Methodological paper:

Benefits from day-ahead and intraday market coupling

This methodological paper has been reviewed in detail and assessed to be "adequate" and "robust" by an external expert in 2018.

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Version	Amendment
18/09/2019	Update of the main methodology in order to consider the linear price spread refinement.

Content

1. Introduction

(1) This document is one of a set of documents describing various methodologies applied in the electricity wholesale markets volume of the annual ACER/CEER Market Monitoring Report (MMR), which is aimed at presenting the results of the monitoring of the performance of the internal electricity market in the European Union (EU).

(2) This paper is intended to describe methodologies used to compute gross short-term benefits (without assessing incurred costs or additional long-term benefits) resulting from day-ahead (DA) and intraday (ID) market coupling at regional or EU level.

(3) The document is organised as follows: the general approach is first described, and then the detailed calculation process for both potential and realised gains is presented. Afterwards, the necessary caveats are described, and finally, the required data and the sources are listed.

2. General approach

(4) From an economic point of view, in an optimal electricity market, cross-zonal exchanges should only flow in the valuable direction[1]. This methodological paper first assesses how efficiently cross-zonal capacity is used, then estimates potential economic gains from coupling markets.

(5) Realised efficiencies in the use of cross-zonal capacities are computed by comparing oriented net transfer capacities (NTCs) and nominations in the economic direction. Without market coupling and when a price spread appears across a border, exchanges flowing opposite to the price spread are assumed to be inefficient[2]. With market coupling, exchanges are expected to always flow according to the economic direction[3].

(6) Potential welfare gains resulting from market coupling are estimated for each non-coupled border by combining (when there is a price spread) the unused available cross-zonal capacity in the economic direction with a realised or estimated price spread.

3. Calculation process

(7) First, in day-ahead markets[4], efficiency in the use of cross-zonal capacity can be computed based on cross-zonal capacity use for a given set of borders as

$$\frac{\sum_{hours}\sum_{borders\ where\ spread(h)>threshold} Nominations_{economic\ direction}(h)}{\sum_{hours}\sum_{borders\ where\ spread(h)>threshold} NTC_{economic\ direction}\ (h)}$$

[1] It should usually flow from cheaper areas to more expensive areas (excluding so-called non-intuitive flows coming from market coupling). Such a direction is also called the economic direction.

[2] Partial use of the valuable cross-zonal capacity is also assumed to be inefficient in this case

[3] i.e. the direction along which welfare increases (which will usually be from lower to higher prices). When a border is coupled for a given time frame, 100% efficiency is assumed

[4] The day-ahead market is expected to correct any inefficient allocation of cross-border capacity in the previous (long-term) timeframes when day-ahead prices are not yet known; as a result, aggregate cross-border capacities (NTCs) and nominations (from day-ahead and previous timeframes) are used.

using oriented nominations[5] and NTCs on each border. The economic direction is defined form low to high prices. For coupled borders, the numerator and denominator[6] are expected to be the same, as all the NTC values are translated in nominations in the economic direction.

(8) The simplified potential welfare gain from applying DA market coupling assumes ‘all else being equal’ had the capacity been fully used in the economic direction[7]. The gain for a given border is then computed by combining the historical price spread with the remaining cross-zonal capacity available in the economic direction as

$$\sum_{hours\ where\ spread(h)>price_{\ threshold}} (NTC_{economic\ dicrection}(h) \quad - Nominations_{economic\ direction}(h)) * Spread_{price}(h)$$

(9) In order to refine the simplified estimate described above, a refined DA welfare gain assumes that the price spread linearly decreases with additional cross-zonal exchanges, leading to the following formula[8]

$$\begin{cases} S_B \cdot (E_H - E_B) - \frac{1}{2}\lambda(E_H - E_B)^2 & if\ S_B - \lambda\,(E_H - E_B) > 0 \\ \frac{1}{2}\frac{{S_B}^2}{\lambda} & if\ S_B - \lambda\,(E_H - E_B) \leq 0 \end{cases}$$

With

S_B	$Spread_{price}(h)$
E_H	$NTC_{economic\ direction}(h)$
E_B	$Nominations_{economic\ direction}(h)$
$\lambda = 1.5\frac{€}{MWh}/GW = 0.0015\frac{€}{MWh}/MW$	Linear change in price spread with additional cross-zonal exchange

(10) Second, in intraday markets[9], the level of liquidity is often limited, and may not be sufficient to use the full available capacity in the economic direction. Hence, in order to measure the efficient use of cross-zonal capacity, a slightly different approach is proposed: efficiency is defined as the percentage of hours where the intraday capacity is ‘sufficiently’ used in the economic direction (based on threshold values). Then, the share of hours with intraday spread efficiently used is expressed as

$$\frac{nb\ hours\ where\ spread(h)>price_{\ threshold}\ and\ ID_{liquidity}(h)>liquidity_{threshold}\ and\ IDATC(h)>capa_{\ threshold}\ and\ IDnomin_{econ\ direction}(h)>exch_{\ threshold}}{nb\ hours\ where\ spread\ (h)>price_{\ threshold}\ and\ ID_{liquidity}(h)>liquidity_{threshold}\ and\ IDATC(h)>capa_{\ threshold}}$$

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[5] Nominations opposite to the economic direction will be counted as negative

[6] In this case, the nomination is always assumed to be fully efficient.

[7] It means market players’ behaviours would have remained the same. It also assumes that marginal orders on both sides of the border have infinite volumes.

[8] See Annex for details

[9] In order to limit the scope for double counting potential welfare gains, for the ID timeframe only the available transmission capacity (ATC) in the ID timeframe and the nominations in the ID timeframe are considered in the formula. By contrast, in the DA timeframe, capacities (NTC) and nominations include both the long-term and the day-ahead nominations.

(11) The thresholds included in the formula above are as follows:

- A 'price spread' threshold (set to 1 euro/MWh for the purpose of the MMR) describes whether cross-zonal trade is valuable for a given border and hour. For borders applying a loss factor (e.g. between the Netherlands and Norway), this threshold is raised to 2euros/MWh.
- One 'sufficient market liquidity'[10] threshold (set to 50MWh in the MMR[11]) describes whether liquidity is sufficient on both sides to allow for cross-zonal trade
- One 'remaining available capacity' threshold (100MW in the MMR) describes whether capacity is available
- One 'active exchange' threshold describes whether this capacity is used in the economic direction (50 MW in the 2016 MMR)

(12) For potential intraday markets gains on non-coupled borders, the aforementioned (DA) indicator may lead to unrealistic results, because the remaining ATC would often be much larger than the market liquidity[12]. In this case, the potential gain would be assessed only for hours with "remaining available capacity" deemed "not active": the potential exchange would be capped to the minimum of the ID liquidity and the threshold for the border to be considered "active", leading to the following potential gain

$$exchange_{potential}(h) = \min(ATC_{economic\ direction}(h), ID_{volume}(h), exchange\ threshold_{for\ exch\ to\ be\ active})$$

$$\sum_{hours\ where\ spread(h)>threshold\ and\ "remaining\ capacity"\ "not\ active"} (exchange_{potential}(h) - Nominations_{economic\ direction}(h)) * Spread_{price}(h)$$

(13) Finally, in order to estimate the realised gains of market coupling (isolated from other effects) one would need to compare market welfare immediately before and after its introduction. On most coupled borders, no information is available on the incremental welfare derived from market coupling. However, it is possible to estimate the gains realised on such borders by assuming that such gains were equivalent to the potential gains on non-coupled borders in proportion to commercial cross-zonal capacity (i.e. yearly average NTCs) [13].

4. Caveats

(14) When applying the methodologies described above, the following caveats and considerations apply:

[10] Based on traded volume

[11] See. MMR2016 – figure 22 p. 49

[12] Liquidity in many ID markets is currently on the order of 50MW, and is often much smaller than ATCs. For example, (for ID markets with still relatively large liquidity), in 2016 the average ID offered capacity from FR to DE (when the ID capacity had an economic value in this direction) was 3604 MW. However, the average ID liquidity in France during those hours was 473 MW. Therefore, assuming full use of cross-border capacity would not be realistic.

[13] In line with https://ec.europa.eu/energy/sites/ener/files/documents/20130902_energy_integration_benefits.pdf (p. 72)

- The methodology is only applicable to assessing efficiency on non-coupled borders where ATC-based capacity calculation applies. Where flow-based market coupling applies, it may be assumed that all the capacity is used efficiently[14].

- Interconnector losses are ignored, whereas, for some borders, they are included in the market-coupling algorithm. As a result, some potential exchanges based on a small price spread would not be efficient[15].

- A price spread threshold has to be defined to select "borders with a price spread" for a given hour.

- For the intraday computation, the overall result may be sensitive to the 'sufficient market liquidity', 'remaining available capacity' and 'active exchanges' thresholds values.

- In continuous intraday trading, there is no unique intraday price, so a decision on the 'adequate' intraday price reference needs to be taken. In the context of this analysis, the most representative prices are assumed to be provided by the closest-to-real-time trades, since they are considered to better reveal the value of cross-zonal capacity at the time when final cross-zonal nominations are determined. In the case of several auction rounds, the closest-to-real-time trades can be valued at the price of the last auction for every delivery hour. In the case of continuous trading, the weighted average intraday prices during the last trading hour can be taken, or alternatively, the weighted average across the whole trading period, considering that in continuous markets, volumes tend to concentrate in the closest-to-real-time hours[16].

- Potential DA/ID/Balancing[17] welfare gains from additional exchanges may not be fully cumulative, because they would probably compete for the same remaining cross-zonal capacity.

5. Data

Table 1: Data required and sources used for the welfare analysis on the benefits from day-ahead and intraday market coupling

Description	**Unit**	**Time granularity**	**Geographic granularity**	**Source**
DA prices	euro/MWh	Market time unit	Bidding zone	ENTSO-E transparency platform (TP)
DA NTC values	MW	Market time unit	Bidding zone border	ENTSO-E TP, Nordpool
ID prices	euro/MWh	Market time unit	Bidding zone	Nominated Electricity Market Operators (NEMOs)

[14] Because the flow-based methodology jointly solves exchanges for all borders, it is highly unlikely that market coupling would not be applied for discrete flow-based markets.

[15] For example, for a border between bidding zones with prices of 100 and 100.5 euros/MWh, with a loss factor of 1%, the loss would amount to 1 euro/MWh, and would thus be larger than the price spread. However, borders with a loss factor usually tend to exhibit highly efficient use (e.g. FR – GB), so that low potential gains are usually computed for these borders.

[16] See MMR 2017, section 4.2.2

[17] See the methodological paper on 'Benefits from balancing markets integration', available at: https://www.acer.europa.eu/en/Electricity/Market%20monitoring/Documents/ACER%20Methodological%20paper%20-%20Benefits%20from%20balancing%20markets%20integration.pdf.

ID offered capacity	MW	Market time unit	Bidding zone border	ENTSO-E TP
Long-term + DA nominations	MW	Market time unit	Bidding zone border	Vulcanus (per scheduling area or country)
ID nominations	MW	Market time unit	Bidding zone border	Vulcanus (per scheduling area or country)
ID traded volumes	MW	Market time unit	Bidding zone	NEMOs

Annex – Refined welfare gains assuming linear price spread evolution with cross-zonal exchanges

(15) This annex describes a methodological improvement aimed at refining price spread estimates when computing potential benefits related to additional commercial cross-zonal exchanges.

(16) The MMR 2017 methodology assumed that (DA or ID) price spreads remain constant when additional cross-zonal exchanges occur. This assumption stems from the fact that the additional exchange is usually much smaller than the base case exchange.

(17) However, based on economic theory, price spreads should usually decrease[18] when additional exchanges take place (e.g. due to the fact that the cheap sources of energy have already been used for the base case exports).

(18) The following study aims at estimating more precisely the benefits, which stem from additional cross-zonal exchanges in DA. For ID, limited market data, as well as the fact that, in the current methodology, the additional exchange is capped by various parameters[19]; make this refinement irrelevant for now. First, the average decrease in price spreads with additional exchanges is estimated; it is then applied to refine the benefits calculation, assuming that price spreads decrease linearly with additional exchanges.

(19) Two main simulations were conducted with PCR for the year 2017[20]

- A historical simulation, relying on historical orders and cross-zonal capacities
- Another simulation, where cross-zonal capacities were scaled up to benchmark capacities (and all other parameters remained the same)

(20) It is assumed that going from historical to benchmark capacities is representative of typical cross-zonal capacity increases. These results will thus allow inferring how much price spreads decrease when increasing cross-zonal capacities.

(21) For a given border, only hours when neither the price spread nor the exchange changed direction are retained (as, for the methodology used for potential DA gains, it is assumed that additional cross-zonal exchanges do not lead to a change in the exchange direction).

(22) The average over all border and hours (excluding outliers[21]), leads to an average decrease of price spread of 1.5 euro/MWh per additional GW of exchange. This value is rather in line with another study conducted for the EC[22], which led to a value of 1 euro/MWh per additional GW (although the methodology was quite different).

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[18] In some rare circumstances (e.g. due to non-linear constraints or coupling with third countries), they may increase.

[19] See paragraph (12)

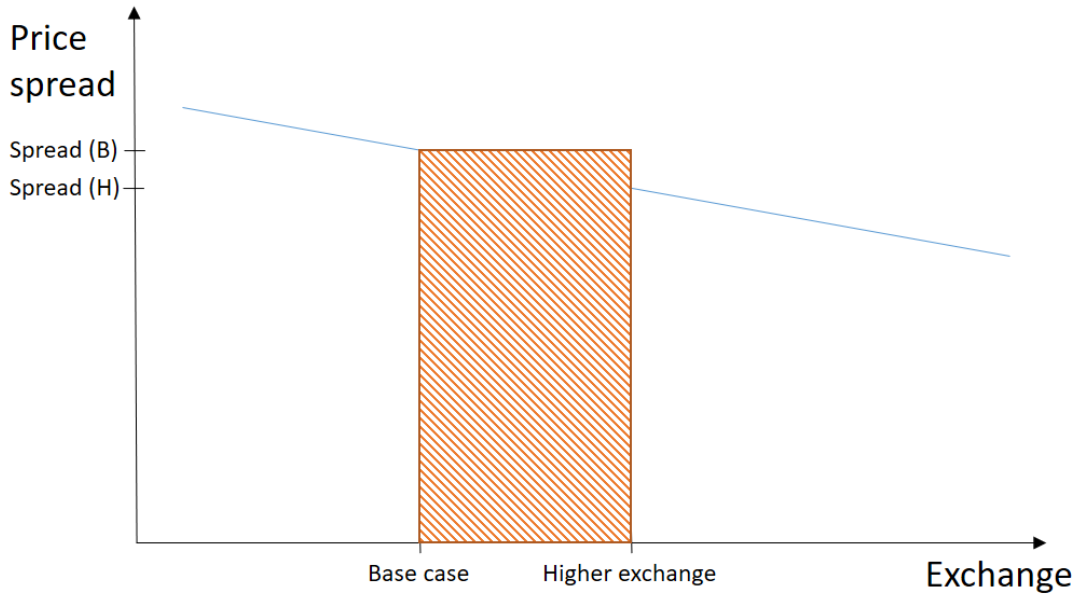
[20] For more information, see the methodological paper on 'Benefits from the application of the Agency's recommendation on capacity calculation' available at https://www.acer.europa.eu/en/Electricity/Market%20monitoring/Documents/ACER%20Methodological%20paper%20-%20Benefits%20from%20the%20application%20of%20the%20Agency%27s%20recommendation%20on%20capacity%20calculation.pdf.

[21] Defined as the top and bottom 5% of the statistical distribution

[22] See https://ec.europa.eu/energy/sites/ener/files/documents/20130902_energy_integration_benefits.pdf (section 8.5)

(23) Assuming that price spreads linearly decrease[23] with additional cross-zonal exchanges for a given border and hour, the simplified methodology computes the benefit from additional exchanges as the area of the orange rectangle below

Figure 1 – Current calculation of benefits of additional cross-zonal exchanges



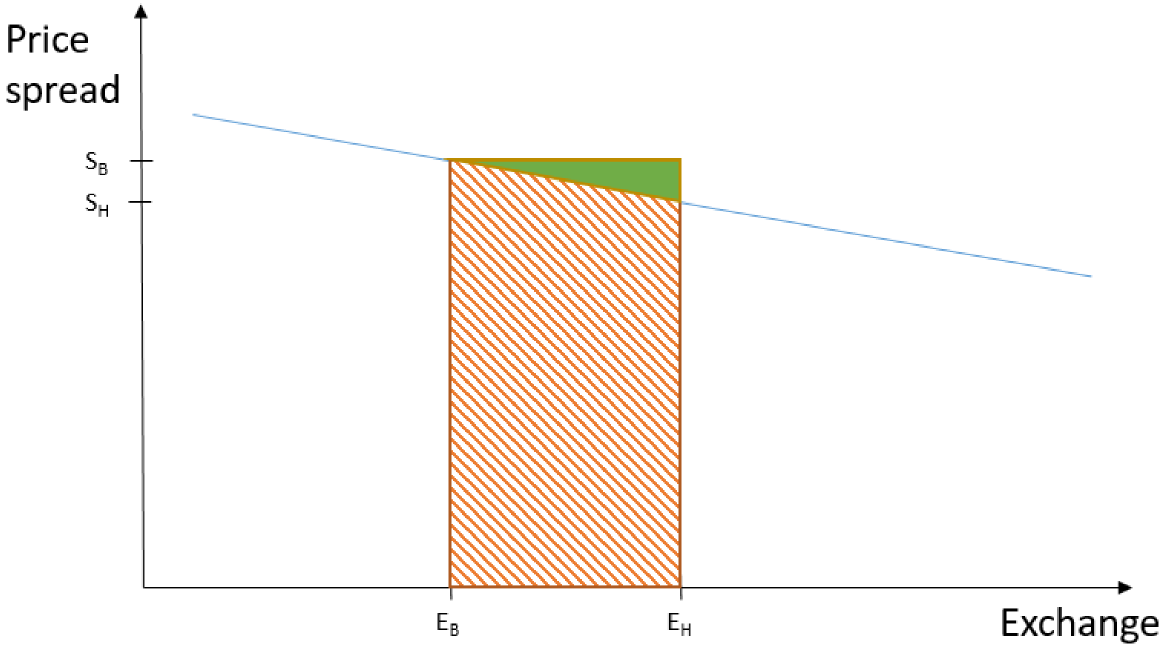
Note: The blue line depicts the linearized price spread decrease with cross-zonal exchange on a given bidding-zone border. The dashed rectangle describes the simplified potential benefit computed, which is an overestimate.

(24) This refined methodology allows inferring the overestimate, in two cases. Either the additional exchange still leads to an expected positive spread (case 1), or the additional exchange leads to an expected zero spread (case 2).

(25) In the first case, the overestimate is the area of the green triangle below

[23] See https://ec.europa.eu/energy/sites/ener/files/documents/20130902_energy_integration_benefits.pdf (section 8.6)

Figure 2 – Estimate of the overestimate of the current methodology



Note: the green triangle approximates the overestimate of the current methodology.

(26) The MMR 2017 methodology relied on the following benefit estimate

$$B^0 = price\ spread_{(basecase)} \cdot \left(exchange_{(high\ exchange)} - exchange_{(basecase)}\right) = S_B \cdot (E_H - E_B)$$

(27) As a result, for a given border and hour, the benefit overestimate would be

$$overestimate^1 = \frac{1}{2}(S_B - S_H)(E_H - E_B)$$

(28) As a result, the refined benefit is

$$B^1 = S_B \cdot (E_H - E_B) - \frac{1}{2}(S_B - S_H)(E_H - E_B)$$

(29) Assuming λ is the linear decrease in price spread with additional exchanges, the refined benefit becomes

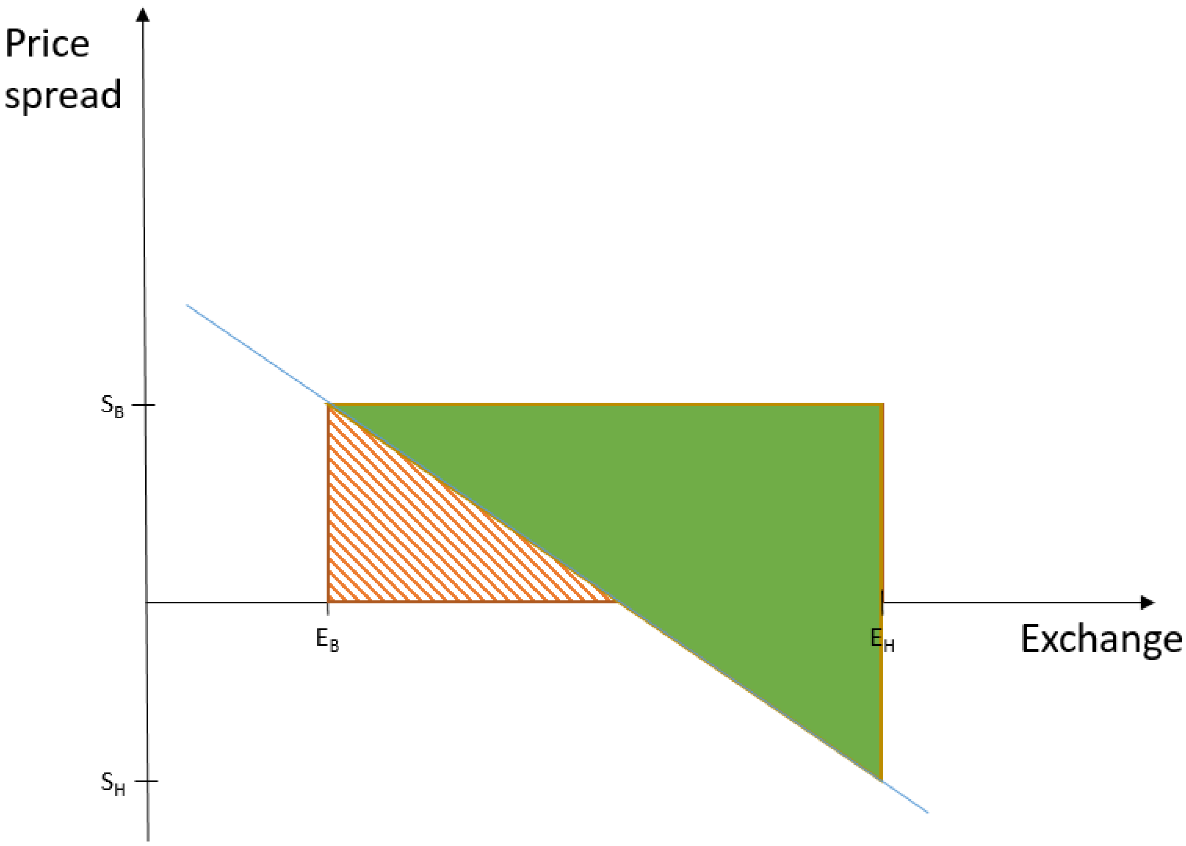
$$B^1 = S_B \cdot (E_H - E_B) - \frac{1}{2}\lambda(E_H - E_B)^2$$

With

$$\lambda = 1.5\frac{€}{MWh}/GW = 0.0015\frac{€}{MWh}/MW$$

(30) When the price spread is low in the base case, the linear approximation of the change in price spread with additional exchange may lead to assume negative price spreads, i.e. a loss of welfare with additional exchanges or a reversal of the exchanges direction (as shown in the figure below). As a result, the benefit estimate coming from the first case may become negative (and unrealistic).

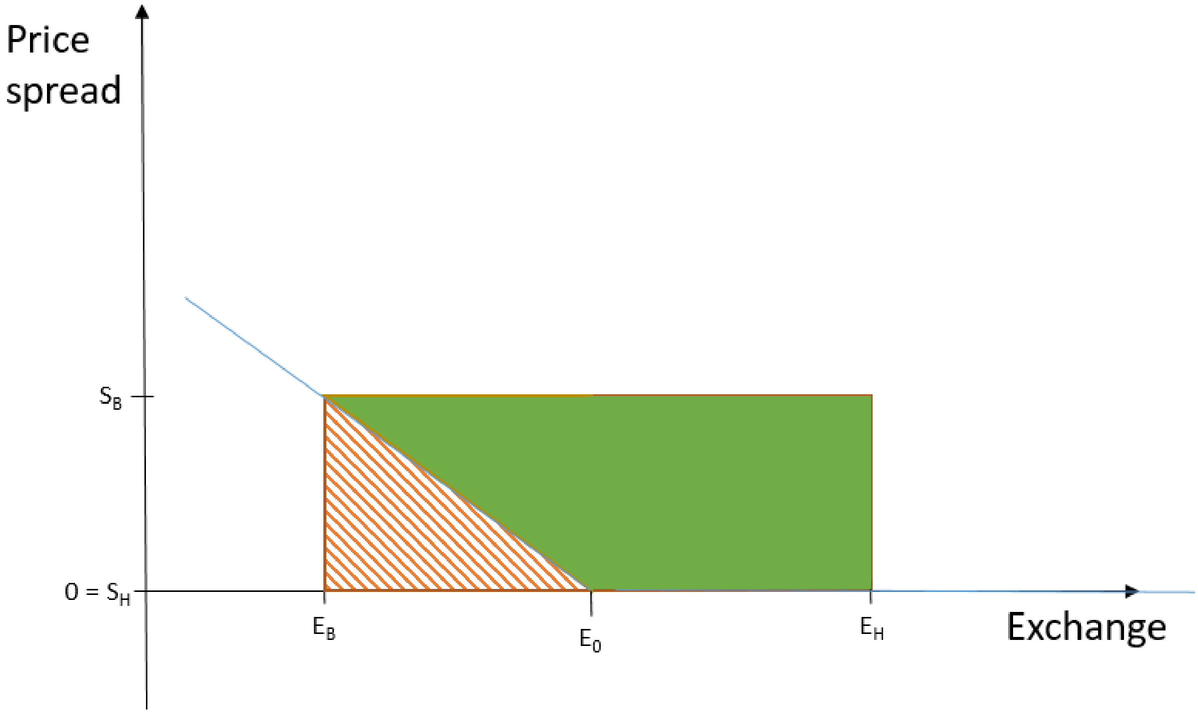
Figure 3 – Issue with linear price spread estimate when the initial price spread is low



Note: the green area depicts the overestimate computed in case 1 when the initial price spread is low. The overestimate is too high, as the price spread should not decrease any further once convergence has been reached.

(31) In order to correct this drawback, when the linear spread forecast leads to a negative price spread for E_B, the second case assumes that the price spread remains zero once full convergence has been reached, leading to the overestimate depicted by the green shape in the figure below

Figure 4 – Computing the welfare estimate when the initial price spread is small



(32) In this case, the overestimate would be the following, with E_0 the smallest exchange with full price convergence

$$overestimate^2 = \frac{1}{2} S_B(E_0 - E_B) + S_B(E_H - E_0)$$

(33) Assuming the same linear change of price spread with additional cross-zonal exchanges as before, full price convergence is achieved for the following exchange level

$$E_0 = E_B + \frac{S_B}{\lambda}$$

(34) As a result, the refined correction becomes

$$overestimate^2 = \frac{1}{2}\frac{{S_B}^2}{\lambda} + S_B\left(E_H - E_B - \frac{S_B}{\lambda}\right)$$

(35) The benefit is the area in orange, i.e.

$$B^2 = \frac{1}{2}\frac{{S_B}^2}{\lambda}$$

(36) Overall, when the high exchange level is below E_0, the equation in paragraph (29) should be used; otherwise the equation from paragraph (35) should be used. As a result, for a given border and hour, the refined benefit is

$$B_{\text{final}} = \begin{cases} S_B \cdot (E_H - E_B) - \frac{1}{2}\lambda(E_H - E_B)^2 & if\ S_B - \lambda\,(E_H - E_B) > 0 \\ \frac{1}{2}\frac{{S_B}^2}{\lambda} & if\ S_B - \lambda\,(E_H - E_B) \le 0 \end{cases}$$