiment.

Appendix

A Volatility Estimation

As in Wolak [39], we first eliminate the multi-seasonal patterns of the price-differential dynamic that are first order in electricity markets through dummies for each days, months and years. Let $\delta_t^{i \Rightarrow j}$ be the deseasonalized price differential between zone i and zone j at time t. From now on, we drop the index i and j to alleviate notation.

We assume that the price differential δ_t follows the autoregressive process such that the conditional variance σ_t^2 influences the conditional mean:

$$\delta_t = \beta_0 + \beta_1 \cdot \delta_{t-1} + \psi \cdot \sigma_t^2 + \epsilon_t$$

where ϵ_t is a white gaussian noise. The volatility σ_t^2 of the error term is:

$$\sigma_t^2 = \exp(\lambda_0 + \sum_{i=1}^{6} \lambda_i \cdot weekday\_i) + \gamma_1 \cdot \epsilon_{t-1}^2 + \gamma_2 \cdot \epsilon_{t-2}^2 + \gamma_3 \cdot \epsilon_{t-3}^2 + \gamma_7 \cdot \epsilon_{t-7}^2 + \nu$$

Multiplicative heteroskedasticity has been introduced relative to the day of the week. The estimated coefficients and the related robust standard errors are reported in Table 11.

Remark A.1 *Various simpler time series models have been tested, i.e. the simple ARCH model used in [29]. The results were quite unsatisfactory since the estimators of the sum of the γ_i were greater than 1 and thus involved a non-stationarity of the volatility. Therefore, we have used a more complex*

ARCH-in-mean model. The estimated coefficients are more satisfactory insofar as the stationarity condition is satisfied and the estimated coefficients are similar for both series. Nevertheless, this model for the volatility remains inconsistant since the Portmanteau test rejects the hypothesis of independence of the residuals at any conventional level.

B Detailed description of the raw data set

The raw data contains 39,189 bids that has been submitted for the period April 01 of 2001 to July 01 of 2005. The data set contains all the bids submitted for 1,581 IFA auctions held in this period. Each bid is characterized by five variables and by the contract he stands for.

Each auction is coded by 5 variables: the first, called "Direction", is a binary variable equal to 1 for the direction "France to England"; the second, called "deb", is the first day of the validity period of the capacity; the third, called "fin", is the last day of the validity period of the capacity; the fourth, called "emission", corresponds to the date of the auction[26]; finally, the variable "type" specifies the type of the auction (from daily to tri-annual).

Each bid is characterized by a set of 5 variables: the identity "ID" of the bidder coded by a number between 1 and 23 where 23 corresponds to the event where this value is missing (about 4% of the whole submitted bids), the price "PRICE ASK" in Euros per MW, the number of Units demanded in MW "QUANTITY ASK", the number of units allocated corresponding to this bid "QUANTITY OBT" and finally the variable "NUMBER" which is supposed to code for the chronology of the whole set of recorded bids in the IFA auctions. The highest recorded number is 43,524, which suggests that more than 3,000 bids have been lost or that some jumps occurred.

C Details of the variables construction

REPAIR is a binary variable that have been constructed in order to capture the days where the auction have been cancelled due to an outage. Unfortunately, our database does not report the reason why no bids have been submitted one day: either because potential buyers have decided not to participate or because the auction has been cancelled. Nevertheless, since it is the same link that is used in both direction, an outage should imply a cancellation of the auctions in both directions. On the other hand, it seems very unlikely that the capacity remains unsold in both direction even with the reserve price of 3 Euros. If the reserve price is binding in one direction because the price differential is expected to be low, then bidders should expect a high price differential in the other direction, which is significantly

[26] This value is missing most of the time. Nevertheless, it has been filled when the same validity contract has been auctioned at different dates.

negatively correlated with the previous one,[27] and then should find profitable to bid. Those arguments lead us to set the variable REPAIR to 1 if no bids have been received in both direction and 0 otherwise. REPAIR equal to 1 is interpreted as the cancellation of the auction by the Operator.

We test that the so-defined variable REPAIR is not random suggesting that outages mostly take place when the value of the interconnector is low (which is reasonable for planned outages). The average ex-post value per MW of capacity is 87.7 (respectively 44.0) Euros for the direction “France to England” (resp. “England to France”) if REPAIR equals to 1. Those values significantly differ from the averages with REPAIR equal to 0: the value of the direction “France to England” (resp. “England to France”) is greater (resp. lower) in the periods with REPAIR equal to one. On the whole, the total average value of the interconnector is lower in period of repair (131.7 Euros) than in period where REPAIR equals to 0 (144.7 Euros). This nearly 10% difference is statistically significant at the $p < 0.05$ level using a one-tailed Wilcoxon nonparametric test.

References

[1] D. Abreu, D. Pearce, and E. Stacchetti. Optimal cartel equilibria with imperfect monitoring. *Journal of Economic Theory*, 39:251–269, 1986.

[2] P. Alsemgeest, C. Noussair, and M. Olson. Experimental comparisons of auctions under single- and multi-unit demand. *Ecomic Inquiry*, 36:87–97, January 1998.

[3] S. Athey and P. Haile. *Nonparametric Appraoches to Auctions*. Handbook of Econometrics, Vol. 6, forthcoming. Amsterdam: NorthHolland.

[4] L. Ausubel. An efficient ascending-bid auction for multiple objects. *American Economic Review*, 94(5):1452–1475, 2004.

[5] L. Ausubel and J. Schwartz. The ascending auction paradox. *Working Paper, University of Maryland*, July 1999.

[6] F. Boisseleau. *The Role of Power Exchanges for the Creation of a single European electricity market: market design and market regulation.* Delft University Press, 2004.

[7] T. Börgers and C. Dustmann. Strange bids: Bidding behaviour in the united kingdom’s third generation spectrum auction. *Economic Journal*, 115:551–578, 2005.

[27] The coefficient of the regression of the price differential of one direction to the other with ARIMA models is significantly negative.

[8] S. Brusco and G. Lopomo. Collusion via signalling in simultaneous ascending bid auctions with heterogeneous objects, with and without complementarities. *Review of Economic Studies*, 69:1–30, 2002.

[9] E. B. Cammack. Evidence on bidding strategies and the information in treasury bill auctions. *Journal of Political Economy*, 99(1):100–130, February 1991.

[10] P. Cramton and J. Schwartz. Collusive bidding in the fcc spectrum auctions. *Contributions to Economic Analysis & Policy*, 1(1), 2002.

[11] G. Demange and G. Laroque. *Finance et économie de l'incertain*. Economica, 2001.

[12] S. Donald and H. Paarsch. Piecewise pseudo-maximum likelihood estimation in empirical models of auctions. *International Economic Review*, 34:121–148, 1993.

[13] D. Engelmann and V. Grimm. Bidding behavior in multi-unit auctions - an experimental investigation and some theoretical insights. mimeo, June 2004.

[14] D. Fudenberg and J. Tirole. *Game Theory*. The MIT Press, 1991.

[15] P. Février, R. Préget, and M. Visser. Econometrics of share auctions. *mimeo*, 2004.

[16] R. Gilbert, D. Newbery, and K. Neuhoff. Allocating transmission to mitigate market power in electricity networks. *RAND*, 35(4):691–711, 2004.

[17] G. Goswami, T. Noe, and M. Rebello. Collusion in uniform-price auction: Experimental evidence and implications for treasury auctions. *The Review of Financial Studies*, 9(3):757–785, 1996.

[18] V. Grimm, F. Ridel, and E. Wolfstetter. Low price equilibrium in multi-unit auctions: the gsm spectrum auction in germany. *International Journal of Industrial Organization*, 21:1557–1569, 2003.

[19] A. Hortaçsu. Mechanism choice and strategic bidding in divisible good auctions: An empirical analysis of the turkish treasury auction market. *mimeo*, 2002.

[20] P. Jehiel and B. Moldovanu. An economic perspective on auctions. *Economic Policy*, pages 271–308, 2003.

[21] M. Jofre-Bonet and M. Pesendorfer. Estimation of a dynamic auction game. *Econometrica*, 71(5):1443–1489, 2003.

[22] P. L. Joskow and J. Tirole. Transmission rights and market power on electricity power networks. *Rand Journal of Economics*, 31(3):450–487, 2000.

[23] J. Kagel and D. Levin. Behavior in multi-unit demand auctions: Experiments with uniform price and dynamic vickrey auctions. *Econometrica*, 69(2):413–454, 2001.

[24] P. D. Klemperer and M. A. Meyer. Supply function equilibria in oligopoly under uncertainty. *Econometrica*, 57(6):1243–1277, 1989.

[25] I. Kremer and K. Nyborg. Underpricing and market power in uniform price auctions. *The Review of Financial Studies*, 17(3):849–877, 2004.

[26] D. Levin, J. Kagel, and J.-F. Richard. Revenue effects and information processing in english common value auctions. *Amer. Econ. Rev.*, 86:442–460, 1996.

[27] P. Milgrom. Putting auction theory to work: The simultaneous ascending auction. *Journal of Political Economy*, 108(2):245–272, 2000.

[28] P. Milgrom and R. Weber. A theory of auctions and competitive bidding. *Econometrica*, 50:1089–1122, 1982.

[29] K. G. Nyborg, K. Rydqvist, and S. M. Sundaresan. Bidder behavior in multiunit auctions: Evidence from swedish treasury auctions. *Journal of Political Economy*, 110(2):394–424, 2002.

[30] K. G. Nyborg and S. Sundaresan. Discriminatory versus uniform treasury auctions: Evidence from when-issued transactions. *Journal of Financial Economics*, 42(1):63–104, September 1996.

[31] A. Ockenfels and A. Roth. Last and multiple bidding in second price internet auctions: Theory and evidence concerning different rules for ending an auction. *Games and Economic Behavior*, 55:297–320, 2006.

[32] M. Perry and P. J. Reny. On the failure of the linkage principle in multi-unit auctions. *Econometrica*, 67(4):895–900, 1999.

[33] W. Pesendorfer and J. Swinkels. The loser's curse and information aggregation in common value auctions. *Econometrica*, 65:1247–1283, 1997.

[34] R. H. Porter. A study of cartel stability: The joint executive committee, 1880-1886. *The Bell Journal of Economics*, 14(2):301–314, 1983.

[35] A. Roth and A. Ockenfels. Last-minute bidding and the rules for ending second price auctions: Evidence from ebay and amazon auctions in the internet. *American Economic Review*, 92(4):1093–1103, 2002.

[36] P. A. Spindt and R. W. Stolz. Are us treasury bills underpriced in the primary market. *Journal of Banking and Finance*, 16:891–908, 1992.

[37] S. R. Umlauf. An empirical study of the mexican treasury bill auction. *Journal of Financial Economics*, 33(3):313–340, June 1993.

[38] R. Wilson. Auctions of shares. *Quaterly Journal of Economics*, 93:675–698, 1979.

[39] F. Wolak. *Identification and Estimation of Cost Functions Using Observed Bid Data*, volume II of *Advances in Econometrics: Theory and Applications*, chapter 4, pages 133–169. Cambridge University Press, 2003.

Figure 1: Source: National Grid Transco

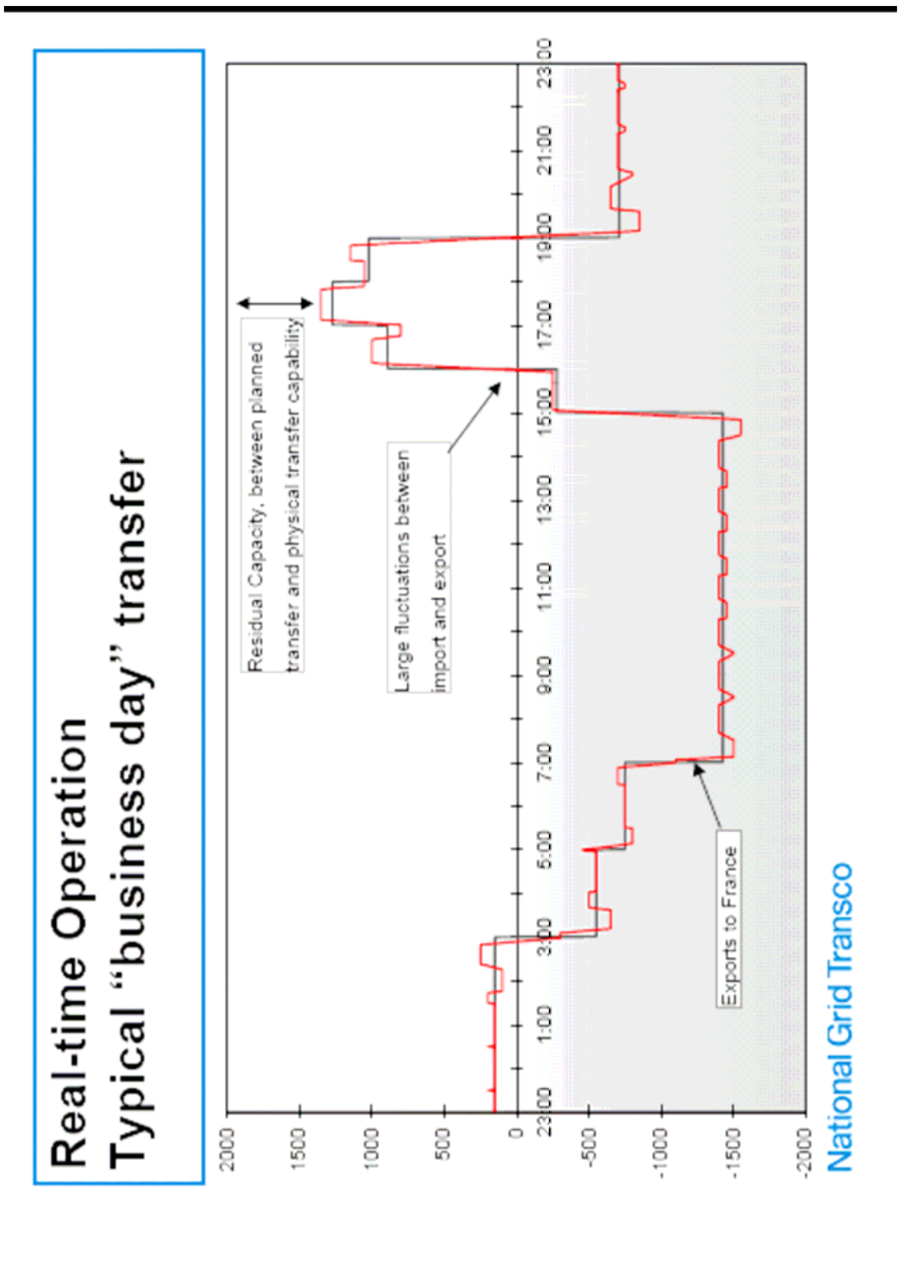

Figure 2: Instability of the margins

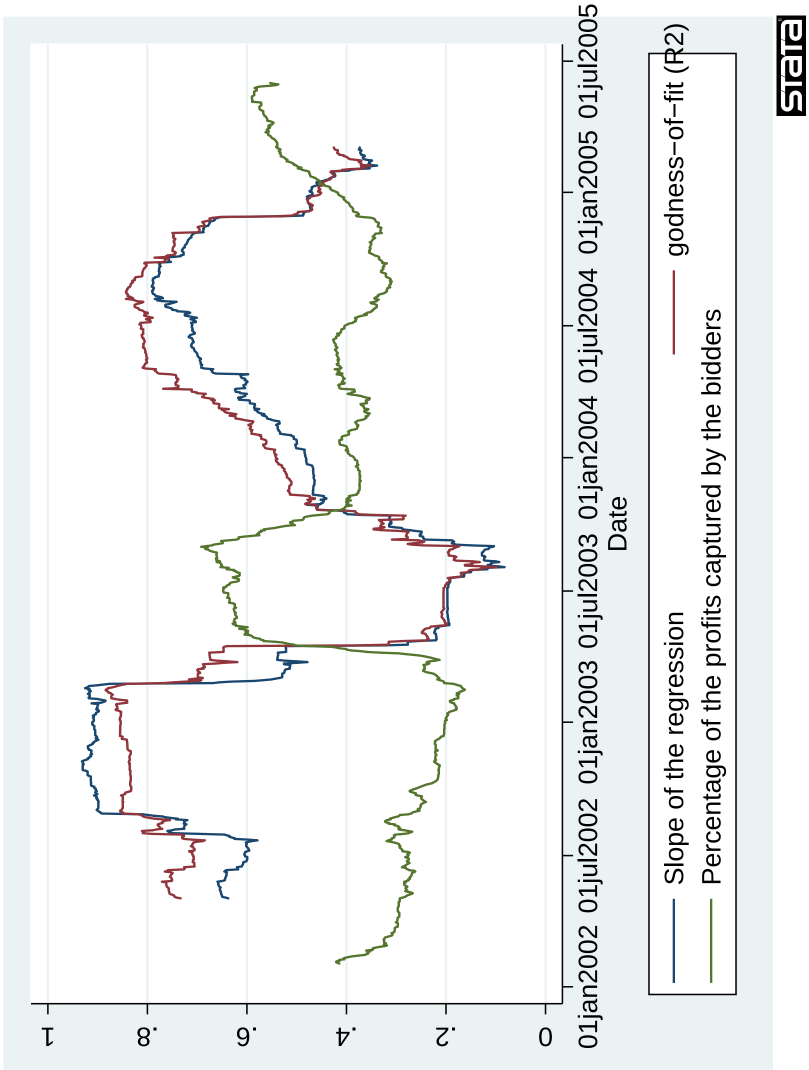

Figure 3: Dynamic of the sequential auctions for the annual contract for the year 2005 in the direction "France to England"

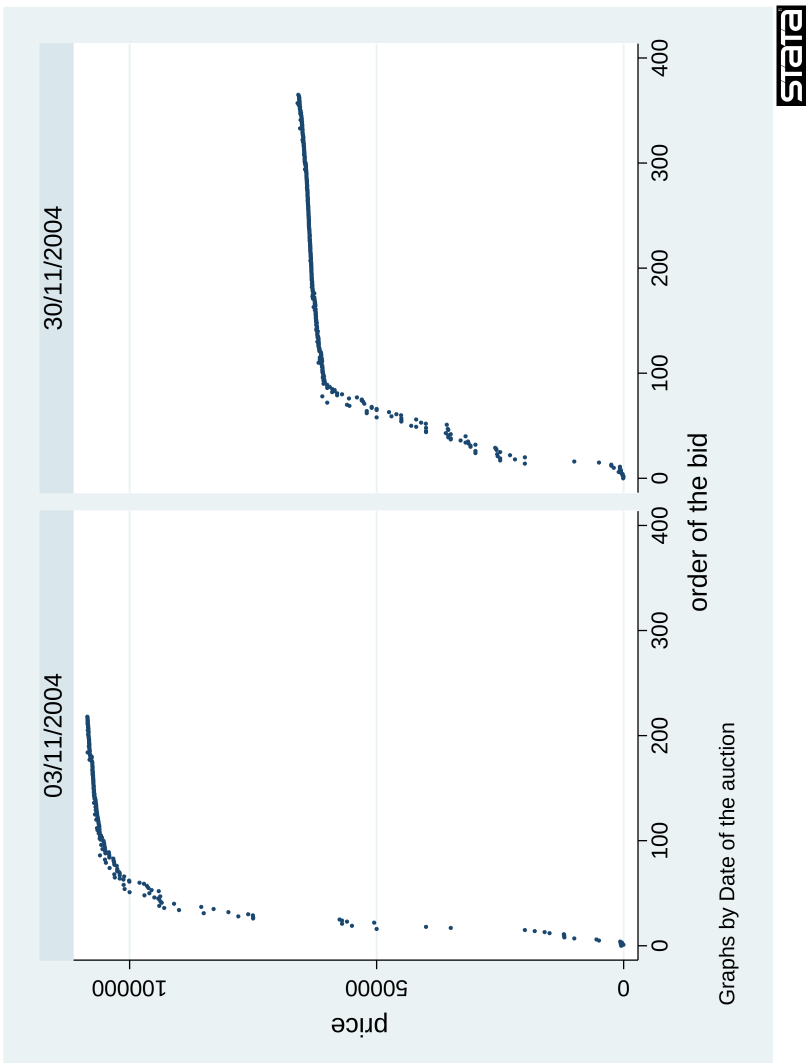

Figure 4: Price differential from France to England: January 2002 - June 2005