Netting of capacity in interconnector auctions

Felix Höffler* and Tobias Wittmann†

September 15th, 2005
PRELIMINARY

Abstract

Scarce interconnector capacities are a severe obstacle to transregional competition and a unified market for electricity in the European Union. These scarce capacities are often allocated in auctions, where a separate auction is held in each direction. We propose a "netting" auction mechanism which makes use of the simple fact that physically electricity flows in opposite directions cancel out. Thus, even small transmission capacities can generate large competitive pressure in both markets if only the auction process allows for the netting of bids in opposing directions.

Keywords: Divisible good auctions, interconnector, electricity markets, competition policy

JEL-Classification: L94, D44

*Max Planck Institute for Research on Collective Goods. Kurt-Schumacher-Str. 10, 53113 Bonn, Germany. ++49(0)228 9141646. hoeffler@coll.mpg.de.

†TU Berlin. Marchstr. 18. 10587 Berlin, Germany. ++49(0)30 31423280. wittmann@iet.tu-berlin.de.

1 Introduction

The liberalization of energy markets has tried to reduce entry barriers into regional and national markets. Since electricity can be transported at the high voltage level at very low cost there could be trans-regional or trans-national electricity markets. A geographically large market, based on imports and exports of electricity, could increase the level of competition and increase efficiency by supplying electricity by the least cost producer. For the European Union, the European Commission has very clearly formulated this goal:

> "Electricity should, as far as possible, flow between Member States as easily as it currently flows within Member States. Improved cross border flows will increase the scope for real competition which will drive economic efficiency in the sector..."(European Commission, 2004a, 3)

A considerable obstacle to this is the limited cross-border transmission capacity between member countries. The Council of European Energy Regulators (CEER) names the "Lack of transmission capacity (in particular, cross-border interconnection capacity)" first among the five major factors hindering the development towards a single energy market. The reason for the low interconnector capacities lie in the past: "Transmission networks were not developed in order to support efficient trade", but rather to optimize intra-country operations (CEER, 2003, 2). With increasing interest in the international trade of electricity, cross-border transmission capacities have now become a bottleneck.

It has become common practice that in case of congestion the scarce capacities are allocated in auctions with the aim of reaching a (statically) efficient and non-discriminatory allocation. In these auctions bidders can acquire transmission capacity for e.g. the next year or the next month. Transmission capacities are offered into both directions of the interconnector.

Although auctions are a transparent mechanism to allocate a given amount of capacity, it is not automatically ensured that the efficient quantity is posted for sale in the auction. There are frequent complaints that integrated electricity companies withhold capacity by putting too little capacity in the auction in order to foreclose their downstream retail market. A particularly confusing observation is that in long-term auctions there is trade in both directions although – by the law of physics – the current can go only in one direction. Thus, if there is demand for transmission in opposite directions there is the opportunity of netting the two flows. If one bidder wants to trade 100 from A to B and the other 40 from B to A, a physical transmission capacity of only 60 is required.

The aim of this paper is to investigate the opportunities of netting which arise from the specific technical characteristics of electricity transmission. We ask whether (i) netting in itself can increase the efficient level of trade between regions and whether (ii) netting can also limit the transmission company's incentive to withhold capacity from the auction. By analyzing auction data from large European interconnector auctions we find that interconnectors are only rarely fully used under the current system without or with incomplete netting. There is idle capacity although there is demand at positive prices which is not served. Thus, there is scope for improvement.

We therefore propose a simple netting mechanism which we analyze theoretically to identify the strategic considerations of the auctioneer and the bidders which might influence the outcome of such a netting mechanism. The mechanism works as follows. First the auctioneer announces the available physical capacity. Then bidders submit bidding functions. The direction for which demand at zero price is smaller is served fully at zero cost. The opposite direction gets offered as capacity this quantity plus the capacity announced by the auctioneer. The price is determined by using the rules of a uniform price auction.

We find that if we restrict bidders to use linear bidding functions that this two stage game has a unique symmetric subgame perfect equilibrium. This we compare to the (also unique) subgame perfect equilibrium of a separate auction setup. The main theoretical result is that the netting mechanism is unambiguously welfare superior to having separate auctions. The smaller market is always served up to the maximum demand and the larger market is never served less than in the separate auction. The auctioneer, however, strictly prefers holding separate actions.

The major obstacle for using netting mechanism is that it requires that booked capacities must be used. Currently, capacities are just options to transport electricity. Thus, netting implies higher risk in the sense that a bidder who has acquired capacity must also find a buyer in the target region. We discuss this issue with the help of an example and show solutions to it.

Congestion management has attracted considerable attention among economist. Nodal pricing (Schweppe, Caramanis, Tabors, and Bohn (1988), Hogan (1992)) addresses the optimal pricing of transmission capacity. Regulation of such prices is analyzed in Vogelsang (2001) and Nasser (1997). A related literature discusses the incentives for expanding congested networks. Joskow and Tirole (2003) provide an overview of this literature. Since we are analyzing auctions as a mechanism for allocating transmission capacity, we rely on theoretical results on divisible good auctions, in particular Ausubel and Cramton (2002). In the more practical debate Consentec and Frontier Economics (2004) have provided a detailed consulting paper to the European Commission touching some of the issues of our paper. However, like most practical contributions, the approach used is to assume some bidding function (which might or might not stem from truthful bidding) and discuss how different mechanisms would translate these bidding functions into allocations. This literature lacks a formal analysis of strategic bidding behavior (which also would yield different behavior in different mechanisms). None of the existing literature explicitly focuses on the issue of incorporating netting of counterflows in the auction process. We also add to the existing literature the combination of analyzing real world interconnector auctions and a theoretical treatment of strategic behavior of both, the bidders and the seller.

The remainder of the paper is organized as follows. The next section provides some more information on the policy issues involved in cross-border transmission of electricity. Section 3 shows by a simple example that netting could indeed increase competitive pressure and thereby increase welfare without having to invest into additional capacity. Section 4 introduces the main characteristics of the most important interconnector auction currently held in Europe. This includes the auction rules and details on observed trading behavior, prices and physical usage of the interconnectors. Section 5 provides the theoretical analysis of a netting mechanism. Section 6 concludes.

2 Competition Policy Issues

Within the European Union it is a clearly spelled out policy target to establish a unified market also for electricity. The European Commission stated:

> "At its meeting in Lisbon on 23 and 24 March 2000, the European Council called for rapid work to be undertaken to complete the internal market in both electricity and gas sectors and to speed up liberalization in these sectors with a view of achieving fully operational internal markets."(European Union (2003))

The increase in cross-border trade has, however, been limited so far. Figure 1 shows the (physical) export of electricity in TWh in the West- and central European area, covered by the UCTE (Union for the coordination of transmission of electricity).[1] The Data indicate that cross-border activities have been growing in the past in continental Europe, but growth has been smaller when looking only at the EU-15 countries covered by the UCTE 1992. The compound annual growth rate 1992 - 2004 has been 6.2% for the total UCTE (including additional member countries), 5.5% (for the countries which were UCTE member in 1992), and 3.9% in the EU-15 countries. This figure is even more disappointing from the EU's perspective if one take into account that the electricity consumption itself increased by 2.2% p.a. between 1992 and 2003.[2]

The Commission has frequently called to remove the bottlenecks for cross-border trade, though with limited success:

> "The [EU] Commission has repeated called for rapid progress to be made on certain network investments, particularly those seeking to increase the integration of national electricity markets. ... Nevertheless results have been very disappointing up to now."(European Commission (2003))

Therefore the EU-Commission has identified additions to existing interconnector capacities as "priority projects" at almost every border between member

[1] Data can be downloaded for each year on a monthly basis from: http://www.ucte.org/statistics/ exchange/ e_default.asp. Data download for graph: 05/09/09.

[2] Consumption figures are published by Eurostat, downloadable http://epp.eurostat.cec.eu.int, following the path "environment and energy - energy - energy consumption - final energy consumption of electricity". Data download 05/09/09.

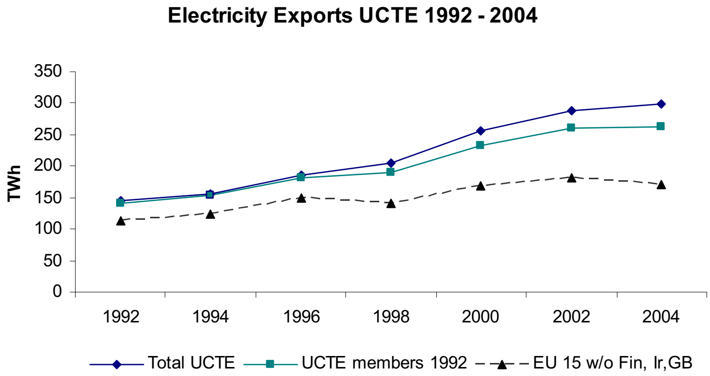

Figure 1: Electricity Exports, Source: UCTE

countries (European Commission (2004b)) in its "TEN-E" program (Trans European Energy Networks).

With respect to the already existing interconnector capacities, which in the past used to be allocated by the network owner in a rather opaque manner, it is now common practice to hold auctions for interconnector capacity in case of congestion. A key question, however, remains: How much capacity is actually available? Not only are there physical limitations, it might also be the case that integrated electricity companies withhold capacity from the auction process in order to make market entry into their home market more difficult.

This is at least a concern spelled out by the energy traders who want to engage in cross-country electricity trade. Their representation, the "European Federation of Energy Traders" (EFET), complains:

> "EFET believes that at nearly all regularly congested borders in the UCTE area potential NTC (Net Transfer Capacity), and therefore actual ATC (Available Transfer Capacity), are systematically underestimated. ... Among the reasons TSOs (Transmission System Operators) may do this are: ...
>
> • Inaccurate or unduly conservative calculation of expected counter and loop flows; ...
>
> • Non-objective approach to capacity reservations claimed by suppliers for legacy import / export contracts; ...
>
> • Over-cautious withholding of capacity within a control area on one side of an interconnection, on the pretext of system security or balancing eventualities; ..."(EFET, 2003, 2)

The system operator clearly has an informational advantage on how much capacity is available. He knows best what capacity reserves are required to ensure the system stability, he knows best the loop flows etc. Thus, he might, as suggested by the EFET, use the informational advantage to withhold capacity from the auction.

While the focus of the EU Commission is on increasing the existing capacities, our approach is concerned with the question of how existing capacities could be used more efficiently. The following section will show by the use of an example that considerable welfare increasing effects are possible by just changing the rules of allocation for capacities and without any additional investment.

3 An Example

Consider two similar countries which differ slightly in market size. The demand for electricity is given for each of the two countries by the following linear demand functions:

$$\begin{aligned} D_1(p_1) &= 100 - p_1 \\ D_2(p_2) &= 98 - p_2. \end{aligned}$$

There are two identical firms, one in each country. For simplicity assume that both produce with the same constant marginal cost, which we normalize to zero. Initially, each national market is served by its incumbent who acts as a monopolist. Therefore, in the absence of cross-country competition the monopoly solution is realized in each country:

Monopoly Solution	Price	Consumption
Country 1	$p_1^M = 50$	$q_1^M = 50$
Country 2	$p_2^M = 49$	$q_2^M = 49$

Now assume that there exists a small interconnector between the two countries with a capacity of 2 units per period. Using this interconnector, a firm can enter the adjacent market. Assume that, in line with the current system used in practice, only the physical capacity is sold in each direction. An entrant acts as a "fringe firm" in the market, and the incumbent optimizes against the residual demand function, assuming that the entrant dumps his capacity in the market. This implies:

Separate auction	Price	Consumption
Country 1	$p_1^S = 49$	$q_1^S = 51$
Country 2	$p_2^S = 48$	$q_2^S = 50$

There is some positive effect from cross-border competition. Since it is rather small, this might call for an extension of the physical capacity of the interconnector. Note that albeit there is some cross-border trade, the interconnector is physically not used. Before calling for additional investments (which would indeed improve the situation) it might therefore be sensible first to investigate how the existing capacity might be used more effectively.

Imagine for a moment that there would be no limit to the interconnector capacity and that the two markets could be considered as an integrated market. Assume that both firms would then act as a Cournot duopolist in the unified market, thus, the price would be the same in the two regions. This would yield the following outcome:

Netting mechanism	Price	Consumption
Country 1	$p_1^C = 33$	$q_1^C = 67$
Country 2	$p_2^C = 33$	$q_2^C = 65$

Each firm produces the same amount of 66 units. Note that to realize this far more competitive solution still only a physical transfer of 1 unit of electricity is necessary (from country 2 to country 1). The interconnector capacity could even be reduced – if only the interconnector capacity could be allocated in a netting mechanism such that the demands of the same size but in opposite directions can cancel out.

This simple example shows that netting of demands for interconnector capacity could produce enormous welfare gains by increasing the competitive pressure in each market without increasing the physical transmission capacity. In contrast to markets where physical transportation in either direction is required (then firm 1 would have to transport 32.5 units into market 2 and firm 2 would have to transport 33.5 units into market 1), in electricity markets the laws of physics imply already a netting of transport quantities, since electricity can flow only in one direction.

4 Current System of Interconnector Capacity Allocation

Before analyzing a netting mechanism we first want to discuss some facts of the existing interconnector auction to be able to relate back the theoretical analysis to the real world problem.

4.1 Rules

The analysis focusses on the interconnector auctions between the UK and France, the Dutch - Belgium - German interconnector and the interconnector between Denmark and Germany. The rules are, however, similar in most other European interconnector auctions.[3]

Typically, transmission capacity is sold in three "tranches": an annual auction, a monthly auction, and a daily auction. In the annual auction, bidders can acquire a "band" for the coming year. That is, they receive the right to transmit a certain amount of Mega Watt (MW) for 24 hours, 365 days. The monthly auction sells a similar band for a certain month. In the daily auction, bidders

[3] The Scandinavian (nordic) market uses a different (implicit auction) mechanism.

[MW]	Total NTC	Year Auction	Month Auction	Day Auction
DK→GER	1200	350	450	400
GER→DK	800	200	400	200

Table 1: Capacity reservation at the Danish - German interconnector

can acquire day-ahead a transmission capacity in MW for a specific hour, e.g. between 8 and 9 p.m., for the following day.

All auctions are uniform price auctions: each winning bidder pays the same price per MW, typically the price of the highest losing bid. The bidding functions bidders are allowed to submit are discrete and consist of no more than ten price / capacity combinations. This is a major difference to spot market auctions for electricity, where, e.g. at the European Electricity Exchange (EEX), bidders have to submit continuous bidding functions.

Since bids are discrete, it can be the case that winning bidders get rationed. The rationing rule is "pro rata on the margin". If rationing is required, because at the highest market clearing price there is excess demand, bidders with highest demand at higher prices get served with priority (see Kremer and Nyborg (2004) for a theoretical analysis of the importance of the rationing rule).

Successful bidders of the annual and monthly auction can resell their capacity to other market participants. Furthermore, they can return it to the auctioneer, who will then include it in the next, more short term auction, and the bidders will receive the auction proceeds for his returned capacity. What is sold in the annual and monthly auction is actually an option to transport electricity. Bidders are not obliged to use the capacity.

The key concern of our paper is not with the pricing rules – which obviously are rather complicated and make a full theoretical treatment very challenging – but with the capacity offered. All current systems take as a starting point the maximum physical capacity of the interconnector (minus loop flows in the network, which are estimated from historic data and cannot be influenced by the market participants). This is the maximum which is offered in each direction. An interconnector between North and South of size 1.000 MW will therefore offer 1.000 MW in the direction $N \rightarrow S$ and 1.000 MW in the opposite direction $S \rightarrow N$. Since the total capacity is sold in three tranches, auctioneers split the maximum capacity for each auction.

For instance, at the German - Danish border, the interconnector has a size of 1.200 MW. There is a technical loop flow of 400 MW from Germany to Denmark, thus the maximum amount offered is 1.200 from Denmark to Germany and 800 from Germany to Denmark. Out of these maximum capacities, the amount for each tranch are calculated, e.g. from Denmark to Germany 350 MW are sold in the annual auction, 450 in the month auction and 400 MW are reserved for the daily auction, see Table 1.

While no more than 350 MW can be offered in the annual auction $DK \rightarrow GER$, in the daily auction more than 400 can be offered by the auctioneer because owners of long term capacity can return capacity they are not going to

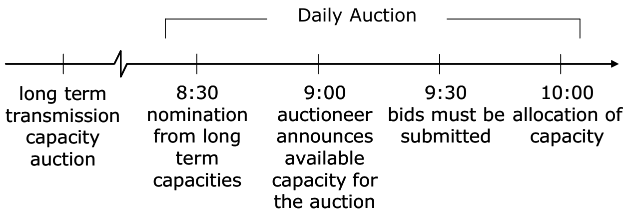

Figure 2: Timing in Daily Auction at the Danish - German Interconnector

actually use. Figure 2 illustrates in detail the process of the daily auction for the Danish - German interconnector auction.

In the morning each holder of capacity must "nominate" his capacity for the following day, i.e. must say how much of his capacity he will actually use. This announcement is binding. If some of the capacity is not used it is returned and included in the daily auction. Thus, if bidder A has acquired 100 MW in the annual auction but will not use it at April 17 from 4-8 am, he will nominate zero capacity for this time in the morning of April 16. The auctioneer will (if no other player returns capacity) then offer 500 MW for 4-8 am on April 17 in the auction held in them morning of April 16.

If all capacity offered in the different auctions are sold in each direction and this capacity would actually be nominated, the interconnector would not be used physically. The flows would totally cancel out. There are, however, occasions where the auctioneers already make use of netting in the daily auctions. Since they know after the nomination how much of the long-term capacity will be used in each direction, they add the nominated amount for one direction to the amount offered for the opposite direction in the daily auction. This is done at the German - Danish interconnector and explains why at some days the amount offered in the daily auction exceeds the physical capacity of the interconnector. In the Appendix we briefly discuss this example. This underlines that the idea of netting of flows in the auction process is in principle viable in practice. The key issue to be analyzed is why netting happens only in daily and not in long-term auctions.

4.2 Auction Results

We have seen that in interconnector auctions only the physical capacity (after deductions for loop flows) is offered in both directions. Therefore, only if there would be no trade in one direction, the physical capacity of the interconnector would be fully used.

When looking at the data of four of the major European interconnector auctions it is obvious that this is not the case. There is trade in both directions in the annual and monthly auctions for all auctions considered here, namely capacity auctions between the UK and France, the Netherlands, Belgium and

From	To	available capacity [MW]	obtained capacity [MW]	Price
Belgium	Netherlands	328	328	18921.60 €
Netherlands	Belgium	328	328	876.02 €
Germany (RWE)	Netherlands	356	356	51700.00 €
Netherlands	Germany (RWE)	356	356	603.35 €
Germany (E.ON)	Netherlands	216	216	51868.01 €
Netherlands	Germany (E.ON)	216	216	603.35 €
Denmark	Germany (E.ON)	350	350	27564.12 €
Germany (E.ON)	Denmark	200	200	16655.00 €
France	UK	150	150	76375.00 €
UK	France	150	150	4918.19 €

Table 2: Results of the year auction at several European interconnectors

Germany as well as between Germany and Denmark.

Table 2 shows the results of the annual auction 2005. Note first that the same amount is offered in both directions in all auctions with the exception of the Danish - German auction (there is a considerable loop flow from South to North responsible for this asymmetry). The second important observation is that there are positive prices for both directions in all auctions. Prices, however, differ with respect to the direction. The data shows a strong demand for capacity towards the Netherlands. Prices paid in the opposite direction only range from 1.2 % to 4.6 % of the prices paid toward the Netherlands. Note, however, that even if prices differ significantly for each direction, a positive price still indicates that not all demand could be satisfied. Put differently, positive prices imply unsatisfied interest in trade in opposite directions which could provide the opportunity of netting the trades in order to achieve a higher utilization of the interconnector. Price differences are lower for the UK - France interconnector. At the Danish - German interconnector prices are still different for each direction but at the same order of magnitude.

The monthly auctions show similar results. Again, bidders pay for capacity in both direction, while prices differ in a similar pattern as in the annual auction for the respective directions. In contrast, in the daily auction there is trade only in one direction. The price for the other direction is always zero.

Observation 1 *In the long-term auctions there is trade in both directions. In the daily auction there is trade only in one direction.*

Table 3 compares the prices at the different time frames for the Danish - German interconnector auction. Prices refer to the transmission of 1 MW for the whole month (i.e. for the annual auction this is just the auction price divided by 12, while for the daily auction it is the sum of all hourly prices for the specific month). There is no clear order of prices between the auctions. While in the direction Germany to Denmark capacity in the annual auction was more than

month	Denmark → Germany			Germany → Denmark		
	year auction [€]	month auction [€]	day auction [€]	year auction [€]	month auction [€]	day auction [€]
Jan 04	1478.67	1547.52	1901.02	2750.00	1637.00	404.33
Feb 04	1478.67	1722.00	1044.17	2750.00	1616.51	547.33
Mar 04	1478.67	1490.00	2251.30	2750.00	556.76	433.27
Apr 04	1478.67	112.66	461.41	2750.00	1224.00	1039.72
May 04	1478.67	997.00	831.56	2750.00	1511.03	2322.80
Jun 04	1478.67	927.00	1290.46	2750.00	2196.00	3981.05
Jul 04	1478.67	818.00	1016.06	2750.00	n.a.	1729.85
Aug 04	1478.67	1028.00	440.45	2750.00	2988.00	2466.23
Sep 04	1478.67	900.00	1046.30	2750.00	2612.03	1287.09
Oct 04	1478.67	1533.00	2217.61	2750.00	1473.00	727.63
Nov 04	1478.67	2435.54	2289.00	2750.00	936.00	993.56
Dec 04	1478.67	2255.15	3583.83	2750.00	867.00	283.05
sum	17744.00	15765.87	18373.17	33000.00	17617.33	16215.91

Table 3: Comparison of annual, monthly and daily auction prices at the Danish - German interconnector 2004

twice the average price of the daily auction, in the opposite direction capacity was slightly more expensive in the daily auction than in the long-term auctions. Higher prices in the long-term auction could be interpreted as the result of risk aversion. Long-term capacities serve as an insurance against the volatility in the daily auction price. However, this is most attractive if the bidder has a long-term electricity supply contract which he has to support by transmission capacity. For short term trading acquiring long-term capacity makes little sense since at many days it would be left unused, which – given the insurance premium of up to 100% over the daily auction prices – seems to be very expensive. This suggests that there is interest in transmission capacity from OTC supply contract in opposite directions. In the Appendix, when discussing the partial netting at the Danish - German interconnector, we provide further support for this conjecture.

Conjecture 1 *There is demand for long-term transmission capacity independent of the short-term spot market price.*

Further evidence for this conjecture is provided by the aggregate data on imports and exports of electricity. Within the same period, member countries within the European Union sell and buy electricity from another member country.[4] We believe that the independent demand for long-term transmission capacity stems from long-term supply contracts and that such long-term supply contracts are signed for opposite directions for overlapping periods. This might

[4] This does, however, not necessarily imply trade into both directions at the same point in time, but be a result of aggregation of - say - different hours where in each hour there was trade only in one direction.

from	to	NTC [MW]	average [MW]	standard deviation
Denmark	Germany	1200	590.4	507.2
Germany	Denmark	800	172.2	291.9

Table 4: Physical properties of the Danish - German interconnector

partially just due to a timing issue: not all contracts are signed at the same time and have the same contract length. Furthermore, incumbents typically loose market shares in their home countries. They try to outweigh this by acquiring customers in other countries, often by acquiring regional distribution companies or municipal utilities. Often the aim is to sell electricity from the own source to the customers of the acquired company, which provides an incentive for cross-border trade relatively independent from the spot market prices. Germany is a good example for this. Foreign firms have acquired retail companies in Germany, while at the same time, Germany also exports electricity to the home markets of the acquiring firms.[5]

We now turn to the question of physical usage of the interconnectors. Although partial netting is sometimes used in short-term auctions, the interconnector is rarely fully used. Data of the physical usage is often proprietary to the network operators and not publicly available.[6] Fortunately, at the Danish - German interconnector these data are available from Nordpool, the Scandinavian energy exchange. The net transfer capacity (NTC, the maximum physical usage), the average physical usage and the standard deviation are provided table 4 for the year 2004. Less than 50% of the physically available capacity has been used on average. Figure 3 visualizes the usage of the interconnector between January 2004 and August 2005 on a hourly basis, measured by the utilization rate as the ratio of used capacity over maximum physical capacity. It shows that full usage of the capacity occurred only 18% of the time, while for one third of the time the physical usage was below 50% of the available capacity – although there was a positive price at these periods and therefore not all demand was satisfied.

Thus, we conclude that the current system leaves interconnector capacity unused.

Observation 2 *Although prices are positive for at least one direction all the time, indicating that some demand has not been satisfied, the interconnectors are rarely used up to capacity.*

[5] EdF has a large stake in EnBW, one of the four German electricity incumbents – and EdF has large power production facilities in France. DONG, the Danish Gas, Oil and Electricity group, has acquired Stadtwerke Lübeck, a German municipal utility. The Dutch Energy group Essent has stakes in many German electricity utilities via its majority shareholding in Stadtwerke Bremen AG.

[6] Integrated electricity companies who are faced with the complaint of withholding interconnector capacity clearly have no incentive to publish these information. There are, however, strong indications that e.g. the Dutch - German interconnector despite the high price paid for exports to the Netherlands is almost never used up to physical capacity.

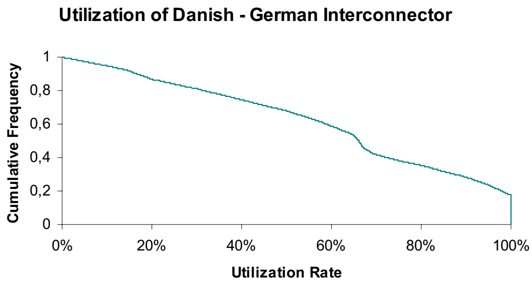

Figure 3: Utilization of Danish - German Interconnector. Source: NordPool

Although it is beyond the scope of the current paper to explain why this is the case, we want briefly mention possible reasons why this could be the case. The current system in which capacities are options, there exists an incentive for "hoarding" of capacity in the long-term auctions. One rational might be hedging: firms want to have the option for trade in case that a positive price differential between two regions arises or if they acquire customers in the target region in the future. We will later discuss the option perspective in more detail. Alternatively, a firm might execute hoarding for strategic purposes. Blocking capacities which could otherwise be used in a netting mechanism to enable more market entry can serve as a devise for market foreclosure.

5 Netting Mechanisms

In this section we want to investigate the effects if netting is introduced not only in the short-term auction but also in the long-term auction. This is of interest since the discussion of the preceding section has indicated that there is real demand for trade in both direction in the long-term auction, which, possibly, could stem from long-term supply contracts.

We proceed in three steps. First, we propose a simple theoretical framework in which we define a netting mechanism. Second, we analyze theoretically the properties of a netting mechanism compared to separate auctions in each direction. In this analysis we allow for strategic behavior of both, the bidders as well as the auctioneer. Finally, we discuss possible practical issues with regard to the interaction between long-term and short-term auctions and the fact that any netting mechanism requires that capacities are not an option to transmit electricity but an obligation.

5.1 Model

To facilitate the theoretical analysis we focus on a single (long-term) auction. Bidders submit bids in either directions. There is no private information and no uncertainty. There are no externalities, thus, in equilibrium, a bidder who received capacity will also want to use it.

Consider the following setup. There are two countries (indexed C), North and South. In the North there are n bidders, in the South s bidders, with demand for transmission capacity into the other country. A bidder's demand for capacity is denoted by q_i, his marginal valuation by $v_i(q_i)$. The payoff π_i of a bidder, who bought q_i units at a (uniform) price of p equals:

$$\pi^i = \int_0^{q_i} v_i(x)\,dx - pq_i. \tag{1}$$

Denote by q^N the aggregate quantity of the North and by q^S the aggregate quantity in the South. Call p^N the uniform price per unit in the North and by p^S the uniform price per unit in the South. The auctioneer is interested only in auction proceeds. There are no cost of providing interconnection services (all infrastructure cost are sunk), thus the auctioneer's payoff equals:

$$\Pi = p^S q^S + p^N q^N. \tag{2}$$

Both countries are connected by an interconnector of size $\overline{K}$. This technological restriction requires:

$$|q_N - q_S| \leq \overline{K}. \tag{3}$$

We call "netting" the following auction rule. First, the auctioneer announces the available net capacity K. The bidders in both countries submit bidding functions $\beta_i(q_i)$ denoting the marginal willingness to pay (i.e. the individual inverse demand functions). Bids are assume to be continuos.[7] The auctioneer then aggregates the demand function for each country to $q^N\left(p^N\right)$ and $q^S\left(p^S\right)$. She then compares for which direction the maximum demand is larger. Assume this is the North, i.e. $q^N(0) > q^S(0)$. In this case bids from the South get all served at a price of zero, while the price for the north is p^N is the one that equates demand to maximum supply:

$$q\left(p^N\right) = \overline{K} + q^S(0). \tag{4}$$

Alternatively, we will consider standard, separate uniform price auctions for each market. The auctioneer posts separate quantities K^N and K^S in the auction, where in equilibrium (3) must be satisfied. Bidders submit bidding functions $\beta_i(q_i)$ and we denote the equilibrium outcome of the auction by p^N, the highest market clearing price in the North, and p^S, the highest market clearing price in the South.

[7] See the results of Kremer and Nyborg (2004) on the equivalence of continuous bidding functions (which is not the current practice in interconnector auctions) and discrete bidding function in the presence of "pro rata on the margin" (which is current practice).

5.2 Analysis of Auction Formats

For comparison of the two auction formats we take the total social surplus, measured as the sum of the players' payoffs:

$$W = \sum_{i=1}^{n} \pi_i^{North} + \sum_{i=1}^{s} \pi_i^{South} + \Pi. \tag{5}$$

First note that for any given bidding functions and auctioneer's capacity announcement, the separate auction setting can never be welfare superior to the netting mechanism. It does strictly worse if there is a positive price in the South. This is trivially true for the South (since some demand is not satisfied due to $p^S > 0$ although – due to our assumption of costless production – could be served at zero additional cost) but also for the North, since this underconsumption in the South also withdraws possible supply from the Northern market, which it could enable by netting the offsetting currents. In particular, with truthful bidding the netting mechanism yields the maximum social surplus for the quantity posted while (with positive equilibrium price in the South) the separate auctions will yield an inefficient result.

Truthful bidding is, however, not likely to be a realistic assumption. Since we lack a good explanation with predictive power of how bidders actually behave, it seems sensible to analyze a fully rational bidding behavior as a benchmark scenario. This will provide us with insights into the direction strategic bidding behavior might deviate from truthful behavior. Bearing in mind the complaints by the market participants like the EFET quoted above, we also want to allow for strategic behavior of the auctioneer.

We want to analyze the auction process as a two stage game and look for a subgame perfect pure strategy equilibrium. First, the auctioneer announces a capacity $K \in \left(\underline{K}, \overline{K}\right)$ in the netting mechanism (and $K^S \in \left(\underline{K}, \overline{K}\right)$ and $K^N \in \left(\underline{K}, \overline{K}\right)$ in the separate auction format). $\underline{K} > 0$ is the minimum capacity level the auctioneer can convincingly argue to be available but it can be arbitrarily small.[8] Then, bidders submit bidding functions $\beta_i(q_i)$. On this basis equilibrium prices are determined as already described.

Although this setup is already highly stylized (compared to the much more complicated real world setting with different time horizons, reselling, and return of capacities), it is already very difficult to provide general solutions to this sort of games. In auction theoretical terms, at the second stage, we have a (i) multi-unit uniform price auction where (ii) bidders have valuations form more than one unit. The auction is a "share auction": bidders bid for a share of a perfectly divisible overall supply. Unfortunately, multi-unit auctions with downward sloping demand functions are analytically difficult and few general results are available. This is even true if attention is restricted to particular auction

[8] We could in principle also allow the auctioneer to choose K from the interval $(0, \infty)$. However, in equilibrium the auctioneer will never post $K = 0$, since this implies zero profits. Letting the auctioneer choose from the set $\left(0, \overline{K}\right)$ would only add additional technical problems to the analysis. We further assume that punishments for violating (3) are sufficiently severe that the auctioneer will never want to post more than $\overline{K}$.

formats, like the uniform price auction, which is most common in interconnector auctions. In his recent textbook on auction theory Krishna summarizes:

> "...[For uniform price auctions] a closed form expression for strategies is not available ... Calculating equilibrium strategies [is] a difficult task even in specific examples..."(Krishna, 2002, 185)

We will therefore make assumptions that considerably simplify the analysis. First, we assume that bidders are identical and have linear marginal valuation functions.

Assumption 1 *Bidders have linear marginal valuation functions:*

$$v_N^i = v_S^i = A - q_C^i.$$

Hence, the two regions differ only with respect to the number of bidders (which is an integer). Let the North be the market with the larger demand. For technical purposes we assume that the difference between the markets is not too small.

Assumption 2 $s, n \in \mathbb{N}$ *and* $s > 2$ *and* $s < n - 1$.

Since it is still difficult to obtained closed form solution in this framework, we further narrow down the analysis. However, even if a analytical result would be available it remains doubtful whether a highly complicated solution would be helpful in evaluating different auction formats for a real world auctions like interconnector auctions. As Paul Milgrom has put it:

> "In practice, auction designers place a tremendous value on the simplicity of an auction's design. Their priorities always include ensuring that the mechanics of bidding are easy, that simple strategies are effective for bidders, and that the outcomes are acceptable when bidders use simple strategies."(Milgrom, 2004, 253)

Hence, we restrict bidders to use linear bidding functions.

Assumption 3 *Bidders use linear bidding functions.*

Since linear bidding function are very simple bidding functions, the analysis relates to the requirement spelled out by Milgrom to be of high priority in practice. However, it is a severe restriction on the bidders strategy space. Thus, there might be non-linear bidding functions to which a bidder could profitably deviate which we exclude by this assumption. At a minium, we rule out many other equilibria which might exist.

5.2.1 Separate Auctions

We first want to analyze the separate auction setup. We focus on the Northern market, the southern market's solution is analogous. We solve the game backwards and assume that some K^N has been announced. For ease of notation we will now drop the regional superscript where this causes no confusion.

With linear bidding functions we are able to explicitly solve for the unique subgame perfect equilibrium of the game. It is a general and well known result that with decreasing marginal valuations bidders will employ "bid shading"(Ausubel and Cramton (2002)). Their bidding function will always lie strictly below the true demand function – except for the first unit.[9] In our context this implies that all bid functions take the form

$$\beta^i = A - b_i q_i, \text{ where } b_i < 1. \tag{6}$$

Since bidders do no bid shading at $q^i = 0$, the true demand function and the bid function differ only in their slope. Thus, the gain from restricting the bidders' strategy space to linear bidding functions implies that bidders optimize only over a parameter (namely b_i) instead of optimizing over functions.

Bid shading is well documented in empirical work, see Kagel and Levin (2001) for experimental evidence and List and Lucking-Reiley (2000) for a field experiment. Since optimizing over all possible bidding functions asks too much from mathematical economists, it is plausible that real decision makers will use more simple forms of optimizing behavior. Kirchkamp and Reiss (2004) report (in a different auction setting, namely, single good, first price auctions) that bidding behavior by experimental subjects were best described by a linear function which could result from a "satisficing" strategy: bidders want to make a certain profit and therefore bid a fixed amount below their true value, independent of their true value. The restriction to linear bidding strategies in our model obviously is a simple rule, saying that at each price the quantity demanded should be $x\%$ below the true demand. This is equivalent to a satisficing strategy with respect to the marginal profit: for the last unit acquired, the profit margin compared to the true valuation should be $x\%$.

Given the bid functions (6), and the equilibrium condition that aggregate demand must equal K, the price in the uniform price auction is determined by:

$$p = A - \frac{K}{\sum_{i=1}^{n} \frac{1}{b^i}}. \tag{7}$$

[9] To see why this is generally true note that a bidder's payoff equals

$$\int_0^{q_i} v_i(x)\,dx - pq_i,$$

thus, a bidding function must satisfy the first order condition:

$$p = v_i(q_i) + \frac{\partial p}{\partial q_i} q_i.$$

Therefore, except for $q_i = 0$, the bidding function is strictly below the true valuation $v_i(q_i)$.

Bidder $i's$ profit is given by:

$$\pi^i\left(b^i\right) = (A-p)\,q^i - \frac{1}{2}q^{i2},$$

which, using (7) and after some rearrangements can be written as:

$$\pi^i\left(b^i\right) = K^2\left(b^i - \frac{1}{2}\right)\left(\frac{1}{b^i\sum_{j=1}^{n}\frac{1}{b^j}}\right). \tag{8}$$

Solving the first order conditions and by symmetry we get as a unique symmetric equilibrium of the subgame:

$$b_I^i = \frac{n-1}{n-2} \text{ for } n > 2. \tag{9}$$

The bid function will be less steep, the higher the number of bidders. For $n \to \infty$ the bid function converge to the true demand functions since each individual bidders influence on the auction prices becomes arbitrarily small.

We now turn to the first stage, the auctioneer's optimization problem in choosing the revenue maximizing levels of capacities for each market. Assume that the auctioneer can solve each market's problem independently. This will be the case if the technologically available capacity is not too small. The exact condition is provided in (14).

Given the bidders' behavior, the auctioneer will choose K to maximize her profit $\Pi = Kp(K)$. The optimal choice of K is given by:

$$K_I^N = \frac{A}{2}\frac{n(n-2)}{n-1}. \tag{10}$$

This implies a price of

$$p_I^N = \frac{A}{2}. \tag{11}$$

For the South the results are similar:

$$p_I^S = \frac{A}{2}, \tag{12}$$

$$K_I^S = \frac{A}{2}\frac{s(s-2)}{s-1}. \tag{13}$$

Treating each market independently is optimal if K_I^N and K_I^S are feasible, which requires:

$$K_I^N - K_I^S \leq \overline{K}. \tag{14}$$

It is instructive to compare this outcome to the monopoly pricing. Consider a monopolist who knows the aggregate marginal demand functions, $Q^N\left(p^N\right) = n\left(A - p^N\right)$ and $Q^S\left(p^S\right) = s\left(A - p^S\right)$. He would set the monopoly price $p_M^N = p_M^S = \frac{A}{2}$ and bidders would acquire in total an amount of $q_M^N = \frac{An}{2}$ and $q_M^S = \frac{As}{2}$. Comparing this to (10) and (13) we observe:

Lemma 1 *Given (14) and provided bidders with linear marginal valuation functions use linear demand functions, the equilibrium quantity will be lower in the auction compared to the monopoly solution. Seller and buyers are better off under monopoly than under the uniform price auction.*

Imposing a single sided auction therefore is a two-edged sword. While it might have advantages in terms of transparency of fair access, it may induce serious inefficiencies. We have neglected inefficiencies which are generic in standard auctions like uniform or discriminatory auctions if bidders are not symmetric.[10] Even in the absence of asymmetries, supply reduction can be an additional source for inefficiencies. If auctioneers have discretion on the amount to be sold, they have an incentive to offer less than in the monopoly solution as rational reaction to the bid shading of bidders.

5.2.2 Netting Mechanism

Under the netting mechanism the smaller market, i.e. the South, gets served for free up to the maximum demand, $p_{II}^S = 0$ and $q_{II}^S = As$. The Northern bidders have to pay a positive price which will never be above the price in the separate auction format. Since the Northern quantity q_{II}^N will not be below the quantity in the separate auction, the netting mechanism is welfare superior: the amount of capacity used is larger and therefore the social surplus higher.

Proposition 2 *There exists a unique symmetrical subgame perfect equilibrium which is welfare superior to the subgame perfect equilibrium in the separate auction format.*

$$\begin{aligned} q_{II}^N &\geq q_I^N, \\ q_{II}^S &> q_I^S. \end{aligned}$$

The profits of the auctioneer are lower in the netting mechanism: $\Pi_{II} < \Pi_I$.

Proof. See Appendix. ■

To get an intuitive understanding it is crucial to see that it is not possible that the equilibrium price is zero in both markets. This cannot happen due to the bidding competition. If nobody pays, it must be the case that the maximum demand is below the possible supply. Thus, a bidder could deviate, get some more quantity and leave the zero equilibrium price unaltered. Such a deviation is profitable even at the margin, where maximum demand just equals supply. A bidder could still deviate which would yield a small increase in the price above zero (which has to be borne by all bidders) but the gain in capacity (which only the deviator receives) overcompensates this effect.

[10] We neglect here that due to bid shading uniform auctions are inefficient in the sense that they cannot guarantee that goods are allocated to the bidders with the highest valuations. Since bidders do not bid truthfully, marginal valuation among asymmetric bidders will in general differ equilibrium.

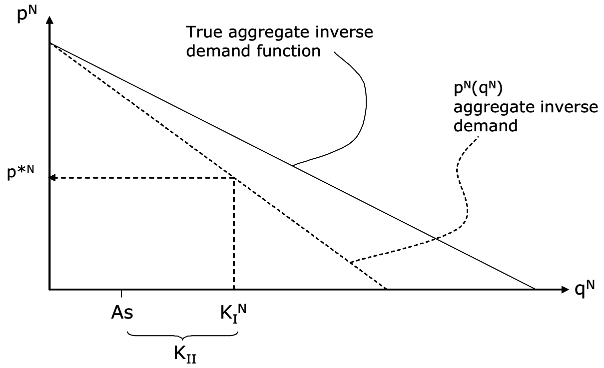

Figure 4: Northern market in netting with small Southern market

Since in equilibrium the price must be positive, the bidders in the South get served their maximum demand they are best off submitting their true bidding function. Since there is a positive price to be paid by the Northern bidders, they behave in the same way as bidders in the separate auction format if they were confronted with a supply of $K^N = As + K$, the maximum amount available given the Southerner's behavior. For the auctioneer this means that she can earn money only on the Northern market. If the Southern market is very small, i.e. As is small, the auctioneer can achieve the same profit in the Northern market as in the separate auction. She adjusts K_{II} such that exactly $q^N_{II} = K^N_I$ will be consumed by setting $K_{II} = K^N_I - As$. This is illustrated in Figure 4.

If the size of the market is similar, the auctioneer will not be able to realize this outcome anymore since she cannot offer less than $\underline{K}$. Since profits decrease the more the supply exceeds $q^N = K^N_I$ the best she can do is to offer the minium amount $\underline{K}$. This will lead to an outcome in which $q^N = As + \underline{K} > K^N_I$, thus also the North is better off than in the separate auction, see Figure 5.

Since the auctioneer can at best earn the same profit in the North under netting compared to separate auctions, but always earns zero in the South, she will strictly prefer a separate auction format. Bidders in the South are always better off since they get more capacity than under separate auctions and they get it for free. Bidders in the North are either indifferent if the Southern market is small, or otherwise prefer the netting mechanism.

Although the strategic behavior brings about that the first best cannot be achieved under netting (this requires $q^S = As$ and $q^N = As + \overline{K}$) the overall capacities traded are strictly higher under netting.[11] Thus, the welfare advan-

[11] One could again compare the outcome to the monopoly outcome. Note that, contrary to the separate auction format, netting can do better than the monopoly solution. The Southern market is always fully served thus the result there is welfare superior to the monopoly solution. The result in the North will also be welfare superior if only the Southern market is not too small: if $(nA/2) < As + \underline{K}$, then the monopoly quantity in the North is lower than the quantity

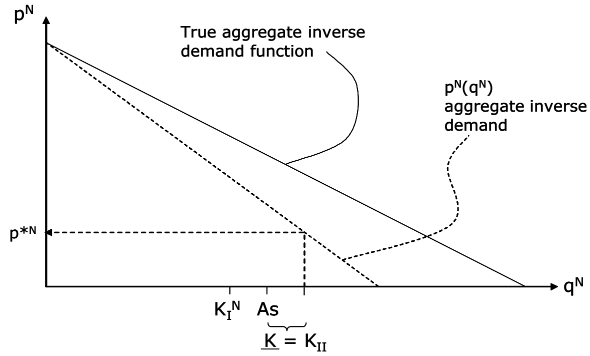

Figure 5: Northern market with netting a large Southern market

tage of netting over separate auctions, which stems from the better utilization of available capacity, seems to be robust against strategic behavior.

5.3 Potential Problems

The big advantage of the current system without netting of transmission capacities is the low level of risk involved, once transmission capacity is acquired by a market participant. An upstream electricity supplier who has bought transmission capacity in the long-term (year or month) auction can be sure that this capacity is available. The network management does not have to care that everybody uses her capacity because even if one direction leaves all capacity unused, physical delivery is still ensured fully into the opposite direction. To see why this is an advantage, it is useful to recall the timing of the transactions, illustrated in Figure 6.

Typically, large supply contracts are long-term contracts. In principle, a supplier could first sign a supply contract, e.g. with a large industrial customer in a different country, and only afterwards acquire the transmission capacity required for delivery. This carries significant risk since in case that the supplier is not successful in the transmission capacity auction, she will not be able to fulfil her supply obligations. This would imply high penalties or payments for purchasing from alternative sources within the customer's country. Suppliers therefore tend to first buy relatively large amounts of transmission capacity, and afterwards try to close contracts with customers and then – potentially – return unused capacity.

With netting matters are more complicated. Transmission capacities are "firm". Someone who has purchased capacity is obliged to physically use it. If a supplier first closes a supply contract and then buys capacity, she will still run the same risk as under the current system, namely the risk of not receiving

in the netting mechanism.

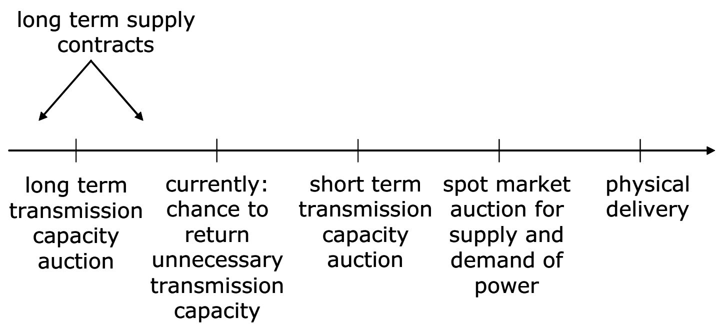

Figure 6: Timing of transactions

capacity and thus being unable to fulfil the supply obligation. If the supplier first buys capacity, she will run into the additional risk of getting no supply contract and thus being unable to fulfil the obligation to use the acquired transmission capacity. To illustrate the problem and its possible solutions consider the following example, depicted in Figure 7.

There are two countries, North and South, connected with an interconnector of capacity 50 MW. Supplier A situated in the South has signed a contract with the Northern customer D. The Northern supplier C hopes to get into a supply contract with the Southern customer E, but has not yet closed it. Supplier B is not yet active. This constellation would be technologically perfectly feasible. With a netting mechanism in the long-term auction, the suppliers could receive the transmission capacity required to fulfil their expected delivery obligations:

Supplier	Capacity N → S	Capacity S → N	$\lvert(N \to S) - (S \to N)\rvert$
A		100	-100
C	150		150
$\sum$	150	100	50

Now imagine that supplier B becomes active and receives the supply contract with customer E. The Northern supplier C now has a problem: She must use the capacity from North to South of 150 MW acquired in the auction but has not customer in the South. If she would be allowed to leave the capacity idle, supplier A would no longer be able to fulfil her obligations towards customer D, although A has enough production capacity and transmission capacity acquired. That situations like this can arise is the major drawback of firm transmission obligations which are a prerequisite for a netting mechanism.

There are, however, solutions for this problem. Supplier B has two alternatives. First, she can try to sell the transmission capacity of 150 from $N \to S$ on the short term market for transmission capacity. Since in a netting mechanism this is the same as buying the same amount from $S \to N$ this will probably imply losses for firm B. If this is unsuccessful, B still has a chance to fulfill her

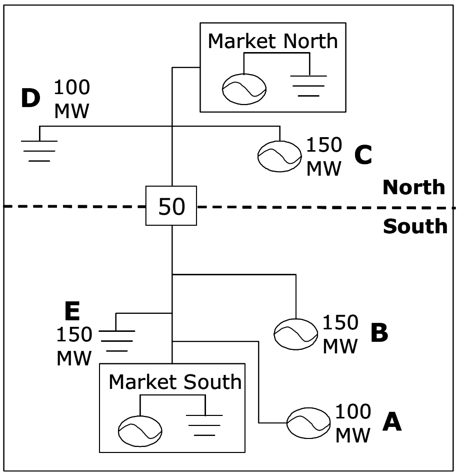

Figure 7: Example of cross-border trade

obligation to use the transmission capacity which she could not sell in the short term auction, by selling the production capacity of 150 MW in the Southern spot market for electricity. It then substitutes Southern production which otherwise would have satisfied the Southern demand expressed in the spot market, with Northern production. Only if this also fails, the network operator would have to jump in by supplying (negative) balancing energy in the South.

Since the netting mechanism may lead to such situations where the owner of capacity is short in demand for her transmission capacity, it is most likely that the market prices for transmission capacities under netting will be lower than they are under the current system. There is a risk adjustment on the transmission price to be expected for the case where a holder of capacity has to dump either the capacity or the production at the spot market. Thus, demand for transmission capacity in the long-term auction will tend to be lower under netting, since "hoarding" of capacity is now risky.

The welfare implications when comparing the current system with a netting mechanism, taking into account the problem discussed in this section, are therefore ambiguous. On the one hand, there is the already discussed welfare gain in increasing the available capacity in the capacity auctions and the increased intensity of competition expected from this. On the other hand there are potentially inefficient production allocations. In our example, firm B has to sell its production capacity on the Southern spot market and underbid suppliers in the South, even if these Southern suppliers are more efficient, in order to avoid paying penalties or expensive balancing energy. If the offers of the Southern suppliers in the spot market would be at marginal cost, the resulting inefficiency is then reflected in the losses of firm B (if it makes losses, otherwise, it would be welfare increasing that B supplies the Southern spot market). Firm $B's$ losses reflect that an inefficient producers has been allocated demand. Therefore, inefficiencies cannot last for ever, since then firms like supplier B would go bankrupt. However, due to the uncertainty involved, inefficient production allocations might arise from time to time. It requires further theoretical and empirical investigation whether the resulting inefficiencies outweigh the efficiency gains from better utilization of the existing transmission capacities.

6 Conclusion

Although transmission capacity is scarce and although this scarcity is regarded as a major obstacle for achieving more efficient market results, actual physical usage of the interconnectors is most of the time well below physically available capacity. In this paper we proposed a netting mechanism to improve the utilization of the available capacity. The effects are twofold. First, netting exploits the fact that counterflows are physically netted and that therefore each unit trade into one direction increases the available capacity in the opposite direction by one unit. In the netting mechanism proposed this effect is exploited such that only that demand cannot be satisfied for which the difference of demands in both directions exceeds the physically available capacity. Thus, for any announced physical capacity the utilization will be higher under netting than under the current system of holding two independent auction, one in each direction. Second, we have shown by theoretical analysis that the leeway for an auctioneer, who wants announce low levels of capacity in order to maximize the auction proceeds, is reduced under a netting mechanism. Thus, netting can support increased cross-border trade of electricity without the need of expanding the existing capacity (which might in addition be sensible).

In our theoretical analysis we assumed that the auctioneer is interested only in the auction proceeds. This is sometimes not realistic. Frequently, the transmission system operator acting as an auctioneer is part of a vertically integrated electricity company. Such a company might have an interest to foreclose the downstream market by providing low transmission capacities. Allowing for this would, however, even strengthen our argument: netting would also limit the scope for market foreclosure.

The current system allows a maximum flexibility to participate in the short-term spot market. It provides a maximum of options for capacity which bidders in the spot market can use to support their offers in the electricity spot market. The price for this is that demand for long-term transmission capacity is often not satisfied although it could be costlessly satisfied and that the transmission capacities are often left unused. In contrast, netting maximizes the physical usage and increases the supply of long-term capacities at the cost of flexibility in bidding in the electricity spot market. It is left to further research to estimate which of the two effects is more important.

7 Appendix

7.1 Proof of Proposition 1

The proof proceeds in three steps.

Claim 1 *Bidders in the South submit their true valuation functions in equilibrium.*

We prove the claim by contradiction. Either $q^N \leq q^S$, then at least one bidder in the North does not get his maximum quantity. He could then increase his bid (submit a less steep bidding function, i.e. choose a lower b_i). This is profitable and does not increase the price, since it nets the larger flows from the South to the North or uses some of the announced capacity which is at least $\underline{K}$. Or $q^N > q^S$, then bidders in the South can increase their bid without increasing the price and still get quantity with positive marginal valuation.

Claim 2 $q^N(0) - As < K$ *cannot occur in equilibrium.*

If it $q^N(0) - As < K$, at least one bidder in the North could increase his bid slightly, gain valuable capacity and still leave the price unchanged at 0.

Claim 3 $q^N(0) - As = K$ *cannot occur in equilibrium.*

In this were the case, the price would still be zero but an increase in bidding would trigger a positive price. However, the price increases only slightly while the deviating bidder makes a discrete jump in capacity allocated to him. Assume $q^N(0) - As = K$ were an equilibrium. Then a bidder i in the North receives at a price of zero the quantity

$$q_i = \frac{As + K}{n},$$

implying a payoff of:

$$\pi_i = \frac{As + K}{n} A - \frac{1}{2} \left(\frac{As + K}{n} \right)^2,$$

and has chosen a $b_i > 1$ (if all choose $b_i = 1$ then them maximum demand would be $q^N(0) = An > As$). Now consider a deviation to $b_i = 1$. The bid function of the competing bidders would be:

$$\beta_j = A - \frac{An}{As + K} q_j,$$

implying an aggregate demand function submitted to the auctioneer of:

$$\widetilde{q}^N = \underbrace{(n-1) \frac{As + K}{An} (A - p)}_{\text{bids of other bidders}} + \underbrace{(A - p)}_{\text{bid of deviator}}.$$

This must equal total supply of $As + K$, implying:

$$\widetilde{p} = A - (As + K) \frac{nA}{(n-1)(As + K) + nA}.$$

Given this price resulting from deviation, we can now calculate the deviation profit $\widetilde{\pi}_i$ which is larger than π_i:

$$\begin{aligned}
\widetilde{\pi}_i &= \frac{1}{2}\widetilde{q}_i^2 = \frac{1}{2}\left(\frac{As+K}{\frac{n-1}{n}\frac{As+K}{A}+1}\right)^2 > \frac{As+K}{n}A - \frac{1}{2}\left(\frac{As+K}{n}\right)^2 = \pi_i \\
\frac{A}{n} &< \frac{1}{2}(As+K)\underbrace{\frac{\frac{n-1}{n}\frac{As+K}{A}+2}{\frac{n-1}{n}\frac{As+K}{A}+1}}_{>1} \\
&\Leftarrow \frac{1}{2}As + \frac{1}{2}K > \frac{A}{n} \\
A\left(\frac{ns}{2}-1\right) + \frac{n}{2}K &> 0,
\end{aligned}$$

which holds for $n, s > 2$, as assumed in assumption 2. Thus, the deviation is always profitable and the claim holds.

Since due to claims 2 and 3 in any equilibrium $q^N(0) - As > K$, there will be a positive price in the auction for Northern bidders. With a positive price and having Southern bidders submit their true valuation, bidders in the North face a situation like in a separate auction where the capacity $As+K$ is posted. We have already shown that in such an auction there is a unique symmetric equilibrium in which bidders submit functions according to (9), which we know is independent of the capacity offered. Bidders in the South receive their maximum payoff thus do also have no incentive to deviate.

What is left to show is the optimal auctioneer's behavior. Her profits are given by (where $p(.)$ denotes the inverse demand function resulting from the bids submitted by the bidders):

$$\Pi_{II} = \left(q_{II}^N + K\right) \cdot p\left(q_{II}^N + K\right)$$

Three cases are to be considered, depending on the size relation between the two markets.

(i) Small Southern market: $As < K_I^N - \underline{K}$.Then by setting $K_{II} = K_I^N + As$, the equilibrium quantity resulting from the auction will be $q_{II}^N = K_I^N$, and the auctioneer's profit equals:

$$\Pi_{II} = q_I^N p_I^N.$$

(ii) Large Southern market: $K_I^N - As \leq \underline{K} < q_{II}^N(0)$. Now the auctioneer would need to set $K_{II} < \underline{K}$ to achieve the same profit as before, $\Pi_{II} = q_I^N p_I^N$. Since the auctioneer optimizes against a decreasing linear decreasing (inverse) demand function $p(.)$, profits are decreasing for $q^N > q_I^N$, thus the profit maximum is given by the corner solution of choosing the minimum feasible level of $K : K_{II} = \underline{K}$.

	Ger -> Den		Den -> Ger	
max. capacity	800		1200	
reserved for long term auctions	600		800	
reserved for daily auction	200		400	
Assume:				
nominated	400		300	
therefore: returned	200		500	
Results:				
Offer in daily auction	200	reserved	400	reserved
	200	returned	500	returned
	300	nomination in opposite direction	400	nomination in opposite direction
	700	total	1300	total
If price is positive Ger -> Den:				
Usage of interconnector	700	if all capacity from daily auction is nominated		
	100	net flow from long term nomination		
	800	total		
If price is positive Den -> Ger				
Usage of interconnector			1300	if all capacity from daily auction is nominated
			-100	net flow from long term nomination
			1200	total

Figure 8: Example of netting in Danish - German interconnector auction

(iii) The case $As \geq q_{II}^{N}(0)$ cannot occur by assumption 2. To see this, note that

$$\begin{aligned} q_{II}^{N}(p=0) &= \frac{(A-p)}{b_i} = (A-p)\frac{n(n-2)}{n-1} = A\frac{n(n-2)}{n-1} \\ A\frac{n(n-2)}{n-1} &> As \\ s &< \frac{n(n-2)}{n-1}, \end{aligned}$$

which is satisfied for $s \leq n-2$. ■

7.2 Netting at the Danish - German interconnector

At the Danish - German interconnector the auctioneer, Eltra, uses a form of netting in the daily auction. The offer in the daily auction for each direction comes from three sources. First, from the capacity reserved ex-ante for the daily auction. In 2004 this was 400 MW from Denmark to Germany and 200 from Germany to Denmark. Second, all capacity from the long-term auctions which has not been nominated in time before the daily auction, is also added. Third, the amount nominated in the opposite direction is added. Figure 8 illustrates this mechanism.

If all capacity sold in the daily auction would be used, then the interconnector would be fully used. However, since also capacities in the daily auction are options, not usage obligations, not all of this is actually used. Unused capacity can therefore be explained by the difference between capacity acquired in the daily auction and the nomination of these capacities. This can happen if an offer in the electricity spot market which had been supported by a transmission capacity was too expensive such that it was above the market clearing price in the spot market auction.

Investigating the auction results provides further evidence that there is some long-term demand for transmission capacity independent of the spot market development. In 2004 we have 8.694 valid observations for hourly prices for transmission capacity auction from Denmark to Germany. Of these 8.694 observations, 6.726 observations (77%) are "standard cases" where the sum of capacity offered in both directions equals 2.000 ($= 800 + 1200$). In these 6.726 cases, the capacity offered from Denmark to Germany exceed the maximum capacity of 1.200. Thus, there must have been nominations from the opposite direction (Germany to Denmark) from the long-term auction which have been netted in the short term auction in 3.632 cases. (Note that this is a lower bound: Netting could also happen in other cases if not all capacity from the long-term auction Denmarkt to Germany have been returned. The the offered capacity might be below 1.200 although netting happened). From these 3.632 cases, the price in the daily auction for capacity from Denmark to Germany was positive in 1.859 cases. In these 1.859 cases there was demand for the direction Denmark to Germany (otherwise the price would have been zero) and at the same time there have been nominations for the opposite direction from Germany to Denmark from the long-term auction. This implies trade in opposite direction at least 21% of the time and provides further evidence for the conjecture that there is an independent long-term demand for transmission capacity.

References

Ausubel, L. M., and P. Cramton (2002): "Demand Reduction and Inefficiency in Multi-Unit Auctions," Working Paper, University of Maryland.

CEER (2003): "Completing the Internal Energy Market: The Missing Steps," Press statement, October 2003, download under http://www.ceer-eu.org/.

Consentec and Frontier Economics (2004): "Analysis of Cross-Border Congestion Management Methods for the EU Internal Electricity Market," Study commissioned by the European Comission, June 2004.

EFET (2003): "EFET Recommendation for Objective Quantificatio and Allocaion of Continental European Cross Border Power Transmission Capacity," download: http://europa.eu.int/comm/energy/electricity/florence/10$_{e}n.htm$.

European Commission (2003): "Towards a Cometitve and Regulated European Electricity and Gas Market," Press release, October 2003, download under http://www.ceer-eu.org/ at 14/09/05.

——— (2004a): "Medium Term Vision for the Internal Electricity Market," DG Energy and Transport Working Paper, 01/03/2004.

——— (2004b): "TEN-E Priority Projects," published by the DG Energy and Transport, 10 June 2004.

European Union (2003): "Directive 2003/54/EC Concerning Common Rules for the Internal Market in Electricity and Reapealing Directive 96/92/EC," *Official Journal of the European Union*, L176/37.

Hogan, W. W. (1992): "Contract Networks for Electric Power Transmission," *Journal of Regulatory Economics*, 4, 211–242.

Joskow, P. L., and J. Tirole (2003): "Merchant Transmission Investment," *NBER Working Paper*, 9534.

Kagel, J. H., and D. Levin (2001): "Behavior in Multi-Unit Demand Auctions: Experiments with Uniform Price and Dynamic Vickrey Auctions," *Econometrica*, 69, 413–454.

Kirchkamp, O., and P. Reiss (2004): "The Overbidding-Myth and the Underbidding-Bias in Rst-Price Auctions," Working Paper SFB 504, University of Mannheim.

Kremer, I., and K. G. Nyborg (2004): "Divisible-Good Auctions: The Role of Allocation Rules," *RAND Journal of Economics*, 35(1), 147–159.

Krishna, V. (2002): *Auction Theory*. Academic Press, San Diego.

List, J. A., and D. Lucking-Reiley (2000): "Demand Reduction in Multi-Unit Auctions: Evidence from a Sportcard Field Experiment," *American Economic Review*, 90, 961–972.

Milgrom, P. (2004): *Putting Auction Theory to Work*. Cambridge University Press, Cambridge, UK.

Nasser, T.-O. (1997): "Imperfect Markets for Power: Competition and Residual Regulation in the Electricity Industry," *Ph.D. thesis, MIT*.

Schweppe, F., M. Caramanis, R. Tabors, and R. Bohn (1988): *Spot Pricing of Electricity*. Kluwer Academic Press, Norwell, MA.

Vogelsang, I. (2001): "Price Regulation for Independent Transmission Companies," *Journal of Regulatory Economics*, 20(2), 141–165.