Assessment of the Shadow Auction mechanism as a fallback procedure for Single Day-Ahead Coupling

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ATC	Available Transmission Capacity
BZ	Bidding Zone
EA	Explicit Allocation
ENTSO-E	European Network of Transmission System Operators for Electricity
LTTR	Long Term Transmission Rights
PTR	Physical Transmission Rights
SA	Shadow Auction
SDAC	Single Day-Ahead Coupling

Abstract

According to Article 44 of the EC regulation 32015R1222 any fallback procedure to the Single Day-Ahead Coupling should lead to an "efficient" way of allocating cross border electricity transmission capacity. Yet, In the past the efficiency of the Shadow Auction as a standard fallback procedure was questioned. As a possible cause, Article 35 of the EC regulation 32016R1719, which contains legislation on remuneration of Long-Term Transmission Rights based on market spreads, was discussed.

In cooperation with ENTSO-E this study was conducted, assessing the question whether the remuneration of Long-Term Transmission Rights based on market spreads reduces the incentives to allocate capacity in the Shadow Auctions and, thus, reduces its efficiency. To assess the economic incentives of market participants to take part in the Shadow Auction mechanism, a Cournot (Nash) model was developed using historical bid curves and other data relatively easily accessible for everyone.

Results show that market participants holding Long-Term Transmission Rights have currently few incentives to take part in the Shadow Auctions, resulting in a loss of public welfare. As a conclusion, the study gives some propositions on how regulation(s) may need to be adapted in future to reach higher efficiency in allocating capacity.

Keywords

Market Coupling, Fallback Procedures, Shadow Auction, Long-Term Transmission Rights

1. Introduction

In the event of unavailability of the Single Day-Ahead Coupling (SDAC) (i.e., decoupling event) fallback procedures are triggered according to Article 44 in the European Commission (EC) regulation "establishing a guideline on capacity allocation and congestion management" (EC 2015). The main fallback procedure used for the allocation of Cross Zonal Capacity in the day-ahead market timeframe, is the Explicit Allocation (EA) in the form of Physical Transmission Rights (PTR) of electrical energy, also known as Shadow Auctions (SA) (JAO 2018).

Article 44 (EC 2015) "Establishment of fallback procedures" mandates that TSOs "By 16 months after the entry into force of this Regulation […] shall develop a proposal for robust and timely fallback procedures to ensure efficient, transparent and non-discriminatory capacity allocation in the event that the single day-ahead coupling process is unable to produce results". With the start of CWE Market Coupling on 9 November 2010 (Weber, Graeber and Semmig 2010), as the main predecessor of today's SDAC, the implementation of the Shadow Auctions Mechanism as the fallback procedure was obvious, as it retained in most parts the widely known former standard procedure for explicit allocation of Cross Zonal Capacity. Since 2010 the Shadow Auctions Mechanism has been standardized and centralized at the Joint Allocation Office (JAO) for different borders but not changed substantially.

So far, the Shadow Auctions Mechanism has been executed only three times – last on 13 January 2021 as IT issues at the European Power Exchange (EPEX) caused a partial decoupling event (SDAC JSC 2021). In the follow up, the Shadow Auctions Mechanism has been criticized by relevant stakeholders, like market participants or regulators, as it seemed to cause (or did not prevent) an inefficient or even – at some borders – incomplete allocation of capacity. Quickly, it was speculated that the complexity of the Shadow Auction Mechanism excludes *de facto* many small and medium market participants and thereby reduces liquidity in the explicit auctions of PTRs in a decoupling event. Yet, this may be only part of the explanation as some major market participants might be in fact not incentivized economically in participating in the explicit auctions. This may be caused by Article 35 of the European Commission regulation "establishing a guideline on forward capacity allocation" (EC 2016) as it rules the remuneration of Long-Term Transmission Rights (LTTR) – which are issued at all borders – to be based on the Day-Ahead market spread.

To address the question why the Shadow Auctions Mechanism as a fallback procedure failed in allocating capacity efficiently, a study concerning economic motivation or demotivation of different types of market participants to engage in explicit auctions in case of a decoupling was conducted. The scientific approach includes modelling probable profit or loss of different types of market participants taking part in the SA based on historical market data. Specifically, the study assesses how LTTR-remuneration on the basis of Day-Ahead market spreads affects market participants incentives to take part in the SA, posing the question whether Article 35 (EC 2016) is compatible to the developed fallback option based on Article 44 (EC 2015).

2. Model approach

Two main objectives were pursued when developing the model: the use of a straightforward and easy to understand modelling approach and the use of public or other easy to access data. The first objective was determined by a tight project-schedule and by the broad target group of the study (ENTSO-E and European TSOs, market operators, various types of market participants, regulators, etc.). Hence, the model development was restricted to a simulation framework for some selected relevant parts of the SA with a focus on assessing the economic incentives of different types of market participants (electricity traders) to allocate cross-border capacity. This simulation framework needed to allow a relative comparison of different scenarios without perfectly modelling reality and, therefore, not necessarily allowing absolute statements. The second objective was determined by the transparency and verifiability of the results. Therefore, the use of publicly accessible data from JAO and ENTSO-E was preferred, to integrate information on market coupling and on grid capacities to the model. Regarding market data, the use was restricted to aggregated bid curves published by market operators publicly or commercially available without using fundamental power plant data or a highly sophisticated network model.

When considering the market situation within a SA, three main types of trading activities can be differentiated:

- Cross Zonal Long-Term & Day-Ahead → Traders that use both LTTRs and trade in the day-ahead markets;
- Cross Zonal Only Day-Ahead → Traders that only use the Day-Ahead to cover their positions and which are not sensitive to LTTR; and
- Day-Ahead only in one or selected bidding zones → Traders that only use the Day-Ahead to cover their positions and which are not active in cross-zonal activities.

Previous decoupling events have shown that only a limited number of traders take part in the SA, while most traders are only active within one or more bidding zones (ENTSO-E 2021). Due to this small number of participants, the market situation of a SA can be interpreted as an oligopoly of trading companies offering the product cross border capacity allocation. Such an interpretation implies that the trading activities of the participants of the SA are characterized by a strategic interaction, while the traders acting exclusively within a bidding zone only submit bids based on marginal costs or marginal utility.

In the past, several theoretical approaches were developed to explain such a corresponding market constellation. In recent years, Cournot (Nash) approaches have been used particularly frequently for modelling energy markets. This is supported by the study of Wolak and Patrick (2001) who are suggesting that Cournot competition appropriately represents the electricity generation market.

Pepermans and Willems (2010) used a Cournot model to numerically derive the social optimal transmission process for cost recovery considering congestions in the grid, while allowing for market power in generation. Müller, Growitsch and Wissner (2011) assessed the extent to which cost- and incentive-based regulatory regimes incentivize investment in intelligent grids. Both papers implement a Cournot based approach towards modeling the incomplete competition caused by limited grid transmission capacities.

Although Cournot (Nash) approaches are subject to some theoretical limitations such as complete market transparency, they have proven useful in the past to gain insights into the strategic behaviour of traders and to compare different scenarios (Lundin and Tangerås 2017, Willems 2002, Salant 1982).

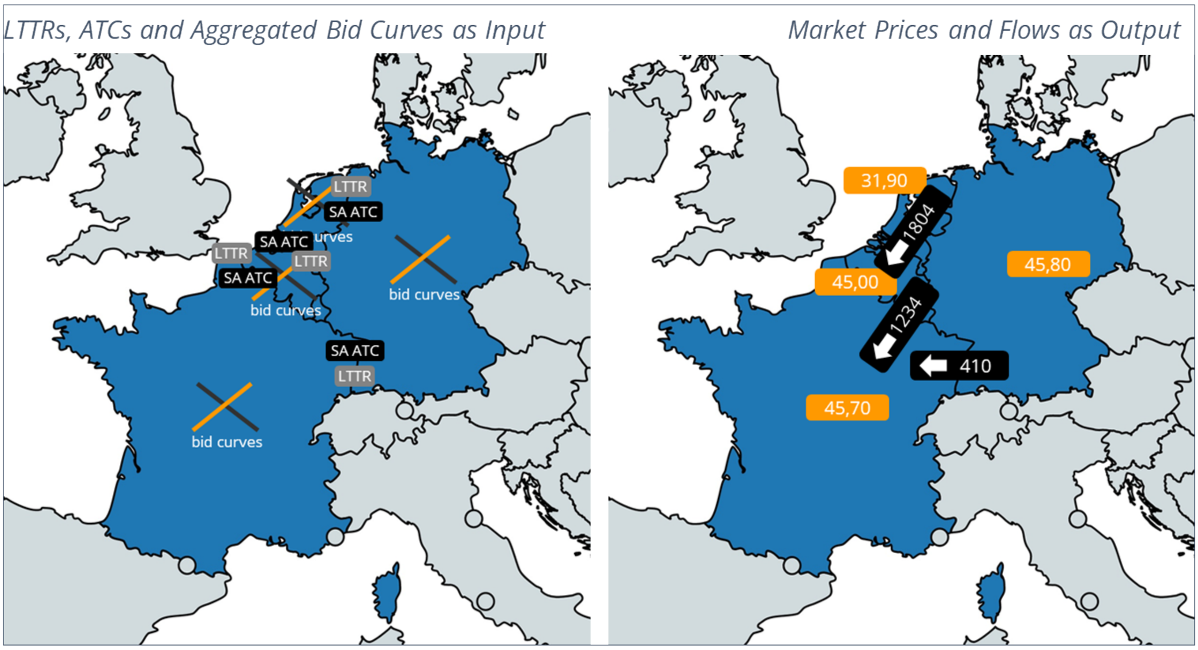

Figure 1: basic modelling approach

Therefore, a Cournot (Nash) approach was decided to be used for the assessment with input and output values as shown in figure 1. In the approach, a finite number n of oligopolistic traders (tr) with $tr = TR1, TR2, \ldots TRn$ participate in the SA. Each of these traders hold a certain amount of LTTRs which can also be zero. For each individual electricity trader an individual LTTR holding can be formally described as $LTTR_{bze,bzi,tr}$ with $tr = 1, \ldots n$ where bze is the exporting and bzi the importing Bidding Zone (BZ) with $bze / bzi = BZ1, \ldots BZn$.

Each trader tr now tries to determine an amount of cross-zonal trading quantities $xtrans_{bze,bzi,tr}$ maximizing the profit while considering the LTTRs. The sum of all $xtrans_{bze,bzi,tr}$ at a zone boundary must be less than or equal to a maximal value $ATC_{bze,bzi}$.

The profit PT_{tr} for a trader results out of the export prices P_{bze} and import prices P_{bzi} at a zone boundary as $PT_{tr} = (xtrans_{bze,bzi,tr} + LTTR_{bze,bzi,tr}) * (P_{bzi} - P_{bze})$, the total profit as the corresponding sum of the activities on all zone borders. The traders acting exclusively within a bidding zone can be integrated into the model using aggregated bid curves, which contain the demand and supply of all traders who do not participate in the SA. The prices P_{bze} and P_{bzi} in the individual BZs thus depend on both the $xtrans_{bze,bzi,tr}$ and the aggregated bid curves in the individual BZs.

In such a Cournot (Nash) approach, an equilibrium is reached if all $xtrans_{bze,bzi,tr}$ are determined in such a way that none of the traders tr can increase their individual profit by changing these amounts.

3. Data

The whole assessment is based on historical data from 2020 for European bidding zones and bidding zone borders and essentially uses only the three data types already presented: LTTR and ATC values as well as aggregated bid curves.

Data on LTTR values can be found publicly available on the website of the Joint Allocation Office (JAO 2021). For modelling the Cournot (Nash) approach monthly and yearly LTTRs taken from the JAO website have been aggregated. This aggregated LTTR can be split to different traders (tr) based on scenarios in the approach resulting in a dataset $LTTR_{bze,bzi,tr}$ for all Traders $tr = 1, \dots n$.

ATC values to use in the Cournot (Nash) approach can also be found publicly available on the website of the Joint Allocation Office (JAO 2021). For the case of a decoupling event, ATC for SA values are published daily by JAO. Essentially, the ATC for SA value corresponds with minor deviations to the aggregated monthly and yearly LTTRs. For the year 2020, not all bidding zone borders ATC for SA values are available as the SDAC included fewer bidding zones as today. Missing ATC for SA values have been added based on the aggregated monthly and yearly LTTRs for the approach resulting in a dataset $ATC_{bze,bzi}$ for all bidding zone borders.

Historical bid curves are available publicly or commercially by all European Nominated Electricity Market Operators (NEMO 2019). The variety of different formats is challenging in this context: some NEMOs offer aggregated bid curves; some offer bid curves which include every single bid; some use XML-format, some xls or csv format; some use local time some do not.

Therefore, in a first step for all bidding zones aggregated bid curves have been prepared using CEST time (like the JAO data) and the same format. As shown in Figure 2, the aggregated bid curves in a bidding zone can be formally described by a finite number of demand segments *(ds)* and supply segments *(ss)* with $ds/\ ss = DS_1/\ SS_1, \dots DS_{dsno}/\ SS_{ssno}$ where $dsno/\ ssno$ describes the total number of respective segments in a bidding zone. For each ds/ss, $PDS_{ds}/\ PSS_{ss}$ describe the constant bid/ offer price of the segment and $CDSC_{ds}/\ CSSC_{ss}$ the cumulated segment-capacity.

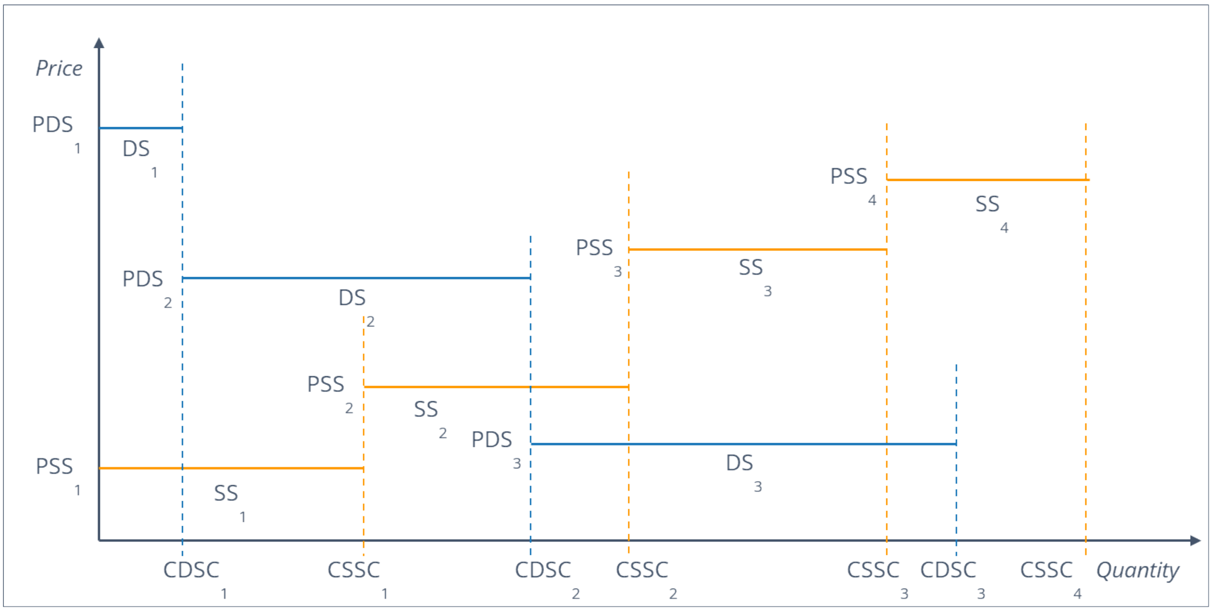

Figure 2: aggregated bid curves

Bid curves offered by the NEMOs contain all bids that are used for market clearing - including the cross zonal implicitly or explicitly allocated capacities. For the use of the aggregated bid curves in the Cournot (Nash) approach, they must be adjusted to receive the domestic demand and supply within a bidding zone and not to underestimate commercial potential for cross-zonal transactions. Exemplarily, figure 3 shows the adjustment of an aggregated supply curve of a bidding zone where implicit coupling has led to an increased supply. For each *ss* the cumulated segment-capacity is reduced by the total allocated import capacity. Likewise, the aggregated supply curve is adjusted based on allocated capacities.

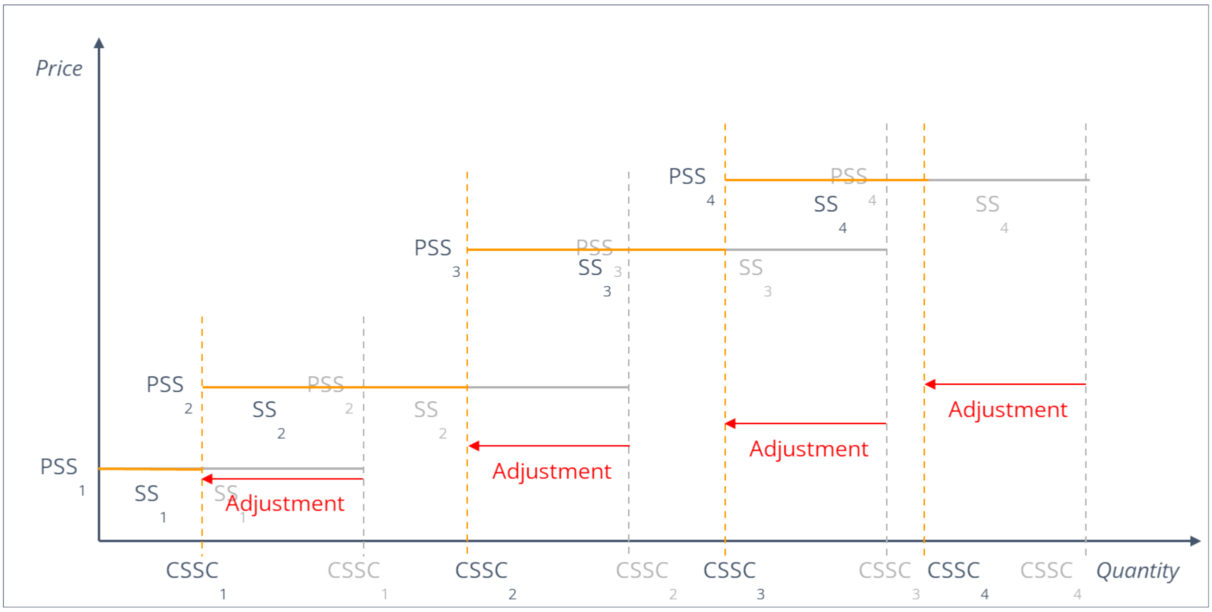

Figure 3: adjustment of aggregated bid curves

However, with the data available on JAO's website, this adjustment is only possible for bidding zones for which cross-zonal capacities are implicitly assigned. Data for other zone borders are not made available. An adjustment based solely on the bidding zone borders for which data is available, however, leads to distortions for bidding zones for which capacities are not implicitly allocated at all borders. To reduce these distortions, a pragmatic approach was chosen to limit the values of the allocated capacities for the adjustment to a maximum of the ATC for SA value. Although this slightly underestimates the potential for cross-zonal allocation in the developed Cournot (Nash) approach, it leads to a more coherent result in the adjustment of bidding zones with a mixed implicit and explicit allocation of capacities. Anyway, the resulting slightly underestimation of the potential for cross-zonal allocation does not significantly affects the further relative assessment as it is the same in all scenarios.

4. Methodology

4.1. Scenarios

All scenarios share the same geographical scope and historical data but differ in the number and types of traders who are active in cross-zonal trading. The geographical scope of all scenarios includes the bidding zones in 13 countries: France, Belgium, the Netherlands, Luxembourg, Germany, Poland, Czech Republic, Austria, Slovenia, Croatia, Hungary, Slovakia and Romania as shown in figure 4.

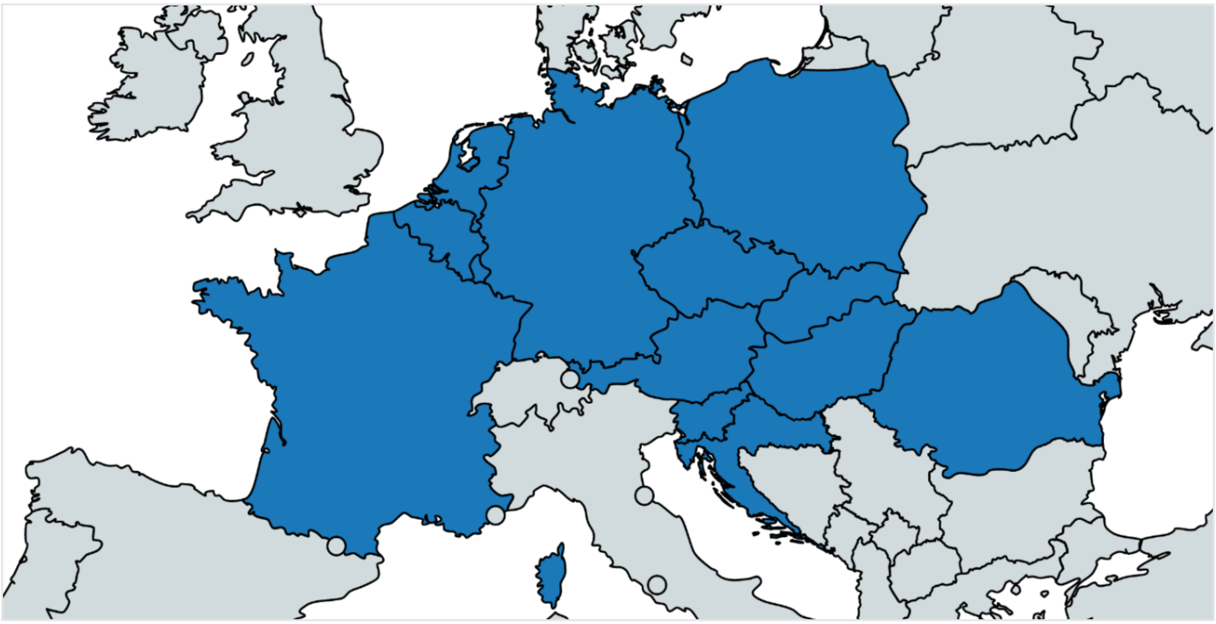

Figure 4: geographical scope of the study

Historical data from the 15th hour of the days 12.4., 22.4., 8.6., 31.7., 9.8., 5.10., 18.11., 24.12. in 2020 is used for all scenarios. The days were selected in such a way that, among others, different seasons, days of the week or weather conditions are considered.

The different numbers and types of traders active in cross-zonal trading in the five scenarios considered in the assessment are shown below:

- Scenario 1 "Welfare Optimum": An infinite number of traders is assumed so that a welfare optimal allocation of capacity is given;
- Scenario 2 "Monopoly": A profit optimized allocation of capacity is carried out by a single trader holding all LTTRs;
- Scenario 3 "4 Traders": 4 Traders are active on each border. Two of them are active on one border only, one holding LTTRs, one no LTTRs. The two others are active on all borders, one holding LTTRs, one no LTTRs. LTTRs are evenly distributed between LTTR-holders;
- Scenario 4 "12 Traders": Each trader from scenario 3 is available three times; and
- Scenario 5 "24 Traders": Each trader from scenario 3 is available six times.

4.2. Welfare optimal allocation of capacity

In Scenario 1, with welfare optimal allocation of cross-zonal capacities, an infinite number of traders is assumed. In such a market situation, the welfare optimum within a bidding zone is given when the social welfare (sum of producer and consumer rent) reaches its maximum (see figure 5). For aggregated bid curves, as used in this approach, it can be shown that with maximal welfare the sum of supply costs and opportunity costs of unmet demand, as given in figure 5, reaches its minimum. This second characteristic is used for the further modelling of a welfare optimal allocation of cross zonal capacity as a linear optimization program.

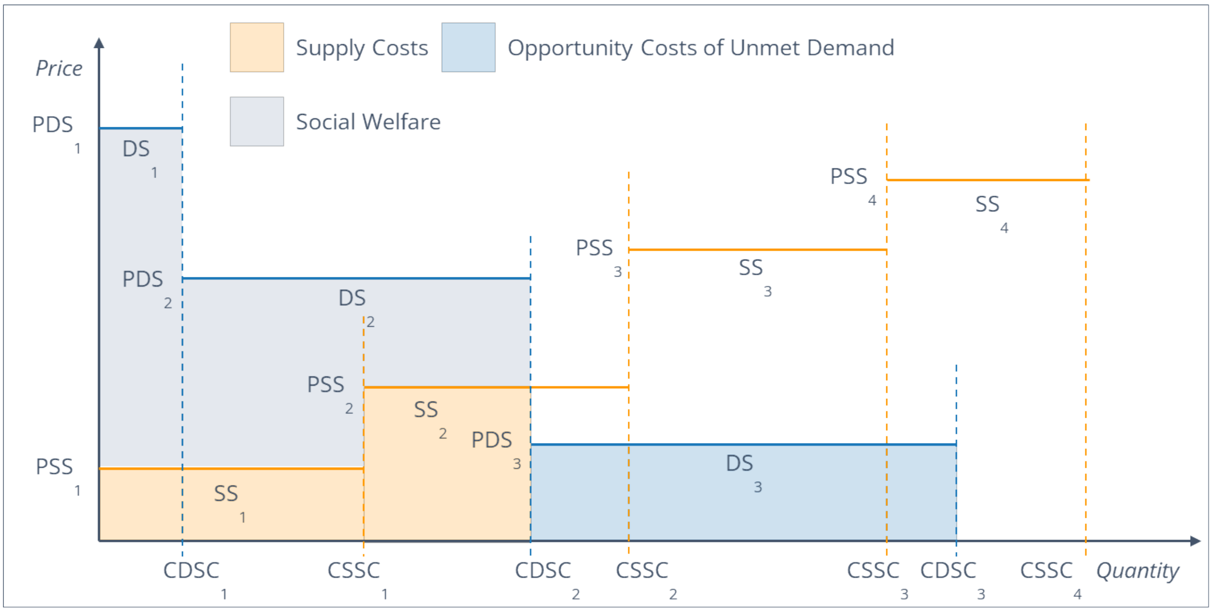

Figure 5: social welfare

To model the supply cost for each bidding zone *bz* and supply segment *ss* a non-negative variable $xss_{bz,ss}$ is defined as well as for each demand segment *ds* a non-negative variable $xds_{bz,ds}$. With $xss_{bz,ss}$ and $xds_{bz,ds}$ we define an objective function with an objective value *Z* to be minimized as shown in equation 1:

$$Z \geq \sum_{bz,ss} pss_{bz,ss} \cdot xss_{bz,ss} + \sum_{bz,ds} pds_{bz,ds} \cdot xds_{bz,ds} \tag{1}$$

For $xss_{bz,ss}$ and $xds_{bz,ds}$ restrictions apply (cf. equation 2):

$$xss_{bz,ss} \leq ssc_{bz,ss} \ ; \quad xds_{bz,ss} \leq dsc_{bz,ss} \tag{2}$$

Where $ssc_{bz,ss}$ / $dsc_{bz,ds}$ is defined as the capacity of each supply / demand segment, which can be calculated using the cumulated supply / demand segment capacities $cssc_{bz,ss}$/ $cdsc_{bz,ds}$.

In addition to the restrictions on $xss_{bz,ss}$ and $xds_{bz,ds}$ another equation for each BZ is needed to make sure that demand is equivalent to supply in each bidding zone considering cross zonal allocation $xtrans_{bze,bzi}$ (cf. equation 3):

$$\sum_{ss} xss_{bz,ss} + \sum_{bzi} xtrans_{bzi,bz} = \sum_{ds} xds_{bz,ds} + \sum_{bze} xtrans_{bze,bz} \quad \forall\, bz \tag{3}$$

For cross zonal allocation of the non-negative variable $xtrans_{bze,bzi}$ we consider the capacity restrictions $ATC_{bze,bzi}$ as follows in equation 4:

$$xtrans_{bze,bzi} \leq ATC_{bze,bzi} \quad \forall\, bze,bzi \tag{4}$$

In figure 6, we can exemplarily see the functioning of the model for 15 October 2020. Based on the ATC for SA we can see the welfare optimal allocation and the resulting market prices.

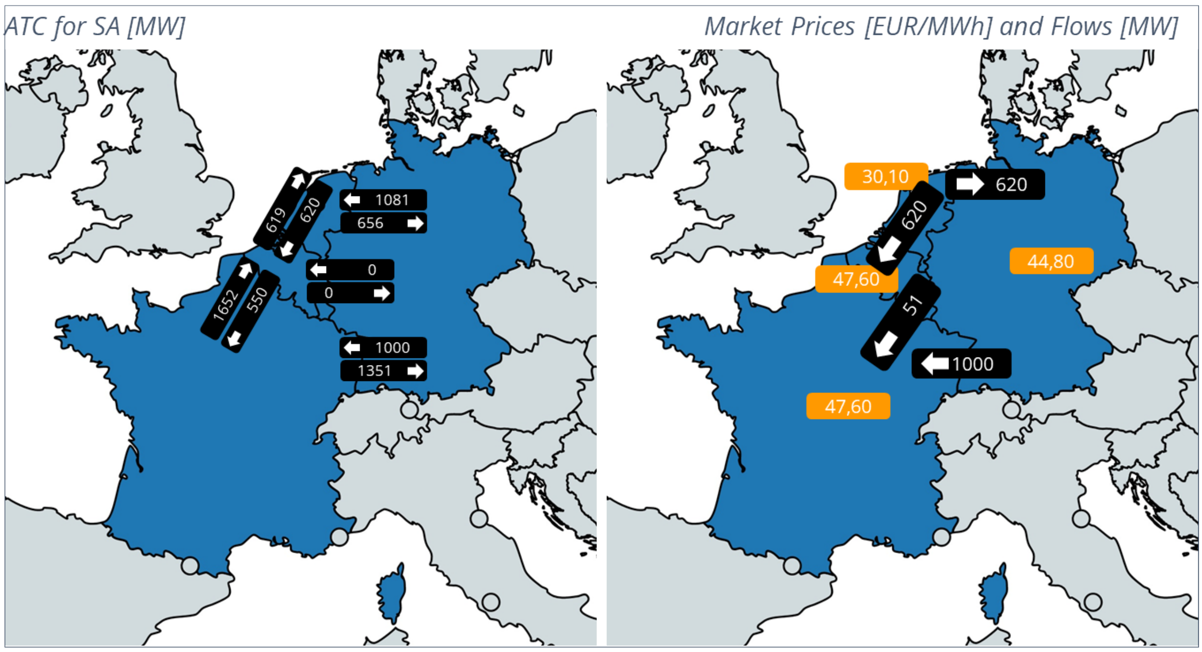

Figure 6: exemplary welfare optimal cross-zonal-allocation

4.3. Oligopoly of traders

The model for an oligopoly of traders seeks for a cross-zonal allocation which maximises profit of each single trader in a way, that none of the traders can increase profit, by changing the allocation. By this approach traders consider demand and supply within each bidding zone in their actions. Therefore, in a first step the residual demand curves are calculated for each bidding zone by subtracting the corresponding aggregated supply curve from the aggregated demand curve (see figure 7). As shown in figure 7, the residual demand curve in a bidding zone can be formally described by a finite number of residual demand segments *(rds)* with $rds = RDS_1, RDS_1, \ldots$. For each *rds*, $PRDS_{rds}$ describes the constant price of the segment and $CRDSC_{rds}$ the cumulated residual segment-capacity. At the equilibrium price we can see a residual demand of 0. For high prices we can see a negative residual demand and for low prices a positive residual demand. For a trader the residual demand curve is a tool to measure the price effect of buying or selling electricity in a bidding zone.

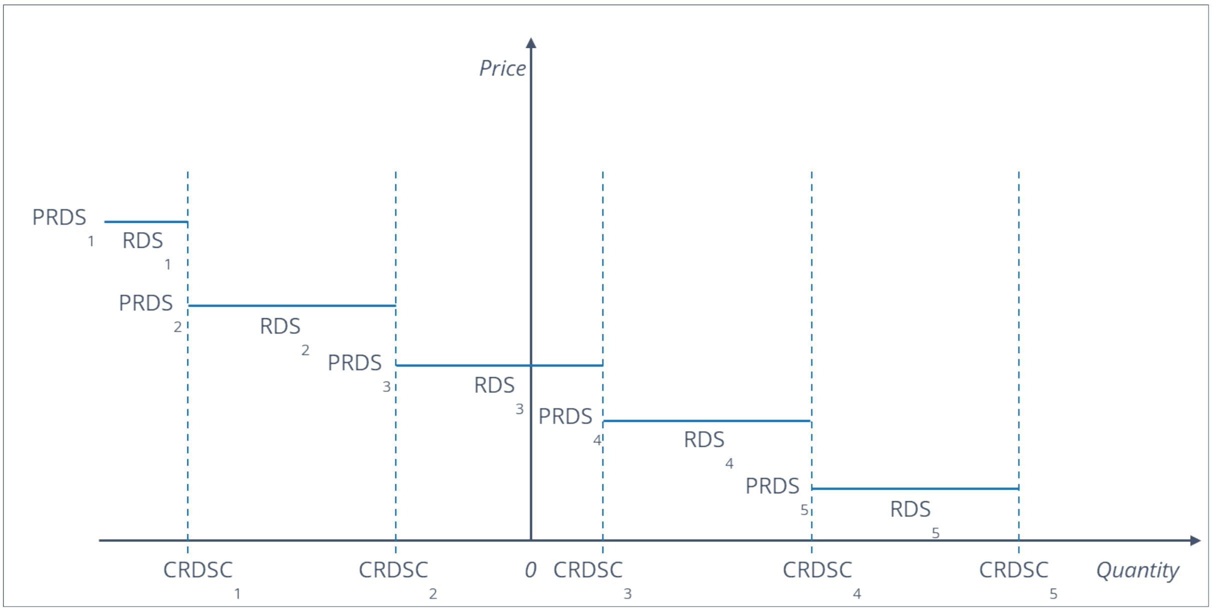

Figure 7: residual demand curve

In a first step, the model for an oligopoly is explained for the special case that only one trader (a monopolist) without LTTRs is active on the market. This trader can buy and sell electricity in all bidding zones. Summing up all sales and subtracting the sum of purchases and the expected price in the SA equals the profit for the trader. The maximum profit for the trader can be calculated using a mixed integer linear program.

In the program, we first use a binary variable $xb_{bz,rds}$ to select a RDS in each BZ. With this selection the market price of the BZ is given automatically together with the corresponding PRDS value. For selecting the RDS with the binary variable, equation 5 is used:

$$\sum_{RDS} xb_{bz,\ rds} = 1 \ \ \forall bz \tag{5}$$

Next, we define a variable $xrds_{bz,rds}$ which defines purchases for negative values and sales for positive values. In each BZ only one variable $xrds_{bz,rds}$ can be unequal to 0 – the one in the RDS selected by the binary variable. Upper and lower limits of the $xrds_{bz,rds}$ variables are given by equations 6:

$$xrds_{bz,rds} \leq CRDSC_{bz,rds} \cdot xb_{bz,rds}; \quad xrds_{bz,rds} \geq CRDSC_{bz,rds-1} \cdot xb_{bz,rds} \quad \forall bz,rds \tag{6}$$

To make sure that a trader can only sell electricity in a BZ, which was imported to that BZ, we implement equation 7:

$$\sum_{bzi} xtrans_{bzi,bz} - \sum_{rds} xrds_{bz,rds} = + \sum_{bze} xtrans_{bze,bz} \quad \forall \ bz \tag{7}$$

For cross zonal allocation of the non-negative variable $xtrans_{bze,bzi}$ we consider the capacity restrictions $ATC_{bze,bzi}$ the same way as in the model for welfare optimal allocation.

With this preparatory work we are now able to define an objective function with an objective value Z to be maximized the sum of all sales and purchases in equation 8:

$$Z \leq \sum_{bz,rds} prds_{bz,rds} \cdot xrds_{bz,rds} \tag{8}$$

To prevent net flows from BZ with high prices to BZs with low prices, which could theoretically occur, although not seen in the real market, we implement another binary variable $xbtrans_{bze,\,bzi}$ to select whether flows are allowed in one direction or not and to amend the equation for the transport restriction (cf. equation 9):

$$xtrans_{bze,bzi} \leq xbtrans_{bze,bzi} \cdot ATC_{bze,bzi} \quad \forall\, bze, bzi \tag{9}$$

With equation 10 we link the binary variable $xbtrans_{bze,bzi}$ to market spreads and allow only flows from low-price to high-price bidding zones where sln is a sufficiently large number:

$$\sum_{rds} xb_{bze,rds} \cdot prds_{bze,rds} \leq \sum_{rds} xb_{bzi,rds} \cdot prds_{bzi,rds} + (1 - xbtrans_{bze,\,bzi}) \cdot sln \quad \forall\, bze,bzi \tag{10}$$

In figure 7, we can see the functioning of the model for 15 October 2020. Based on the ATC for SA we can see the profit optimal allocation and the resulting market prices.

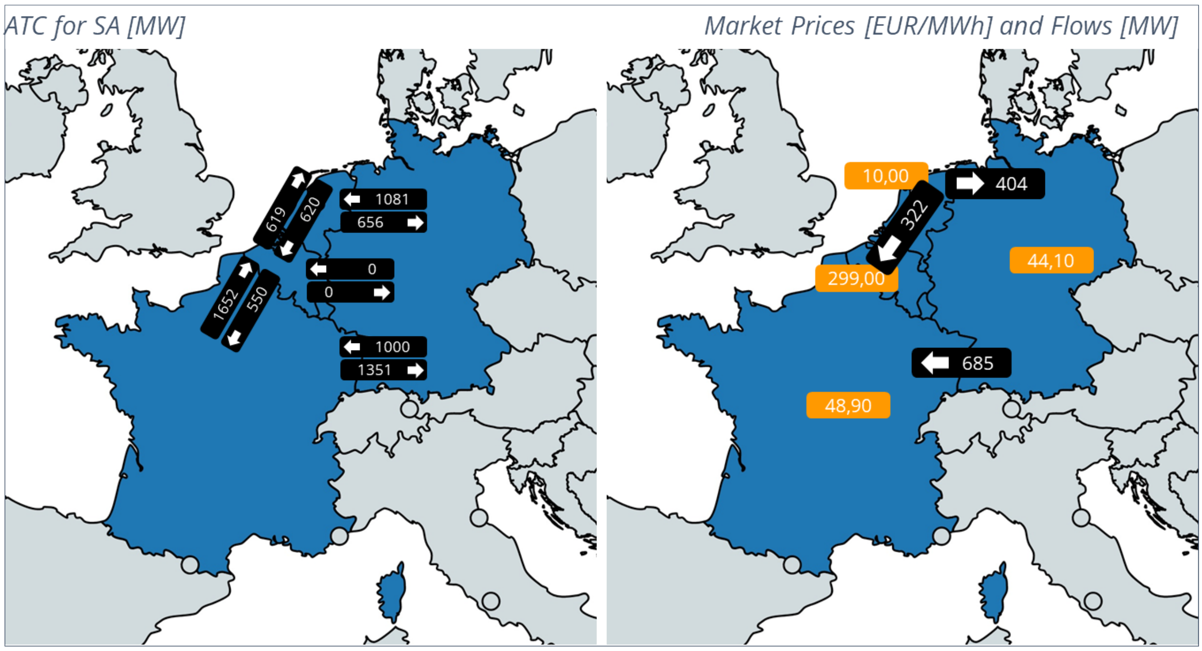

Figure 8: exemplary cross-zonal-allocation in a monopoly without LTTRs

To include LTTRs in the model we can use the same basic modelling idea as with the cross-zonal allocation: LTTRs are modelled as cross-zonal flows $xlttrtrans_{bze,bzi}$ with LTTR amounts as a capacity restriction but not influencing bidding zone prices (cf. equations 11-13):

$$xlttrtrans_{bze,bzi} \leq LTTR_{bze,bzi} \quad \forall\, bze, bzi \tag{11}$$

$$\sum_{bzi} xlttrtrans_{bzi,bz} - \sum_{rds} xlttrrds_{bz,rds} = + \sum_{bze} xlttrtrans_{bze,bz} \quad \forall\, bz \tag{12}$$

$$xlttrrds_{bz,rds} \leq sln \cdot xb_{bz,rds}; \qquad xlttrrds_{bz,rds} \geq sln \cdot xb_{bz,rds} \quad \forall bz,rds \tag{13}$$

To include LTTRs in the objective function we add the variable $xlttrrdstrans_{bz,rds}$ to $xrds_{bz,rds}$ in equation 14. The second term in the equation includes the costs for SA estimated by a trader. This estimation is based on the price spread ($price_{bzi}$ - $price_{bze}$) of a previous run of the model multiplied with the percentage value *transcost*.

$$Z \leq \sum_{bz,rds} prds_{bz,rds} \cdot (xrds_{bz,rds} + xlttrrds_{bz,rds}) - \sum_{bze,\,bzi} xrds_{bz,rds} \cdot \max\,(0,(price_{bze} - price_{bzi})) \cdot transcost \tag{14}$$

In figure 9, we can again see the functioning of the model for 15 October 2020. Based on the ATC for SA we can see the profit optimal allocation and the resulting market prices. However, in this model-setup, the monopolist considers profit out of cross-border-transactions and LTTRs for his cross-border activities.

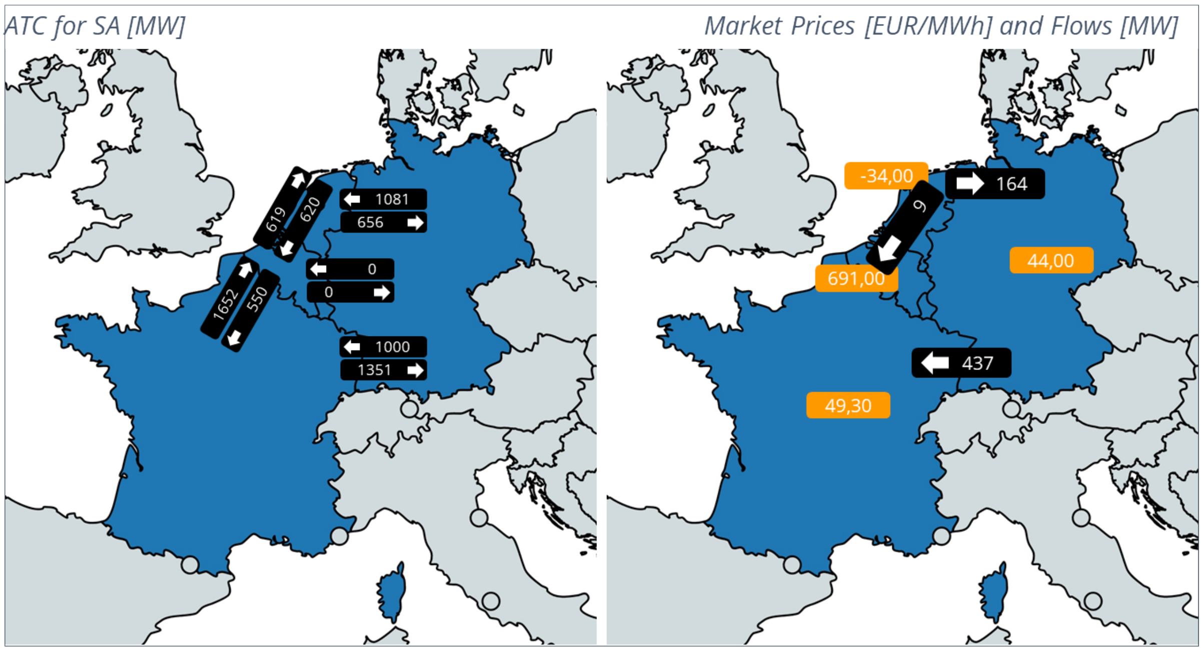

Figure 9: exemplary cross-zonal-allocation in a monopoly with LTTRs

To allow multiple traders in the approach, the mathematical model of the SA is not changed but the model is iteratively calculated for each trader until no more changes to cross-border allocation occur. In this iterative calculation some parameters are changed for each iteration. In the beginning, a starting solution based on a model solution for a monopoly is used. The cross-zonal capacity allocated by the monopolist is simply divided by the number of traders at each border and assigned to each trader.

Some steps are needed to start the run of the model for a trader. First, the allocated cross zonal capacity of all other traders is determined based on the starting solution or later on the model runs of each trader. Second, based on this allocated capacity, the residual demand curve is changed. Therefore, purchases and sales of the other traders are integrated in the residual demand curves. Finally, the ATC values are changed in a way, that the allocated capacity by all other traders is subtracted. Now a model run can start again changing the parameters described afterwards. This procedure is continued until no more changes of allocated capacity occur for any trader.

In figure 10, we can exemplarily see the functioning of the model for 15 October 2020. Based on the ATC for SA we can see the profit optimal allocation and the resulting market prices. In this model-setup the monopolist considers profit out of cross-border-transactions and LTTRs for his cross-border activities.

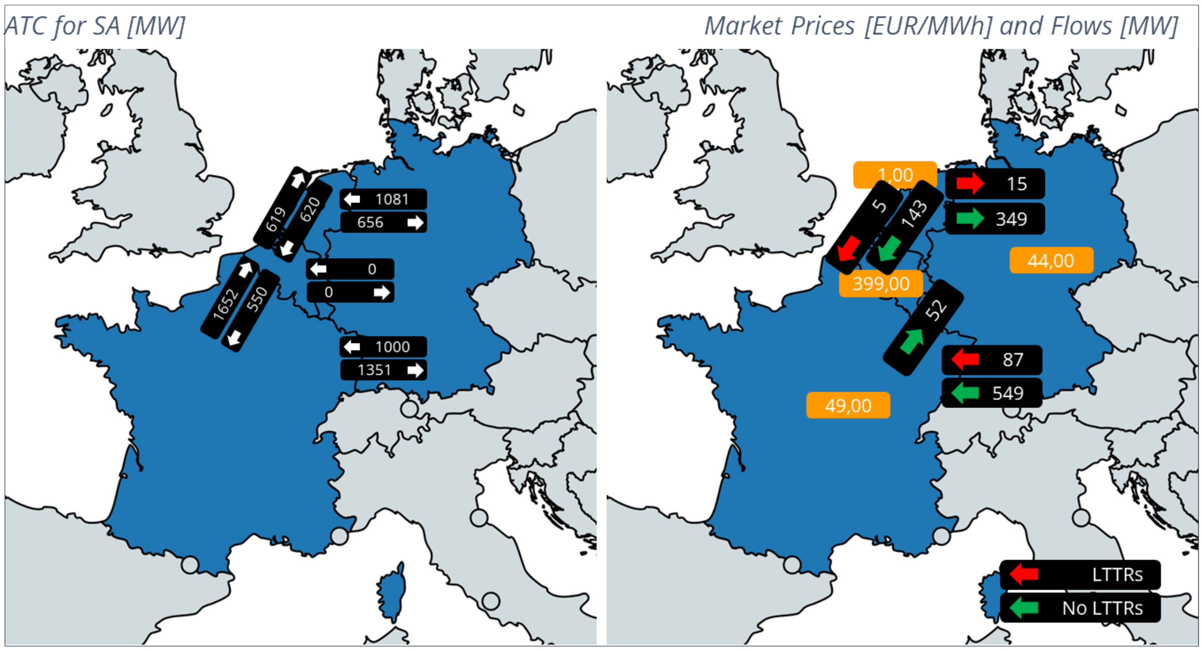

Figure 10: exemplary cross-zonal-allocation in an oligopoly

5. Results and Discussion

A market equilibrium has been calculated for each of the scenarios described in chapter 4. As a first step we have analysed the amount of allocated capacity in the different scenarios. In figure 11, the allocated capacity is shown as the sum over all zonal borders in the scenarios. Allocated SA-Capacity increases with competition, yet stays lower compared to the welfare optimum. Even in the scenario with 24 traders, on each border the allocated capacity in the simulation is on average more than 30% lower than for the welfare optimum. These results reaffirm that implicit market-coupling is superior to explicit market coupling even in market situations with many traders. However, we assume that with a growing number of traders, the allocated capacities will come closer and closer to the welfare optimum.

Figure 11: allocation of capacity (in MWh) in all considered scenarios

In a next step, we have further analysed allocated capacity and compared allocated capacities between traders holding LTTRs and traders not holding LTTRs. Figure 12 shows that the percentage of allocated capacity by LTTR holders is 15% on average and less than 30% of total allocated capacity in all simulated scenarios. Figure 12 also shows that under the model's conditions the economic incentives to allocate capacity in a SA situation are quite low for LTTR holders. This might explain why traders holding LTTRs were significantly underrepresented in the SA, resulting in inefficiently allocated capacity in historical SA-situations.

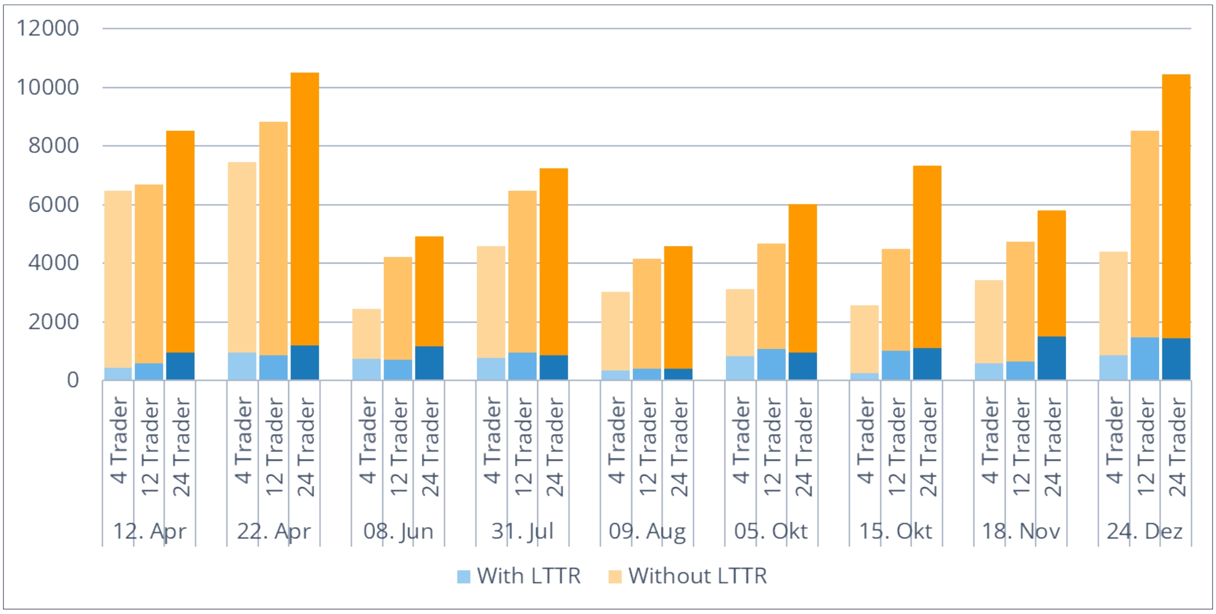

Figure 12: allocation of capacity (in MWh) by types of traders

In addition to allocated capacities, welfare effects for the different scenarios were analyzed. These effects are represented in figure 13 as an average relative to scenario 1. Social welfare (1) is defined thereby as the sum of consumer and producer rent, total economic surplus (2) as social welfare + congestion rent + traders' profit and effect on total economic surplus as effect on social welfare + congestion rent + traders' profit – congestion rent in the welfare optimum.

The first important finding concerning welfare effects is that the effect on social welfare decreases significantly with growing competition.[1] This development is even more evident when assessing the total economic surplus. However, it turns out that even in scenarios with

[1] To understand the relative low effects on social welfare (4) compared to other figures discussed for decoupling events it has to be explained that welfare based on the SA ATC (3) is already significantly lower than with flow-based market coupling due to lower transfer capacities.

high competition, significant distributional effects remain. Compared to the welfare optimum, the LTTR remuneration at the expense of tariff payers still increases by a factor of 50.

	Total Social Welfare [EUR][1]	*Congestion Rent [EUR]*	*Traders Profit [EUR]*	*LTTR Remuneration [EUR]*	*Total Economic Surplus [EUR][2]*
Welfare Optimum with SA ATCs[3]	*183.379.375*	*42.416*	*-*	*43.169*	*183.422.544*
	Effect on Social Welfare[4]	**Congestion Rent**	**Traders Profit**	**LTTR Remuneration**	**Effect on total Economic Surplus[5]**
Monopoly	-1.542.386	654.443	234.603	8.970.718	-695.756
4 Traders	-1.409.083	802.620	267.540	7.450.912	-381.339
12 Traders	-704.999	422.742	140.914	2.964.685	-183.759
24 Traders	-469.112	343.909	114.636	2.333.125	-52.983

Figure 13: average welfare effects of the scenarios 2-5 relative to scenario 1

6. Conclusion and Policy Implications

Article 44 (EC 2015) mandated a fallback procedure "to ensure efficient, transparent and non-discriminatory capacity allocation" in case of a decoupling event. The simulation shows that the probability of a trader holding Long Term Transmission Rights (LTTRs) to allocate cross-border capacity in Shadow Auctions (SA) is significantly reduced compared to those traders not holding LTTRs. The 50% traders holding LTTRs are responsible for only 15% of the allocation on average. This is because the profit out of allocating cross-border capacities is usually smaller than the decline in LTTR remuneration due to smaller market spreads. Therefore, LTTR remuneration based on market spreads significantly reduces the incentives to take part in the SA for LTTR holders. Allocating capacities for LTTR holders is economically not reasonable in most cases. Therefore, Article 35 (EC 2016) does have a negative impact on the functionality of the current fallback option developed as mandated by Article 44 (EC 2015)

Even with high numbers of traders, the design of SA mechanism reduces social welfare. In a scenario with 24 traders active on each border the negative impact on social welfare is still only reduced by about 50% compared to a monopoly situation and strong distributional effects at the expense of tariff payers occur.

In our opinion, based on the modelled Cournot (Nash) approach we propose the following points for further discussions to optimize or replace Shadow Auctions as fallback options in case of unavailability of the Single Day-Ahead Coupling (SDAC) – e.g. a decoupling event.

First, as LTTR holders are disincentivised to allocate significant amounts of capacity in the SA, more traders, which do not hold LTTRs, should be motivated to take part in the SA. This will help to allocate more capacities as it has been shown that traders without LTTRs allocate about six times more capacity than traders holding LTTRs.

Second, new ways to remunerate LTTRs in decoupling events, which are not closely linked to market spreads, should be developed to increase incentives to allocate capacities. However, it should be considered that LTTR remuneration is directly linked to Day-ahead auction results and new ways to remunerate LTTRs can reduce bid prices in the LTTR-auction.

Third, the development of alternatives to the whole shadow auction process. In our opinion, the process is quite complex compared to the low incentives to allocate capacities for the traders in a decoupling event. A simple way of implicit coupling as an alternative to today's SA process maybe worth considering. In view of the upcoming implementation of Intraday Auctions, they could be an alternative fallback.

Data Availability

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Appendix

Symbols

bze	exporting Bidding zone
bzi	importing Bidding Zone
$cdsc_{bz,ds}$	cumulated demand segment capacities
$CDSC_{ds}$	cumulated segment bid-capacity
$CRDSC_{rds}$	cumulated residual segment capacity
$cssc_{bz,ss}$	cumulated supply segment capacities
$CSSC_{ss}$	cumulated segment offer-capacity
ds	demand segments
$dsc_{bz,ds}$	capacity demand segment
P_{bze}	export prices
P_{bzi}	import prices
PDS_{ds}	constant bid price
$PRDS_{rds}$	constant price of the segment
PSS_{ss}	constant offer price
PT_{tr}	profit for a trader
rds	residual demand segments
ss	supply segments
$ssc_{bz,ss}$	capacity supply segment
tr	traders
$xb_{bz,rds}$	binary variable to select a RDS in each BZ
$xds_{bz,ds}$	non-negative variable demand segment
$xlttrtrans_{bze,bzi}$	LTTRs modelled cross-zonal flows
$xrds_{bz,rds}$	purchases for negative values and sales for positive values
$xss_{bz,ss}$	non-negative variable supply segment
xtrans	cross-zonal trading quantities
Z	objective value