Empirical Analysis of the Congestion Revenue Cycle in Europe's Electricity Grid

Christof Duthaler and Matthias Finger

***Abstract*—In the light of the ongoing electricity market integration in Europe, the debate has turned to a more regional approach of network access. Among other things, this leads to new questions with regard to the handling of congestion revenues. This paper explores the importance of a comprehensive view at the Congestion Revenue Cycle, consisting of the three stages revenue generation, revenue distribution and revenue usage. The relationship between available capacity and congestion revenue is examined and the effect of several revenue distribution keys is empirically investigated. The findings show that a revenue distribution must consider revenue generation and revenue usage to achieve sustainable results.**

I. Introduction

IN recent years and based on the legal framework provided by EC regulation 1228/2003 and its guidelines, the concept of market-based access to cross-border transmission capacity in electricity networks has been established quite well throughout Europe. In the light of the ongoing electricity market integration, the debate has now turned to a more regional approach of network access. One of the concepts discussed e.g. in the Central Eastern and South Eastern regions of Europe foresees the introduction of so called flow-based capacity auctions with source-sink bidding. In this case, transmission capacity at several national borders of a region would be auctioned simultaneously in a coordinated fashion. Another attempt is to directly couple national electricity markets, as proposed for the Central Western region of Europe [1]-[3].

Among other things, both flow-based capacity auctions and market-coupling lead to new questions regarding the handling of congestion revenues. As there is no longer a bidding for individual borders, congestion revenue wouldn't accrue directly to specific borders any more (as it is the case today), but would rather be collected by a regional fund. Clearly, how to re-distribute such a fund to participating countries and Transmission System Operators (TSOs) is a crucial issue which gained quite some attention recently [4], [5]. Nonetheless, the actual "value-chain" of congestion revenue is often discussed by considering only some isolated steps of it, e.g. by focusing on revenue distribution keys while ignoring aspects linked to revenue generation or revenue usage. Such a partial view might however lead to inadequate conclusions and could eventually result in unintended incentives given to TSOs.

This paper takes a different perspective and proposes an integrated view on the whole Congestion Revenue Cycle (CRC), consisting of the three parts revenue generation, revenue distribution, and revenue usage (Fig. 1). For each part of the cycle, the paper investigates some of the crucial aspects and questions, to be then able to bring these elements together and conclude on longer-term incentives and planning from a regulatory perspective.

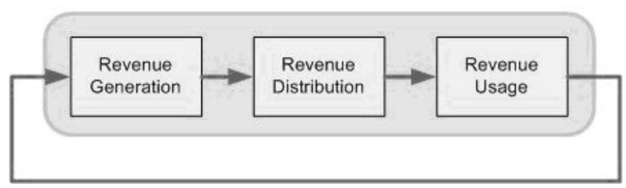

Fig. 1. Congestion Revenue Cycle.

II. Congestion Revenue Generation

A. Background and overview

The first step of any Congestion Revenue Cycle (CRC) consists in actually generating the revenue by allocating scarce grid capacity to interested parties. As the transmission grid forms a natural monopoly, a possible approach to grant non-discriminatory access to it is to apply administrative procedures[1] and regulated prices, which is however neither an efficient nor a market-based solution to this task [6].

Indeed, it wasn't until the introduction of explicit auctions that a market-based solution for the allocation of transmission capacity became available. Auctions allow market participants to directly bid for and thus value (cross-border) transmission capacity. In this regard, the explicit auctions on the interconnectors between Germany and Denmark, Germany and the Netherlands as well as between France and Britain, all of them launched between 2000 and 2001, may be seen as a pioneering work [6], [7]. In the meantime, cross-border capacity auctions have been established on most frontiers throughout Europe [1].

[1] First-come first-served or pro-rata allocations are examples of administrative procedures.

Manuscript of September 12, 2008.

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From an institutional point of view, it's important to realize that at the time market-based capacity allocations became necessary in Europe, liquid energy market platforms were not yet in place in most parts of the continent, and thus system operators took the responsibility for this task. Since then, capacity auctions have been complemented or replaced by a coupling of national energy markets in some regions, which will be discussed later on.

In order to gain a general idea of the current cross-border congestion and capacity auction situation in Europe, Fig. 2 provides an overview of the revenues collected by explicit capacity auctions in 2007, classified by border and direction. The chart is based on raw data of yearly, monthly and daily auction results collected by the authors for 23 borders.

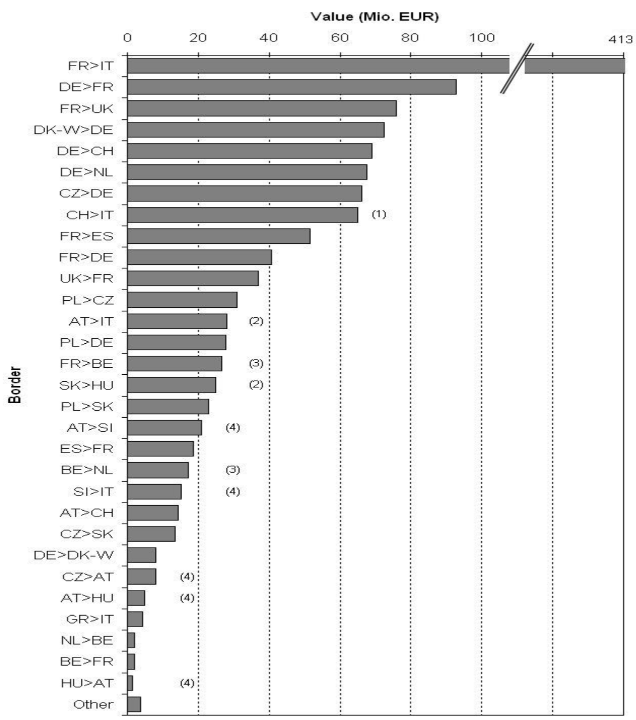

Fig. 2. Capacity auction revenue by border and direction, 2007. Sources: ETSOVista, own analysis.

Notes on Fig. 2:

(1): In 2007, the Swiss-Italian border was only partly auctioned.

(2): For the border directions of AT>IT and SK>HU, no information on daily auctions was available. Total auction revenue is thus likely to be higher.

(3): For FR>BE and BE>NL, only yearly and monthly explicit auctions were considered, while congestion rent from day-ahead market-coupling is not included.

(4): For all of these borders, the total revenue of daily auctions was extrapolated from a subset of days distributed throughout the year. This was due to limited batch access to data.

Due to unavailability of data, the border between Spain and Portugal is not included in this survey.

While the retrieval of such information on a large scale was almost impossible just a few years ago, the situation has improved significantly thanks to the arrival of ETSO's transparency platform ETSOVista, which was launched in November 2006. The access to capacity and auction data, commercial schedules and physical flows is now open to the public and got a lot more comfortable for researchers, too[2].

As can be derived from Fig. 2, the total revenue of explicit capacity auctions collected in 2007 amounts to some 1400 million Euros[3]. Compared to the average spot market value of electricity consumed in the UCTE region (some 115 billion Euro[4]), cross-border capacity auction revenue currently represents roughly 1.5 % (excluding cost for redispatch measures). Based on the spot market value of UCTE cross-border exchanges (some 18 billion Euro[5]), auction revenue accounts for approximately 8.5%.

B. Theoretical relationship between congestion revenue, market prices and transfer capacities

Regardless of whether two energy markets are coupled or merely linked by capacity auctions, the following two factors with an impact on congestion revenue[6] can be identified:

- **National bid and offer curves:** Every energy market possesses a characteristic demand and supply structure, which is primarily based on generation cost and consumption usages. Generation cost in turn may be driven by a combination of technological, natural and political factors. In the absence of market power, these costs are independent from the grid topology and any grid reinforcements. Demand and supply structure result in typical bid and offer curves, which eventually define an equilibrium market price.
- **Available transfer capacity:** The available transfer capacity between two energy markets specifies the maximum energy exchange between these two markets. Remember that an export out of a market A leads to a higher market price in A, while an import into market B leads to a lower market price in B.

To illustrate the relationship between these two variables, Fig. 3 shows supply and demand curves of two energy markets A (low price) and B (high price), which are connected by a transfer capacity of 1000 MW. Note that market A exports 1000 MW (demand curve shifts right, market price goes up), while market B imports 1000 MW (supply curve shifts right, market price goes down). Demand and supply shifts are indicated by arrows in Fig. 3.

[2] See www.etsovista.org

[3] Revenue from implicit auctions (i.e. market coupling) between France, Belgium and the Netherlands as well as between Spain and Portugal is not included and may add another 50 to 100 million Euros (own estimation based on market price differences and ATC values).

[4] 2200 TWh * 50 EUR/MWh. UCTE consumption without countries BA, BG, CS, MK, RO, UA (as they are not included in the congestion revenue survey). 50 EUR/MWh is the average of 2007 averaged spot prices at EEX, Powernext and IPEX. Sources: UCTE and GME (Italian market operator).

[5] 350 TWh * 50 Euro/MWh. Sources : UCTE and EEX, comments see footnote 4.

[6] In this paper, congestion revenue is defined as a general term for either congestion rent (in case of coupled markets) or auction revenue (in case of capacity auctions).

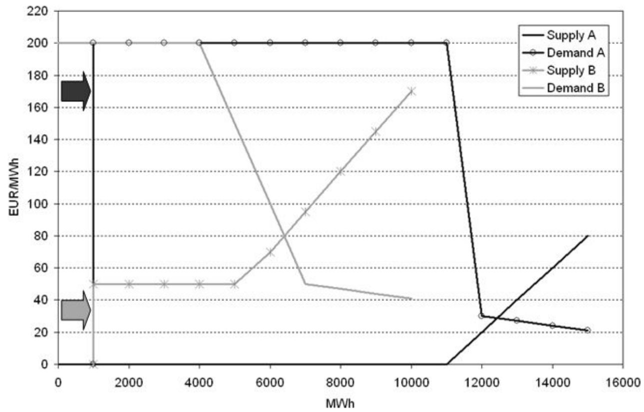

Fig. 3. Supply and demand curves of two markets A and B.

Next, Fig. 4 derives the congestion revenue graphically. Congestion revenue equals the remaining white surface after coloring demand and supply surpluses in markets A and B, i.e. 1000 MW times the market price difference[7]. In case of coupled markets, this revenue is collected as congestion rent by the market operator. In case of explicit capacity auctions, congestion revenue is split between the market operator on one hand, who receives the auction revenue, and traders on the other hand, who receive the delta between the actual market price difference and auction price as a margin. This margin also hedges risks resulting from inaccurate anticipation of future energy prices.

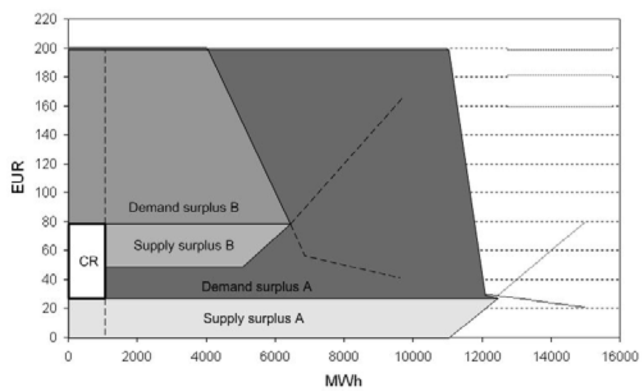

Fig. 4. Congestion revenue derived from supply and demand surpluses.

By looking at Fig. 3 and 4, it becomes clear that additional transfer capacity yields additional congestion revenue as long as market prices in A and B do not converge substantially. Such additional congestion revenue might be used to refund further transmission capacity expansion, for example. However, if the steep part of the demand curve in A is reached (higher demand elasticity, Fig. 3), market prices in A will start to rise significantly and converge towards the level of B, thereby diminishing congestion revenue. This time, there is no extra money available to refund a capacity expansion project. It may be collected from network tariffs, or it may be taken from congestion revenue generated elsewhere in the region. We'll come back to this point in the third and fourth section of this paper.

C. *Empirical evidence from explicit capacity auctions – the Laffer curves*

While the supply and demand curves of national electricity markets (i.e. their merit orders) aren't directly visible for an external observer, what may be visible is the bidding behavior of market participants at explicit capacity auctions[8]. As illustrated in the previous section, this bidding behavior anticipates future market price differences, which in turn rely on supply and demand curves of national energy markets and available transfer capacity.

The relationship between auction revenue and available transmission capacity is an aspect of particular relevance with regard to the Congestion Revenue Cycle and TSO incentives. This is because a sound regulatory policy must prevent TSO's from "creating" congestion as a potential source of income, as this would clearly impede an efficient cross-border energy market. For instance, congestion could be created artificially by announcing capacity values lower than required by security standards[9], or by avoiding necessary grid expansions. Indeed, such concerns have been expressed by market actors and regulators as well [8], [9]. Based on these considerations, the current section is going to provide some insights into how exactly available transfer capacity (ATC) influences auction revenues at European borders.

For this purpose, let's recall that a typical capacity auction applies a principle known as uniform or marginal bid pricing, i.e. the last accepted bid sets the clearing price for all accepted bids[10]. The auction revenue is thus given by the product of available transfer capacity times the marginal bid price (also called the clearing price, CP), see formula 1:

$$\text{Auction revenue} = ATC * CP \qquad (1)$$

The so called bid curve displays bid prices and bid volumes as submitted by auction participants. By multiplying the corresponding bid prices and volumes, an auction revenue curve as illustrated in Fig. 5 is obtained. This curve features two main parts: First, there is an upward slope, which means that auction revenue is rising along with increasing demand. At some point, the curve reaches its maximum, which corresponds to the static maximum auction revenue (see below). In the second part of the curve, there is a downward slope, which means that the additional demand can no longer compensate the falling marginal bid price, and the auction revenue begins to decrease until it's zero.

Such a relationship is well known in tax theory as the "Laffer Curve", which states that a government's tax income

[7] The sum of all the supply and demand surpluses, plus the congestion revenue, yields the total market value.

[8] Public access to bid curves (e.g. on TSO websites) depends however on local Auction Rules, which differ from border to border.

[9] E.g. by considering unrealistic worst-case scenarios, or by applying unfounded security margins.

[10] For a discussion of uniform vs. pay-as-bid auction, see e.g. [26]

increases up to a certain tax rate, before it starts falling as taxable substrate becomes less, e.g. because taxable entities relocate to other regions or stop working. For both of the two extremes (i.e. 0% or 100% tax rate), the tax income will be zero.

For our purpose, the interesting question is whether ATC values on European borders lie on the upward or on the downward slope of the auction revenue curve. An ATC on the upward slope implies rising auction revenue by additional capacity, whereas an ATC on the downward slope signifies less revenue with every additional MW and may indeed incentivize a revenue seeking TSO to reduce announced capacity. In analogy to the taxation Laffer curve, auction revenue will be zero if there's no capacity available to be auctioned or if capacity is abundant and there is no congestion (Fig. 5).

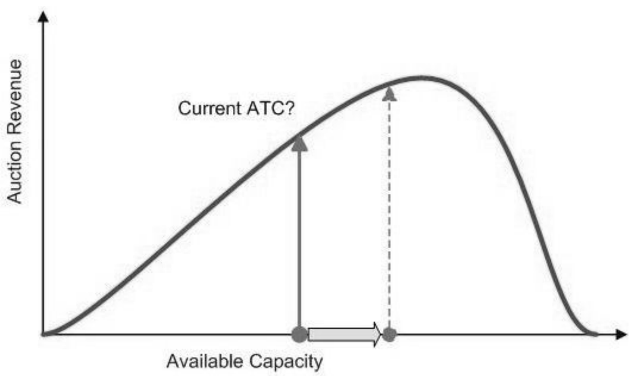

Fig. 5. Theoretical Auction Revenue Curve ("Laffer Curve").

As a matter of fact, the analysis of an auction revenue curve is of static nature. Underlying bid curves depend crucially on the available capacity. This is because it influences expected market price differences (Fig. 3), which in turn determine the bidding behavior. A substantial change in ATC (e.g. by building a new line) thus implies a redrawn revenue curve. For smaller, e.g. calculatory ATC changes[11], however, the revenue curve is assumed to be static and can be linearized around the current ATC level.

To explore the relationship between ATCs and auction revenues empirically, the authors examined ATC values and bid curves (where accessible) of several European borders. As an example, Fig. 6 displays the revenue curve of the monthly auction between France and Germany from August 2008. As can be seen, the ATC value lies far below the maximum revenue level on the upward slope of the revenue curve. In this case, for smaller, e.g. calculatory capacity changes, more capacity would lead to more auction revenue.[12] For larger capacity changes, e.g. by infrastructure expansions, auction revenue would increase with capacity as long as the impact on market price convergence is relatively low. When market prices start converging due to additional cross-border capacity, auction revenue is likely to fall. In general, this situation was observed for several of the commercially significant European borders, i.e. those linking large markets with a substantial price spread (Fig. 2 and 9). These findings are consistent with theoretical foundations provided in the former section.

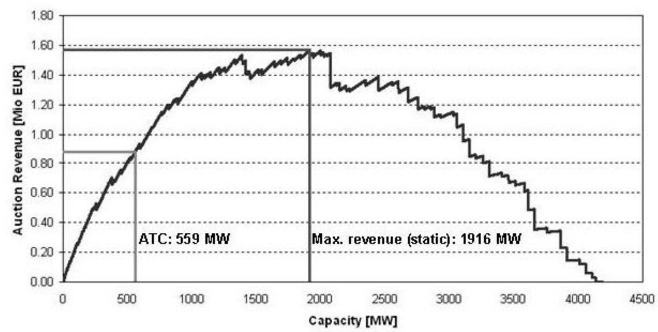

Fig. 6. Auction revenue curve from France to Germany, August 2008. Data Source: RTE.

The most recent example of how congestion revenue can finance new interconnections is provided by the NorNed cable between the Netherlands and Norway, which became operational in May 2008. With a capacity of 700 MW and total project cost of 600 million Euros, NorNed auction revenues amounted to approx. 50 million Euros within the first two months of operation, i.e. 8% of the total investment cost. This implies a full cost recovery within a time span of only 2 years[13].

D. *Remarks on TSOs and financial incentives*

It may be argued that TSOs are in fact revenue-neutral entities, for example because they are obliged to transfer congestion revenue directly to customers by lowering their network tariffs, or increase those tariffs to fund grid investments. In this case, though, the spotlight shifts from TSOs to regulators, as they usually determine or approve network tariffs and thus may have an interest in a continuous flow of congestion revenue as a means to subsidize these tariffs. We'll take a closer look at revenue usage later on in this paper, but sure enough, the observed details of revenue generation will play their role in the upcoming considerations.

At any rate, the analysis so far suggests that financial incentives might not be a suitable means to guide the behavior of TSOs, e.g. with respect to maximizing transfer capacities. As suggested by our empirical findings, TSOs indeed would already have such an incentive at several commercially significant borders in Europe, at least for smaller (e.g.

[11] In contrast to an infrastructure related change in ATC, a calculatory change may consist of different assumptions regarding load flow patterns, for example.

[12] This is true regardless of whether an annual or a monthly auction is observed. For daily auctions, the creation of Laffer curves is usually not possible. This is because every hour of the following day is auctioned individually and there often aren't enough bids per hour to review the relationship empirically.

[13] Numbers provided by the Dutch TSO TenneT (www.tennet.org) and the NorNed auction website (www.norned-auction.org).

calculatory) capacity augmentations. The fact that they don't do so hints at the relevance of more profound aspects related to grid security, which TSOs must primarily take into account. Having in mind the costs of a serious grid security failure, i.e. a black-out[14], there is no room left to maximize commercial capacity beyond security limits.

III. Congestion Revenue Distribution

A. Introducing congestion revenue distribution keys

After the congestion revenue has been generated, the next step of the Congestion Revenue Cycle is about distributing the money. Traditional explicit auctions have been defined in a bilateral way between adjacent countries[15]. Following this logic, auction revenue accrues to the border where it was generated and it is usually distributed in equal parts to the TSOs of the adjacent countries, which in turn are usually the direct or indirect owners of the cross-border interconnectors.

In contrast, if the congestion revenue stems from flow-based capacity auctions with source-sink bidding, or from a multilateral market coupling scheme, then the revenue is collected centrally for all participating countries (as there is no longer a "bidding" for individual borders). The question of how to re-distribute the region-wide congestion revenue now becomes one of utmost importance to participating TSOs and regulators.

That said, it's worth recalling that the congestion revenue belonging to a specific interconnector (or country border) is by definition given as the price difference over that interconnector (or border) times the flow through it (or a normative ATC value, for that matter). This definition remains unchanged even if coordinated flow-based capacity auctions or a market coupling scheme is introduced. It can be considered as a "natural revenue distribution", while any other distribution would imply a reallocation of congestion revenues, which needs some sort of justification [10].

South-East Europe (SEE) was one of the first continental European regions to tackle the question of auction revenue distribution in the wake of their "Dry-run for coordinated, flow-based explicit auctions" launched in 2003. During their pioneering work, the involved parties came up with a variety of conceivable distribution-keys and discussed their pros and cons in detail [11], [12].

Based on this discussion, the authors conducted an empirical survey of European borders to study the prospective impact of these distribution keys (if applied in Central Europe). The goal was not to simulate specific auction results as snapshots, but to gain a high-level understanding of the different impacts on revenue distribution. The following section provides a very short description of several distribution keys and presents the findings of the empirical investigation. For a more detailed discussion of the distribution keys, please refer to the sources mentioned above.

TABLE I
Auction Revenue Distribution Keys

Category	Key
A. Grid-usage	a. Absolute grid-usage
	b. Relative grid-usage
B. Economic signals	a. Difference in market clearing prices
	b. Shadow prices
C. Asset-based	a. Asset base or investment plan

A.a Absolute grid-usage: Congestion revenue is distributed according to the physical usage of the grid, i.e. load flows. The idea is to encourage maximization of transfer capacities. However, the key honors capacity investments regardless of their overall efficiency. Also, it would channel money to borders where no congestion exists (and no investment is needed). Last but not least, it should be noted that in Europe, third-party "grid-usage" ought to be covered by the ITC mechanism.

Fig. 7 shows the 2007 distribution of load flows within UCTE[16].

A.b relative grid-usage: Congestion revenue is distributed according to the relative usage of transfer capacities. The idea is to channel money to borders which are intensively used and may need expansion. However, the key sets an incentive to artificially create congestion by lowering ATCs or by not investing. Also, money would accrue to borders with no congestion. Finally, ATC values are commercial values and are not a well defined reference for such purposes. Fig. 8 underlines this conclusion, showing that flows may reach far above commercial transfer capacities[17].

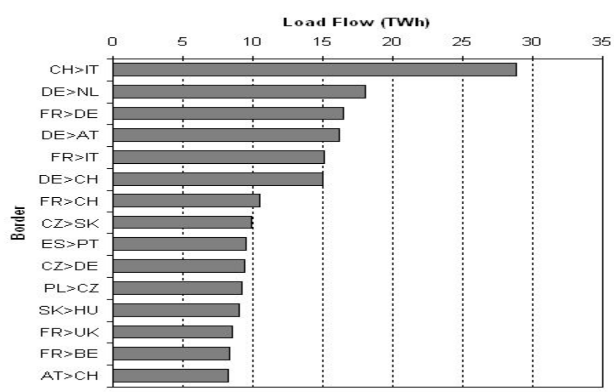

Fig. 7. Top 15 of cross-border load flows in 2007. Source: UCTE.

[14] For example, the Italy blackout of 28 September 2003 cost approx. 1 bn EUR, the US North-East blackout of 14 August 2003 cost approx. 4.8 bn USD, and the costs of a potential black-out on the Austrian extra high-voltage grid are estimated to 40 mn EUR per hour. Source: Austrian Verbund.

[15] Even if capacity calculations or auction operation are performed in a coordinated, multilateral fashion. See e.g. the existing coordinated auction office for Central Eastern Europe (based in Prague) or the coordinated capacity assessment at the Italian Northern borders.

[16] Please note that load flows include unscheduled "loop-flows" as well as natural flows, which take place without any exchange.

[17] This is mainly due to unscheduled load flows, i.e. loop-flows.

B.a Difference in market clearing prices: Congestion revenue is distributed according to the difference in market clearing prices between two adjacent countries. The idea is to allocate money to borders where adjacent market prices have not yet converged. However, the key sets incentives to keep up congestion. Fig. 9 displays averaged yearly and monthly bilateral auction clearing prices as a reference for market price spreads.

B.b Shadow prices: Congestion revenue is distributed according to shadow prices. The shadow price of a border equals the additional, regional congestion revenue collected by increasing the capacity of that border marginally (e.g. by 1 kW). The idea is to channel money to borders where a capacity increase is of highest economic value. However, shadow prices are a very volatile figure and can't provide any longer-term incentives. Also, such a distribution would discourage capacity investments, as a border loaded with 99% of its capacity has a shadow price of zero and wouldn't receive any congestion revenue. As shadow prices are actual snapshots of a specific auction result, no high-level overview is provided. To a certain extent, shadow prices are however linked to market price spreads (Fig. 9)

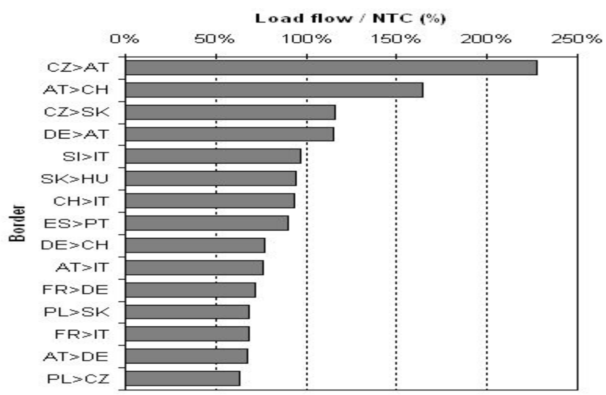

Fig. 8:. Top 15 of physical usage of cross-border capacity, defined as the ratio of load flow to averaged NTC value, 2007 data. Sources: UCTE, ETSO.

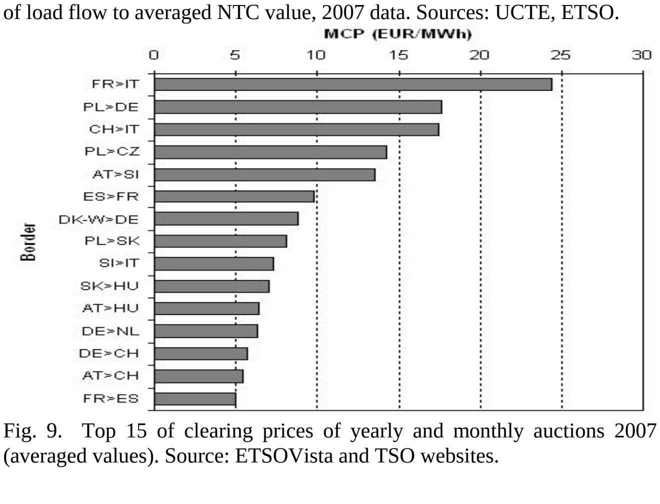

Fig. 9. Top 15 of clearing prices of yearly and monthly auctions 2007 (averaged values). Source: ETSOVista and TSO websites.

C Asset base or investment plans: Congestion revenue is distributed according to either existing asset values (of cross-border interconnectors) or according to future investment projects. The idea is to refund existing infrastructure or future investments by channeling congestion revenue accordingly. However, relevant asset values are hardly transparent and comparable so far. Also, the key may lead to inefficient investment projects. As data on assets or investment plans isn't publicly available, no empirical comparison was conducted.

B. Distribution keys: A sustainable approach?

Our empirical analysis of the distribution keys suggests that different keys result in substantially different revenue distribution patterns. Furthermore, incentives given to TSOs depend to a large extent on the choice of the distribution key and may diverge remarkably. The preliminary conclusion of SEE working groups, i.e. that there is no single best distribution key, was confirmed. As a possible solution to this dilemma, SEE proposed to combine several keys into a hybrid-key, which could balance the pros and cons of individual keys according to regulatory intentions.

Our paper adds a different perspective: If revenue distribution is considered as a central part of the CRC, then it becomes obvious that in fact all of the distribution keys implicitly assume two things: (1) That capacity expansions can't be financed by additional congestion revenue generated through the expansion itself, and (2) that re-distributed revenue could indeed be invested in feasible projects at the selected borders. However, the first assumption is likely to be unjustified at least for some of the commercially important European borders (see Section II), whereas the second assumption remains critical in practice, as will be shown in the next section.

Therefore, a sustainable congestion revenue distribution scheme must consider revenue generation and realistic revenue usage. It could be based on the natural distribution key, i.e. price spread times load flow or ATC value, which would also be in accordance with EC rules for merchant transmission lines (i.e. same distribution, but different usage of congestion revenue).

IV. CONGESTION REVENUE USAGE

A. From EC regulation 1228/2003 to the 3rd package

As mentioned in the introduction, EC regulation 1228/2003 is the valid legal framework for the topic of cross-border electricity exchanges and capacity allocation. Article 6.6 of the regulation specifies that congestion revenue must be used for any of the following three purposes: (a) Guaranteeing actual availability of allocated capacity (i.e. redispatching), (b) maintaining or increasing capacities by investment, or (c) Reducing network tariffs. In its 2007 report on the experiences gained from the application of regulation 1228/2003, the European Commission regretted that congestion revenue had been used primarily for lowering network tariffs, while only few network investments had been realized [13]. According to the EC sector inquiry, between

2001 and 2005 no more than 16.8% to 33.3%[18] of congestion revenues had been reinvested in infrastructure [14].

Still in 2007, the EC published its proposal for a third energy package, revising Directive 2003/54 and Regulation 1228/2003. Concerning congestion revenues, the EC proposed to restrict their usage to (a) guaranteeing the actual availability of allocated capacity and (b) maintaining or increasing capacities by investment. Lowering network tariffs would no longer be allowed. In case congestion revenue can't be spent immediately by investment, the money would be placed on a special account, until such investment projects become available.

It looks like the EC proposal was inspired by the current congestion revenue framework of Nordel, the body for co-operation between the TSOs in Denmark, Finland, Iceland, Norway and Sweden[19]. Nordel foresees the use of congestion rents, which reached approx. 100 million Euro in 2005, for the exclusive purpose of covering redispatch cost or expanding capacity between Nordic states or between the Nordic region and adjacent regions[20]. In this regard, Nordel has identified several priority projects [15].

On one hand, this approach is convincing thanks to its progressive aim at regional grid planning and market integration. On the other hand, real-world experience seems to indicate that such an "investment-only" approach faces hurdles in its practical implementation. First of all, it appears difficult enough to find an agreement among stakeholders on priority projects at a regional scope. And even if an agreement is eventually found, such projects all too often can't be accomplished due to local resistance from the political-environmental side. Previously collected congestion revenues may thus get blocked for years and don't flow back to loads who had to pay it initially, which may bring TSOs under suspicion of withholding congestion revenues [16], [17]. Also, the pressure to re-invest congestion revenues (no matter how) could lead to inefficient investment decisions.

While Nordic TSOs don't reallocate congestion revenues directly to suppliers of load as a hedge against their congestion cost[21], this is exactly what the so called Congestion Revenue Rights (CRR) model does, which is applied in many of the restructured US electricity markets. In general, the relationship between loads bearing investment costs and loads bearing congestion cost should be explored in more detail. In Europe, these two load groups are overlapping, but they are not equal and usually belong to different countries.

[18] The numbers apply to vertically integrated TSOs and ownership-unbundled TSOs, respectively

[19] In the EC commentary on the 3rd package proposal, the Nordel is indeed mentioned as an exemplary model.

[20] Statnett's financing of the NorNed cable between Norway and the Netherlands is such an example.

[21] Instead, Nordpool introduced so called Contracts for Differences (CFDs) in 2000, which have no connection to the TSO or to the congestion revenue, but are concluded among market participants to swap their locational risk-profiles [24].

B. Congestion revenues: Sufficient to finance the grid?

To what extent could congestion revenue possibly contribute to grid expansion projects in Europe? Pérez-Arriaga et al. showed that for a theoretical, optimally expanded electricity grid[22], the congestion revenue from short-term locational marginal pricing of electricity is exactly equal to the total network cost[23] and thus sufficient to recover investments for any time interval. In practice however, congestion rents of actual power systems "grossly fail" to recover total network cost. According to Pérez-Arriaga, this is due reasons such as sub-optimal network planning, the strongly discrete nature of grid investments, economies of scale or reliability constraints, all of which lead to over-investment and under-recovery of network cost. Pérez-Arriaga cites field-studies from Latin American countries, Spain, New Zealand and South Africa confirming that congestion revenues generally recover no more than 30% of actual network cost, and sometimes as little as 4%. Therefore, a two-part tariff scheme, which imposes a fixed transmission tariff in addition to revenues from locational pricing, is essential to fully finance an actual grid [18]-[22].

In central Europe, congestion revenue is collected only on borders between countries, as there is no locational pricing within countries[24]. As derived in Section II, cross-border congestion revenue amounts to approx. 1.5 billion Euros per year. By 2006, the UCTE extra high voltage electricity network consisted of approx. 220'000 km of overhead lines (220 to 400 kV). Its net book value is estimated to about 40 billion Euros[25], and an additional 10 to 20 billion Euros is expected to be invested by TSOs till 2015, i.e. 1 to 2 billion Euros per year [23]. Compared to these numbers, it appears that congestion revenue could indeed cover a non-negligible part of new cross-border investment projects, but it's definitely not sufficient to finance total grid costs.

V. Conclusions

A. Preliminary remark on flow-based capacity auctions with source-sink bidding

As was shown in a previous paper, the zonal flow-based model relies on assumptions that are not fulfilled in the UCTE grid [25]. Additionally, flow-based capacity auctions with source-sink bidding may actually impede planning certainty for market participants. This is because they introduce new interdependencies between individual borders, which can't be controlled or foreseen by any market participant, without providing a direct access to foreign energy markets. Initially

[22] Grid expansion is optimal if a system operator invests to the point when incremental investment cost equal incremental incurred savings in total operation cost.

[23] Total network cost consists of investment cost and operation cost including transmission losses.

[24] Without locational pricing, congestion revenue transforms into to producer and consumer surplus.

[25] The estimated net book value is cited as a comparison value only. It is not the relevant number with regard to future investments.

designed as a political compromise and a “first step”, it remains to be seen if it’s a step forward or backward with regard to electricity market integration and grid security.

B. Conclusions on the Congestion Revenue Cycle

The findings of this paper point at the importance of a comprehensive view of the Congestion Revenue Cycle. Above all, revenue distribution should clearly consider both where (and how) the revenue was initially generated and how it is to be used. Congestion revenue accrues naturally to a transmission line according to the price spread over it times the flow through it (or times a commercial ATC value). When setting up a re-distribution of congestion revenue, it should be taken into account that grid expansions at commercially significant European borders may indeed be financed by additional congestion revenue generated by the expansion itself. Also, an investment-only revenue usage policy (as proposed by the third Energy Package of the EU) is likely to face hurdles in its practical implementation due to local resistance and political-environmental concerns, and could produce inefficient investments. Finally, the relationship between loads bearing investment costs and loads bearing congestion costs should be further explored for the European case.

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