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THE IMPACT OF IMPLICIT ELECTRICITY MARKET COUPLING ON THE SLOVENIAN-AUSTRIAN BORDER ON THE EFFICIENCY OF CROSS-BORDER TRANSMISSION CAPACITY ALLOCATION AND SOCIAL WELFARE IN SLOVENIA

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ABSTRACT: *On the Slovenian-Austrian border cross-zonal capacities (CZCs) are currently allocated at explicit auctions, although in the future to comply with the European Target Electricity Model one can expect implicit auctions within market coupling to be implemented. Via a simulation, this paper aims to study the impact of implicit electricity market coupling on the Slovenian-Austrian border on the efficiency of CZC allocation and social welfare in Slovenia. The simulation results show that the use of implicit auctions would increase the efficiency of CZC allocation, reduce the price of electricity and increase the volume of trading in the Slovenian electricity exchange market. Further, implicit market coupling on the Slovenian-Austrian border would increase social welfare in Slovenia.*

Keywords: *market coupling, implicit auctions, day-ahead electricity market, Slovenia*

JEL Classification: L94, L51, Q47

DOI: 10.15458/85451.47

1. INTRODUCTION

Electricity trading is conducted on the basis of long- and short-term contracts for the purchase or sale of electricity without constraints within an individual country in the EU. However, cross-zonal trading on energy borders among EU member states is limited by cross-zonal capacities (CZCs) (Meeus, Vandezande, Cole & Belmans, 2009). CZCs can be allocated by transmission network system operators (TSOs) by using various non-market- or market-based methods.³ As non-market methods are prohibited by legislation (Regulation (EC) 1228/2003), since 2006 CZCs have been allocated at explicit or implicit auctions on all energy borders within the EU (Zachmann, 2008).

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3 For a more detailed explanation of the market and non-market methods of allocating CZCs, see Kristiansen (2007a).

At explicit auctions, orders for the purchase of CZCs are submitted separately from orders for the purchase or sale of electricity. Each cross-border electricity trade consists of two transactions: the purchase of CZCs at an explicit auction and the purchase or sale of electricity in a bilateral or exchange market. When CZCs are being allocated at exchange markets at the same time as orders for the purchase and sale of electricity, this is referred to as an implicit auction (Kladnik, Artač, Štokelj & Gubina, 2010).

In July 2011, the Agency for the Cooperation of Energy Regulators (ACER) published the Framework Guidelines on Capacity Allocation and Congestion Management for Electricity in compliance with the requirements of Regulation (EC) 714/2009 and defined the method of implicit auctions within market coupling for the Target Electricity Model for short-term CZC allocation within the EU (ACER, 2011).⁴

The main measures used to evaluate whether CZC allocation is better by means of implicit auctions than through explicit auctions are the better price convergence and greater efficiency of CZC allocation (Jullien, Pignon, Robin & Staropoli, 2012).⁵

Greater efficiency in CZC allocation enables TSOs and market participants to have larger volumes of cross-border trade and quality price signals for the value of CZCs. Consequently, TSOs have a more accurate basis for decision-making with regard to investments in the transmission network and for market participants with regard to the cross-zonal purchase or sale of electricity. An improvement in CZC allocation efficiency is therefore also reflected in greater social welfare (Kristiansen, 2007a).

The unified and competitive "Northern Market" is regarded as the first example of price market coupling in Europe. The Northern Market developed gradually. In 1991, the Norwegian National Exchange Market was established, which by 2000 was liaising with the neighbouring four countries and had grown into a regional market. Sweden joined in 1996, Finland in 1998, part of western Denmark in 1999, and eastern Denmark in 2000 (NordPool, 2004).

Northern Market integration was followed by the trilateral price market coupling (TLC) of the Belgian, French and Dutch markets in 2006. The German and French markets were price coupled in 2007. In 2009 and 2010, the German market integrated with the Danish and Swedish markets through volume market coupling. In 2010, the TLC was merged with the price market coupling of the German and French markets in a unified price market coupling of the Central West Region (CWE). In the same year, the Polish and Swedish markets were price coupled as well. The Slovenian market joined the market coupling implementation processes in January 2011 when the Slovenian and Italian markets were price coupled. In the same year, the Norwegian and Dutch markets were also merged

4 Market coupling can take the form of either price or volume market coupling. With price market coupling, the trading platform algorithm is able to determine prices, quantities and flows for each of the coupled markets, whereas with volume market coupling only the net flows across the borders are calculated (Pellini, 2012).

5 For a more detailed description of the differences between explicit and implicit auctions, see Jullien et al. (2012) and Belpex (n.d.).

through volume market coupling (Farrington, 2011). The Czech and Slovak markets were price coupled on 31 August 2009 (SEPSAS, 2009). Since 1 April 2010, the Finnish and Estonian markets have been price coupled as well (Tere, 2010). Since 11 September 2012, the Hungarian market has been price coupled with the Slovak/Czech markets (CEPS, 2012).

The coupled markets or regions differ due to their use of various trading systems, market rules, and exchange markets closing times. For this reason, six power exchanges (APX, Belpex, EPEX, GME, NordPool and OMIE) joined forces in a project to integrate the regional markets to form a joint European market through which the mentioned differences are being dealt with (Farrington, 2011).

ELES, the Slovenian TSO, and BSP, the Slovenian electricity exchange, have been engaged in CZC allocation on the Slovenian-Italian border through implicit auctions since January 2011. On the Slovenian-Austrian border, CZCs are allocated by means of explicit auctions. Since this is not in compliance with the ACER target model, it is expected that in the future implicit auctions will be carried out on this border as well. Although on the Slovenian-Croatian border CZCs are allocated through explicit auctions, the CZC allocation will not be changing in the near future because there is no active power exchange in Croatia and so it is not possible to conduct implicit auctions. There are no interconnectors between Slovenia and Hungary and CZCs are thus not allocated on the border between these two countries.

The purpose of this paper is to study the impact of implementing implicit auctions on the Slovenian-Austrian border in the Slovenian electricity exchange market by means of a simulation. We investigate whether implementing implicit auctions on this border would be more effective than the existing explicit auctions in terms of CZC allocation. In addition, the impact of implicit auctions on the Slovenian-Austrian border on social welfare in Slovenia is analysed.

In the paper, we verify the hypotheses that, following the implementation of implicit auctions on the Slovenian-Austrian border the electricity price differences between the Slovenian and Austrian electricity exchange markets will decrease (*H1*), the average electricity price in the Slovenian electricity exchange market will decrease (*H2*), the efficiency of the available CZC utilisation will increase (*H3*), the trading volume in the Slovenian electricity exchange market will rise (*H4*) and that social welfare in Slovenia will increase (*H5*).

The paper is structured as follows. Section 2 provides a brief review of the literature on electricity market integration and on different capacity allocation mechanisms. In section 3, we present the theoretical background on how CZC allocation influences social welfare. In section 4, we describe the data and outline the simulation of implicit auctions on the Slovenian-Austrian border. In section 5, we analyse the results of the simulation. Finally, the findings and conclusions are summarised in section 6.

2. LITERATURE REVIEW

The economic literature on electricity market integration and capacity allocation mechanisms can be classified in three main categories. The first category consists of literature that analyses the impact of different market integration models on the degree of competition in electricity markets. The second category highlights the inefficiencies of the explicit auction mechanism for allocating CZC. The third category researches the impact of introducing implicit auctions on the efficiency of allocating CZC and on social welfare.

Borenstein, Bushnell and Stoft (2000) show that the introduction of a transmission capacity between two separated symmetric monopoly markets fosters competition and, moreover, that even a modest expansion of transmission capacity between markets that suffer from market power problems may have very high payoffs in terms of increased competition in electricity markets. Harvey and Hogan (2000) explore the comparative effects on competition of nodal pricing vs. zonal pricing and conclude that nodal pricing supports the market and expands the range of tools available to mitigate market power. Joskow and Tirole (2000) provide a study of the effects of market coupling/splitting bid-based pools with financial transmission contracts and bilateral contracting systems organised with tradable physical transmission contracts in constrained two-node and three-node networks. In their study, they argue that physical transmission contract rights may have worse welfare effects than financial transmission contracts rights because they can be withheld from the market, thereby reducing effective transmission capacity and introducing production inefficiency. Further, Neuhoff (2004) explores the comparative effects on competition of market coupling/splitting with financial transmission contracts vs. bilateral trading with physical transmission contracts and concludes that market coupling/splitting reduces the market power of generation companies compared to a market design relying on bilateral trading with physical transmission contracts. Gilbert, Neuhoff and Newbery (2004) extend previous studies by analysing a larger range of cases for different market designs and by studying welfare effects when transmission rights are obtained in an auction or inherited as legacy rights. Ehrenmann and Smeers (2005) and later on Ehrenmann and Neuhoff (2009) explore the comparative welfare effects of introducing two different capacity allocation design options (an integrated market design or a coordinated transmission auction) and demonstrate that an integrated market design performed better. In addition, Jullien et al. (2012) compare the two design options and come to the same conclusion that an integrated market design is more efficient than a coordinated transmission auction.

The second category of the literature provides an assessment of the inefficiencies of the explicit auction mechanism for allocating CZC. Analysing the results of auctions held for the Dutch-German interconnector and for the French-England interconnector, Newbery and McDaniel (2002) find that with explicit auctions CZCs are underused as a result of no flows netting. Moreover, imperfect arbitrage is present as the average price of daily capacity is lower than the monthly and annual prices. Similarly, while assessing the performance of the Kontek cable and of the interconnector between West Denmark and Germany Kristiansen (2007b) also finds evidence of imperfect arbitrage. Bunn and Zachmann

(2010) demonstrate that with an explicit auction, a generator which is both a dominant player in one market and a competitive player in another, has an incentive to acquire transmission rights to export against the price differential, thus resulting in inefficient use of cross-border interconnections. In addition, Bunn and Zachmann (2010) claim these inefficiencies occur because the energy and transmission markets are decoupled through the ex ante nature of the capacity auctions. Implicit auction approaches with nodal pricing would preclude these inefficiencies. Meeus (2011) computes a performance indicator for no-coupling, volume market coupling and price market coupling auction mechanisms on the Kontek Cable between Denmark and Germany and finds that price coupling is able to outperform both no-coupling and volume-market coupling.

The third category of the literature focuses on the impact of implicit auctions on the efficiency of allocating CZCs and on social welfare in the integrated markets. Hobbs, Rijkers and Boots (2005) analyse the potential impact of market coupling for the Belgian and the Dutch markets before the start of the Trilateral Coupling project among Belgium, France and the Netherlands. The authors estimate the project's welfare effect by simulating a Cournot Nash equilibrium model with five alternative market settings. The results show that, if the Belgian incumbent plays strategically, the change in the aggregate social surplus due to the market coupling is quite significant, but it occurs at the expense of Dutch consumers. On the other hand, when the Belgian incumbent acts as a price-taker, market coupling brings about a smaller increase in the aggregate social surplus, but it is more equally distributed among Belgian and Dutch consumers. Finon and Romano (2009) analyse the effect of market integration on electricity prices, showing that consumers living in countries with a high variable cost of capacity enjoy a price fall at the expense of consumers living in countries with a low cost capacity. Similarly, Pellini (2012) analyses the impact of market coupling in the Italian electricity market and confirms that, in the Italian case, market coupling maximises the use of the interconnection capacity with neighbouring countries, allows flows-netting, eliminates inefficient arbitrage that may occur with the explicit auction mechanism and increases the welfare gain of the coupled markets.

There are also some studies investigating the market coupling of the Slovenian and Italian electricity markets. The study of GME, Borzen and BSP (2008) identifies four efficiency gains from the adoption of implicit auctions on the Slovenian-Italian border. Namely, lower operational risks, lower trading risk/cost, higher liquidity of markets and more efficient use of the interconnection capacity. In addition, while analysing price convergence between the Slovenian and Italian electricity markets after the implementation of market coupling Parisio and Pelagatti (2014) find that the two markets are still far from being strongly integrated in terms of prices. Further, Cavaliero (2013) shows that the introduction of implicit auctions on the Slovenian-Italian border has influenced the efficiency of CZC allocation since in 2011 and 2012 the cross-border flows determined by market coupling resulted to be efficient in 100% of cases, compared with 98.2% guaranteed by the previous mechanism based on an explicit auction.

An empirical assessment of the effect of the market integration of the Slovenian and Austrian electricity markets from introducing implicit auctions on the Slovenian-

Austrian border is still to be carried out. Therefore, this paper aims to contribute to the empirical literature on market integration, presenting a comprehensive investigation on the efficiency of the CZC allocation and the welfare effect caused by the use of implicit auctions on the Slovenian-Austrian border.

3. CAPACITY ALLOCATION AND SOCIAL WELFARE

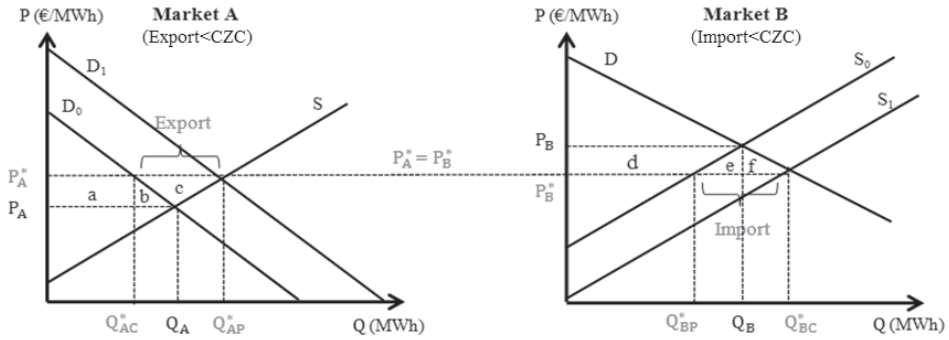
Connecting two isolated electricity exchange markets is possible if interconnectors or CZCs are available. In order to conduct cross-border electricity transactions, a market participant has to gain the right to use CZCs. The CZCs of an individual interconnector pose a quantity constraint on trading between the two markets (Neuhoff, 2004).

If the CZCs are not fully utilised and there is no transmission network congestion between the two markets, electricity prices in both markets are equalised (Figure 1). Let us assume that at the beginning the electricity price (P_A) in Market A is lower than the electricity price (P_B) in Market B and therefore Market A will export electricity to Market B. Exported electricity is bought in the export area of Market A (additional purchase of electricity in Market A shifting the position of demand D_0 to position D_1), and is sold in the import area of Market B (additional selling of electricity in Market B shifting the position of supply S_0 to position S_1). Consequently the electricity price in Market A will increase and decrease in Market B. If CZCs for the export of electricity from Market A to Market B are sufficient, the prices in both markets will equalise $P_A^* = P_B^*$ (Adamec, Indrakova, & Pavlatka, 2009).⁶

The producer surplus in Market A increases since the electricity produced in this market can be sold by the producers at a higher price than before the market coupling (area a+b+c). The consumer surplus in Market B increases as well because the electricity in this market can be purchased by consumers at a lower price than before the market coupling (area d+e+f) (Figure 1) (Jacottet, 2012). On the contrary, the consumer surplus in Market A decreases since consumers have to purchase electricity at a higher price than before the market coupling (area a+b). Further, the producer surplus in Market B is also decreased because the electricity produced in this market can be sold by the producers at a lower price than before the market coupling (area d) (Figure 1) (Jacottet, 2012).

⁶ For mathematical proof that market prices equalise if there are no CZC constraints between two or more markets, see Coenraad (2011).

Figure 1: Social welfare effects of market coupling with an uncongested interconnection



Sources: Adapted from Jacottet, 2012; Adamec et al., 2009.

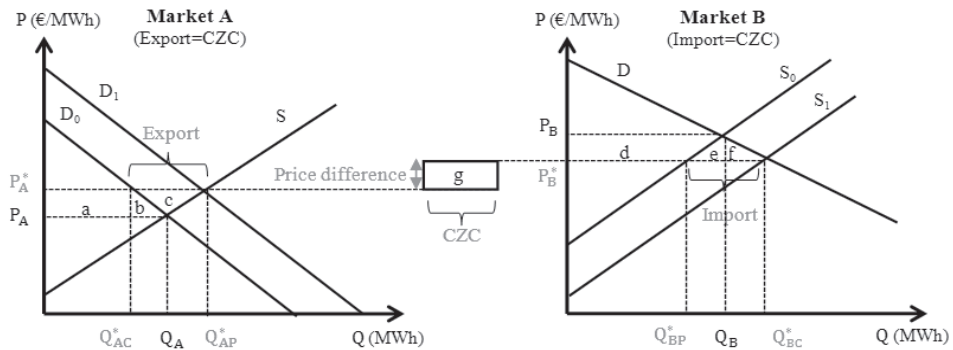
Notwithstanding the mentioned losses of individual participants in Markets A and B, the coupling of the two markets has net benefits for them both. Namely, the losses of an individual market participant are compensated for by the gains of other participants in this market. The social welfare of both coupled markets, between which CZCs are not fully utilised, is greater than the social welfare of the two isolated Markets A and B when calculating the net benefits due to the increased exports in Market A (area c) and the net benefits from increased imports in Market B (area e+f). The areas c, e and f represent the increase in social welfare due to the coupling of the two markets without CZC constraints between them (Figure 1) (Jacottet, 2012).

If the CZCs between the two markets are fully utilised, network congestion occurs and electricity prices in both markets are not equalised (Figure 2). With CZC allocation, electricity prices between the two markets are drawn nearer to the moment when the last CZC unit is allocated between the two markets. After CZC allocation, the price in an individual market is formed according to the remaining orders for the purchase or sale of electricity in that market (Coenraad, 2011). In this case, the quantity of electricity exchanged between Market A and Market B is equal to the complete CZCs available between the two markets. Exported electricity is purchased in Market A at price P^*_A and sold in Market B at price P^*_B . The difference between prices P^*_A and P^*_B , multiplied by the CZCs used, represents income of system operator from the network congestion (area g) (Figure 2) (Adamec et al., 2009).

In two coupled electricity markets between which CZCs are fully utilised, the price in both markets is not equalised, since Market B cannot import sufficient quantities of electricity from Market A as it would wish to based on the price difference. Nevertheless, because the electricity offer flows from the lower to the higher price range, the prices of the two markets are brought closer together, yet not to the extent as in price market coupling between two markets without CZC constraints between them (Coenraad, 2011).

The social welfare of two coupled markets between which CZCs are fully utilised is greater than the social welfare of two isolated Markets A and B when calculating the net benefits due to the increased exports in Market A (area c) and the net benefits from the increased imports in Market B (area e+f) and the congestion rent (area g) (Figure 2). Areas c, e, f and g represent the increase in social welfare due to the coupling of two markets with CZC constraints (E-Bridge, 2009). The increase in social welfare due to the coupling of two markets with CZC constraints is smaller than with the coupling of two markets where the CZCs are not constrained (Coenraad, 2011).

Figure 2: Social welfare effects of market coupling with a congested interconnection



Sources: Adapted from E-bridge, 2009; Adamec et al., 2009.

Explicit and implicit auctions (considering the assumptions that CZCs are allocated in completely competitive markets where market participants have all information available, there are no uncertainties, and where the results of trading are completely predictable) lead to the same result when calculating the social welfare (Ehrenmann & Neuhoff, 2009).

In practice, the mentioned assumptions are not completely realised, leading to inefficiencies that reduce the social welfare (Creti, Fumagalli & Fumagalli, 2010). Due to market power abuse by market participants and unreliable information resulting from the two-stage process of cross-border transactions (first, a market participant acquires the right to use CZCs at explicit auctions, and then it conducts a transaction for the purchase or sale of electricity), explicit auctions are less efficient than implicit ones because cross-border transactions for the purchase or sale of electricity are conducted concurrently with CZC allocations between the two markets (Consentec & Frontier Economics, 2004).

4. MARKET COUPLING SIMULATION ON THE SLOVENIAN-AUSTRIAN BORDER

4.1. Data sources

Data were acquired from various sources. Data on CZCs on the Slovenian-Austrian border were acquired from the Central Allocation Office website (CAO, n.d.). Data on CZCs on the Slovenian-Italian border and data on offers for purchases or sales in the Slovenian day-ahead market were acquired from the internal materials of the Slovenian electricity exchange – BSP (BSP, 2012). Data regarding the price on the day-ahead market on the Italian electricity market were acquired from the Italian electricity exchange website – GME (GME, n.d.). Data regarding the price on the day-ahead market on the Austrian electricity market were acquired from the Austrian electricity exchange website – EXAA (EXAA, n.d.).

Data were based on an hourly level for all 365 days or 8,784 hours in 2012 during which electricity was traded. The data consist of 351,196 offers for the sale of electricity on the Slovenian day-ahead market and 241,784 offers for the purchase of electricity on the Slovenian day-ahead market. In addition, 17,566 CZCs on the Slovenian-Italian border, 17,566 CZCs on the Slovenian-Austrian border, 8,784 prices of electricity in the Italian day-ahead market and 8,784 prices of electricity in the Austrian day-ahead market were used.

4.2. Reference scenario

Prior to assuming the implementation of implicit auctions on the Slovenian-Austrian border, short-term CZCs are being allocated at explicit auctions. Consequently, according to the gained rights to use CZCs at explicit auctions and their business strategy, Slovenian market participants can enter their offers for the purchase and sale of electricity in the order book of the Slovenian electricity exchange market and Austrian market participants in the order book of the Austrian electricity exchange market. Since the Slovenian electricity exchange market is connected to the Italian electricity exchange market via implicit auctions within the market coupling, the order book of the Slovenian market is combined with the order book of the Italian electricity exchange market.

The calculations of actual/reference trading results were made with the EuroMarket trading system that is used by the Italian and Slovenian electricity exchanges (Mercatoelettrico, n.d.). The trading results in the Slovenian electricity exchange market were calculated on an hourly basis for all hours of the leap year 2012 based on data from the common order book of the Slovenian and Italian electricity exchange markets, taking into account that the rights to use CZCs on the Slovenian-Italian border were allocated at implicit auctions.⁷

⁷ As the Slovenian and Italian electricity exchange markets were coupled in 2011, the calculation of both the reference and the simulation scenario also needs to consider the Italian electricity exchange market (the northern zone).

In addition, the short-term CZCs on the Slovenian-Austrian border allocated at explicit auctions were also used in the reference scenario. Results calculated on such bases are treated as the reference scenario.

4.3. Simulation scenario

For the purposes of analysing the impact of using implicit auctions on the Slovenian-Austrian border in the Slovenian electricity exchange market, the explicit auctions for allocating CZCs on the Slovenian-Austrian border are replaced by a simulation of the use of implicit auctions for allocating CZCs on that border.

In the simulations for the Slovenian-Austrian border and the Slovenian-Italian border, the rights to use CZCs are granted at the same time as offers for the purchase or sale of electricity. The calculations of the trading results of the simulation scenario were conducted by a programmed calculation in Excel that simulates the operation of the EuroMarket trading system algorithm. The programmed calculation was based on the assumptions explained in section 4.3.1. The trading results in the Slovenian electricity exchange market were calculated on an hourly basis for all hours of the leap year 2012 based on data from the common order book of the Slovenian, Italian and Austrian electricity exchange markets, taking into account that the rights to use CZCs on the Slovenian-Italian border and on the Slovenian-Austrian border are allocated at implicit auctions. Results calculated on such bases and with such a simulation are treated as the simulation scenario.

4.3.1. Assumptions

In 2012, the Italian market price for the northern zone ($P_{\text{GME_Nord}}$) was higher than the Slovenian market price (P_{BSP}) for 6,962 hours, which means that Slovenia exported electricity with the utilisation of complete CZCs in the direction Slovenia-Italy. For 1,800 hours, the Italian market price for the northern zone ($P_{\text{GME_Nord}}$) was the same as the Slovenian market price (P_{BSP}), where electricity was imported into Slovenia for 14 hours with the utilisation of part of the CZCs in the direction Italy-Slovenia, and for 1,786 hours electricity was exported from Slovenia with the utilisation of part of the CZCs in the direction Slovenia-Italy. For 22 hours, the Italian market price for the northern zone ($P_{\text{GME_Nord}}$) was lower than the Slovenian market price (P_{BSP}), which means that electricity was imported into Slovenia with the utilisation of complete CZCs in the direction Italy-Slovenia (Table 1).

Table 1: *Imports and exports of electricity from/to the Italian exchange market in 2012*

	Total hours	Number of hours with IM and EX from/to IT	Number of hours with one-way IM from IT	Number of hours with one-way EX to IT	Number of hours with full CZC utilisation from IT	Number of hours with full CZC utilisation to IT
$P_{BSP} > P_{GME_Nord}$	22	0	22	0	22	0
$P_{BSP} < P_{GME_Nord}$	6,962	0	0	6,962	0	6,962
$P_{BSP} = P_{GME_Nord}$	1,800	0	14	1,786	0	0
Total	8,784	0	36	8,748	22	6,962

Sources: GME, *n.d.*; BSP, *n.d.*; CAO, *n.d.*

To sum up, in 2012 Slovenia exported electricity to Italy for 8,748 hours, or 99.5% of the time. Consequently, CZCs for the direction Slovenia-Italy represented additional demand in the Slovenian electricity exchange market. For 36 hours, or 0.4% of the time, Slovenia imported electricity from Italy, which means that CZCs for the direction Italy-Slovenia represented additional supply in the Slovenian electricity exchange market (Table 1).

Due to the small quantities of CZCs between the countries, the cross-zonal demand or offer of the Slovenian electricity exchange market cannot influence the aggregate demand or aggregate supply in the Italian electricity exchange market to such an extent that would cause the price in the Italian electricity exchange market to change. For this reason, we assume that in the Italian electricity exchange market the Slovenian electricity exchange market appears as an additional buyer (buying electricity up to the extent of the maximum CZCs for the direction Italy-Slovenia) when the Italian electricity exchange price is lower than the Slovenian electricity exchange price. In addition, we also assume that in the Italian electricity exchange market the Slovenian electricity exchange market appears as an additional seller (selling electricity up to the extent of the maximum CZCs for the direction Slovenia-Italy) when the Italian electricity exchange price is higher than the Slovenian electricity exchange price.

Similarly as for the Italian electricity exchange market, we analyse the differences in electricity prices between the Slovenian and Austrian electricity exchange markets (Table 2). In 2012, the Austrian electricity exchange price (P_{EXAA}) was higher than Slovenian electricity exchange price (P_{BSP}) for 2,107 hours (within these hours electricity was exported from Slovenia with the utilisation of complete CZCs in the direction Slovenia-Austria in 38 hours), for 127 hours Austrian electricity exchange price (P_{EXAA}) was the same as Slovenian electricity exchange price (P_{BSP}) and for 6,550 hours Austrian electricity exchange price (P_{EXAA}) was lower than the Slovenian electricity exchange price (P_{BSP}) (within these hours electricity was imported from Austria with the utilisation of complete CZCs in the direction Austria-Slovenia in 2,180 hours).

Table 2: Imports and exports of electricity from/to the Austrian exchange market in 2012

	Total hours	Number of hours with IM and EX from/to AT	Number of hours with one-way IM from AT	Number of hours with one-way EX to AT	Number of hours with full CZC utilisation from AT	Number of hours with full CZC utilisation to AT
$P_{BSP} > P_{EXAA}$	6,550	3,356	3,140	54	2,180	0
$P_{BSP} < P_{EXAA}$	2,107	1,930	103	74	38	0
$P_{BSP} = P_{EXAA}$	127	110	17	0	0	0
Total	8,784	5,396	3,260	128	2,218	0

Sources: EXAA, n.d.; BSP, n.d.; CAO, n.d.

On the basis of the data shown in Table 2, we can determine the following: in 2012, for 3,214 hours (3,140 hours + 74 hours), or 36.6% of the time, electricity was exchanged in the direction from the lower towards the higher price range; for 157 hours (103 hours + 54 hours), or 1.8% of the time, from the higher towards the lower price range; for 17 hours, or 0.2% of the time, it was exchanged at equal prices between the two price ranges; and for 5,396 hours (3,356 hours + 1,930 hours + 110 hours), or 61.4% of the time, it was exported from the lower to the higher price range, and at the same time imported from the higher to the lower price range.

For the market participants which imported electricity from the higher to the lower price range in the above examples, we can assume that they had wrong expectations regarding in which of the neighbouring electricity markets a higher price would be formed and in which a lower one. This clearly shows the inefficiency of the explicit two-step CZCs allocation method in which market participants first have to participate in explicit auctions for allocating CZCs and then trade in electricity in two neighbouring markets on the basis of predictions made about the price differences between these two markets.

The Austrian electricity exchange market has great depth since this market is indefinitely connected to the German electricity exchange market (the CZCs between the two markets are in excess). Consequently, CZCs on the Slovenian-Austrian border and the cross-zonal demand or offer of the Slovenian electricity exchange market cannot influence the aggregate demand or aggregate supply in the Austrian electricity exchange market to such an extent that would cause the price in the Austrian electricity exchange market to change.

When simulating the market coupling on the Slovenian-Austrian border, we assume that electricity would be exported from Slovenia to Austria (to the extent of the maximum CZCs for the direction Slovenia-Austria) when the Austrian electricity exchange price is higher than the Slovenian electricity exchange price, and that electricity would be imported from Austria to Slovenia (to the extent of the maximum CZCs for the direction Austria-Slovenia) when the Austrian electricity exchange price is lower than the Slovenian electricity exchange price. The CZCs that are assumed to be available for implicit allocation

via the electricity exchange market are calculated as the difference between the net transfer capacity (NTC)⁸ and already allocated transfer capacity (AAC).⁹

4.4. Social welfare calculation¹⁰

4.4.1. The Slovenian electricity exchange market before the use of implicit auctions on the Slovenian-Austrian border

Before using implicit auctions on the Slovenian-Austrian border, the order books of the Slovenian and Austrian electricity exchange markets were not directly linked. On the Slovenian-Austrian border, CZCs are allocated through explicit auctions. The aggregate demand curve ($P_d = f_d(Q_i)$) and aggregate supply curve ($P_s = f_s(Q_i)$) in the Slovenian electricity exchange market are step functions. The two step functions are constructed from the historical buy and sell bids (which are ranked separately for the buy and sell curve accordingly to their type, taking into account their price level and time stamp) entered into the Slovenian electricity exchange market order book in 2012. Based on these data (bids), we calculate the consumer surplus (CS) and producer surplus (PS) for an individual hour in 2012 as follows:

$$CS = \sum_{i=0}^{j=Q_{BSP}} (f_d(Q_i) - P_{BSP}) \quad (1)$$

$$PS = \sum_{i=0}^{j=Q_{BSP}} (P_{BSP} - f_s(Q_i)) \quad (2)$$

where:

P_{BSP} is the price of electricity in the Slovenian electricity exchange market before implementing implicit auctions;

Q_{BSP} is the quantity in the Slovenian electricity exchange market before implementing implicit auctions.

The congestion rent of the Slovenian TSO¹¹ on the Slovenian-Austrian border (CR_{SI-AT}) for an individual hour in 2012 before implementing implicit auctions on that border from the direction Slovenia-Austria is calculated as follows:

$$CR_{SI-AT} = (P_{CZC,SI-AT} * Q_{CZC,SI-AT})/2 \quad (3)$$

⁸ Net transfer capacity is defined as the maximum total exchange program (MW) between two interconnected power systems available for commercial purposes for a certain period and direction of active power flow (ETSO, 2001).

⁹ Already allocated capacity is the total amount of already allocated transmission rights, i.e. transmission capacity reserved by long-term contracts and the previously held transmission capacity reservation auctions (ETSO, 2001).

¹⁰ Social welfare is calculated on the theoretical basis described in section 3.

¹¹ Congestion rent of the Slovenian TSO accounts for half of the congestion rent acquired on the SI-AT and SI-IT border as regulated in agreement between the pertinent TSOs.

where:

$P_{CZC, SI-AT}$ is the price of the CZCs allocated at an explicit auction in the direction Slovenia-Austria;

$Q_{CZC, SI-AT}$ is the amount of the CZCs allocated at an explicit auction in the direction Slovenia-Austria.

The congestion rent of the Slovenian TSO on the Slovenian-Austrian border (CR_{AT-SI}) for an individual hour in 2012 before the implementing of implicit auctions on that border in the direction Austria-Slovenia is calculated as follows:

$$CR_{AT-SI} = (P_{CZC, AT-SI} * Q_{CZC, AT-SI})/2 \quad (4)$$

where:

$P_{CZC, AT-SI}$ is the price of the CZCs allocated at an explicit auction in the direction Austria-Slovenia;

$Q_{CZC, AT-SI}$ is the amount of the CZCs allocated at an explicit auction in the direction Austria-Slovenia.

The congestion rent of the Slovenian TSO on the Slovenian-Italian border ($CR_{SI,IT}$), where capacities are allocated at implicit auctions, for an individual hour in 2012 before implementing implicit auctions on the Slovenian-Austrian border, is calculated as follows:

$$CR_{SI,IT} = ((|P_{GME_Nord} - P_{BSP}|) * Q_{CZC, SI,IT})/2 \quad (5)$$

where:

P_{GME_Nord} is the price of electricity in the northern zone of the Italian electricity exchange market before implementing implicit auctions on the Slovenian-Austrian border;

P_{BSP} is the price of electricity in the Slovenian electricity exchange market before implementing implicit auctions on the Slovenian-Austrian border;

$Q_{CZC, SI,IT}$ is the amount of CZCs allocated at implicit auctions on the Slovenian-Italian border.

4.4.2. Coupled electricity exchange markets on the Slovenian-Austrian border

After simulating the use of implicit auctions on the Slovenian-Austrian border, the Slovenian electricity exchange market is, for those hours when the Slovenian electricity exchange price was lower than the Austrian electricity exchange price, the market that exports electricity to the Austrian electricity exchange market, and otherwise the market that exports electricity from the Austrian electricity exchange market. The latter was considered for the calculation of the consumer surplus (CS^*), producer surplus (PS^*), and the acquired congestion rent on the Slovenian-Italian border ($CR_{SI,IT}^*$) in the simulations scenario.

In addition, the calculation of the congestion rent on the Slovenian-Austrian border () for an individual hour in 2012 after market coupling on the Slovenian-Austrian border

slightly changes and is calculated as follows:

$$CR_{SI,AT}^* = ((|P_{EXAA}^* - P_{BSP}^*|) * Q_{CZC,SI,AT}^*)/2 \quad (6)$$

where:

P_{EXAA}^* is the price of electricity in the Austrian electricity exchange market after implementing implicit auctions on the Slovenian-Austrian border;

P_{BSP}^* is the price of electricity in the Slovenian electricity exchange market after implementing implicit auctions on the Slovenian-Austrian border;

$P_{CZC,SI,AT}^*$ is the amount of CZCs allocated at implicit auctions on the Slovenian-Austrian border.

The change in Slovenian social welfare (ΔSW) after implementing implicit auctions on the Slovenian-Austrian border for an individual hour in 2012 is calculated as follows:

$$\Delta SW = \Delta CS + \Delta PS + \Delta CR \quad (7)$$

$$\Delta SW = (CS^* - CS) + (PS^* - PS) + ((CR_{SI,AT}^* + CR_{SI,IT}^*) - (CR_{AT-SI} + CR_{SI-AT} + CR_{SI,IT})) \quad (8)$$

5. ANALYSIS OF THE SIMULATION RESULTS FOR MARKET COUPLING ON THE SLOVENIAN-AUSTRIAN BORDER

5.1. Comparison of electricity prices between the Slovenian and Austrian electricity exchange markets before and after simulating implicit auctions on the Slovenian-Austrian border

The results of the price analysis show that the prices in the Slovenian and Austrian electricity exchange markets before implementing implicit auctions on the Slovenian-Austrian border were equal 127 times during 8,784 hours of the year, or 1.45% of the time, considering the results of the reference scenario. After implementing implicit auctions on that border, the prices in the Slovenian and Austrian electricity exchange markets would be equal 6,746 times during 8,784 hours of the year, or 76.81% of the time.

The price equalisation for a greater number of hours is not surprising since the price in the Slovenian electricity exchange market is historically dependant on the price in the Austrian/German electricity exchange market, regardless of which mechanism is applied for allocating CZCs on this border (Orešič, 2012).

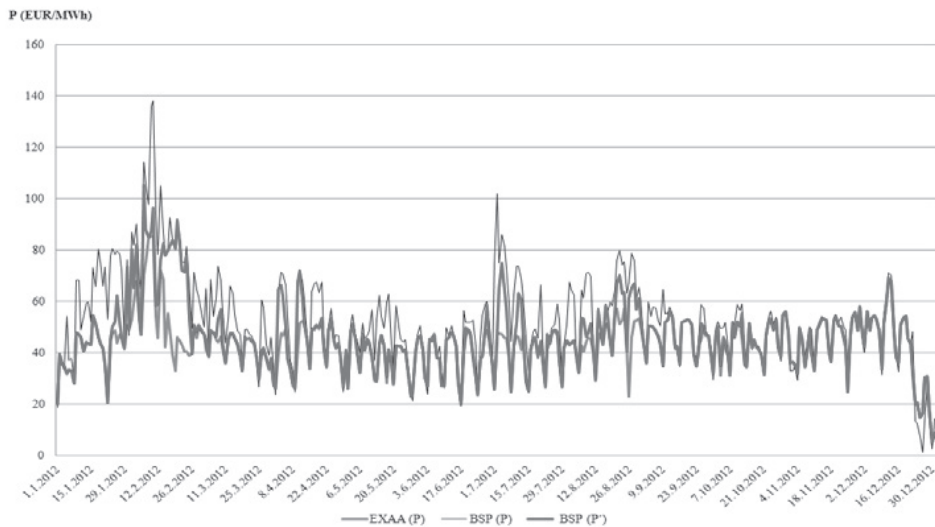
The use of implicit auctions on the Slovenian-Austrian border would reduce the price differences between the Slovenian electricity exchange market (BSP) and the Austrian electricity exchange market (EXAA). Figure 3 shows that before using implicit auctions the differences between the Slovenian electricity exchange price (P_{BSP}) and Austrian electricity exchange price (P_{EXAA}) are bigger in comparison to the difference in the Austrian

electricity exchange price (P_{EXAA}) and the Slovenian electricity exchange price (P_{BSP}^*) after implementing implicit auctions.

Based on the results of the analysis, we may conclude that after introducing implicit auctions on the Slovenian-Austrian border the Austrian and Slovenian electricity exchange prices would be brought closer together or even equalise, thereby confirming our first hypothesis ($H1$).

Further, we may also conclude that, after the implementation of implicit auctions on the Slovenian-Austrian border, the average electricity price in the Slovenian electricity exchange market would decrease by €6.84/MWh (13%) annually, thereby confirming our second hypothesis ($H2$).

Figure 3: Price comparison between Slovenian and Austrian electricity exchange markets before and after the simulation of implicit auctions on the SI-AT border



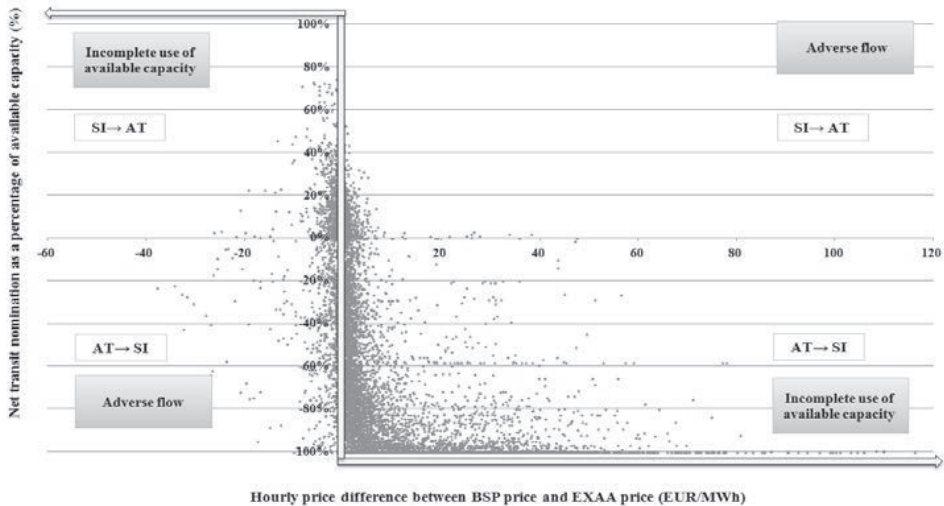
Sources: BSP, n.d.; EXAA, n.d.

5.2. Comparison of the utilisation of allocated day-ahead capacities before and after simulating implicit auctions on the Slovenian-Austrian border

According to the actual explicit auction results of the Central Allocation Office, Slovenia imported from Austria 2,108,228 MWh of 2,930,554 MWh of available CZCs and exported to Austria 684,649 MWh of 12,096,955 MWh of available CZCs in 2012 (CAO, n.d.). CZC utilisation in the direction Austria-Slovenia was 71.94%, and 5.66% in the Slovenia-Austria direction.

CZC utilisation in implicit auctions is one of the measures showing the greater efficiency of implicit auctions in comparison to explicit auctions (Jullien et al., 2012). Namely, from the efficiency viewpoint, it may be useful to utilise CZCs according to the demand that flows from the higher to the lower price market. Otherwise, part of the CZCs remains unutilised even though it would be wise to use it.

Figure 4: *Inefficiency of explicit auctions on the SI-AT border*

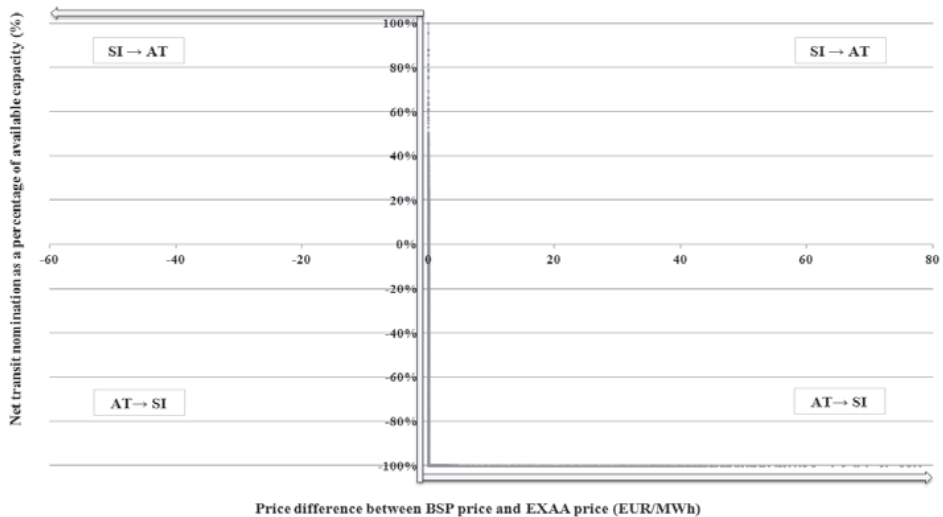


Note: Net transit nominations of CZCs on the Slovenian-Austrian border are calculated as the difference between the used quantities of exported CZCs and the used quantities of imported CZCs.

Figure 4 shows the CZC utilisation between two markets at an explicit auction. Efficiently utilised CZCs are represented by the points on the y-axis and in the marked area on the left and right sides of the y-axis. The area of less efficiently utilised CZCs is represented by the points in the upper-left and lower-right fields. The area of inefficiently utilised CZCs is represented by the points in the upper-right and lower-left fields.

When allocating CZCs at explicit auctions and subsequently trading on two unconnected electricity exchange markets, inefficiencies in CZC utilisation and even adverse flows appear. Adverse flows are a consequence of inaccurate predictions made by market participants as regards the price differences between the domestic and foreign markets. APX et al. (2008) note that, at implicit auctions where CZCs are allocated together with electricity, markets with a lower electricity price always export to markets with a higher electricity price. Consequently, adverse flows cannot emerge. Better CZC utilisation efficiency on the Slovenian-Austrian border after the implementing of implicit auctions is shown in Figure 5. All points representing efficiently used CZCs are on the y-axis and in the marked area on the left and right sides of the y-axis.

Figure 5: Efficiency of implicit auctions on the SI-AT border



Following the implementation of implicit auctions on the Slovenian-Austrian border, Slovenia would import from Austria 1,241,481 MWh of 2,930,554 MWh of available CZCs and export to Austria 349,180 MWh of 12,096,955 MWh of available CZCs.¹² CZC utilisation in the direction Austria-Slovenia would be 42.36%, and 2.89% in the direction Slovenia-Austria.

According to the explicit auction results, on the Austrian-Slovenian border CZCs would be allocated more efficiently at implicit auctions, confirming the third hypothesis (*H3*). Namely, the results show that this CZC allocation method relieves their non-optimised utilisation and eliminates adverse flows, which also corresponds to the findings of APX et al. (2008) with regard to the elimination of adverse flows by using implicit auctions.

5.3. Comparison of the trading volume in the Slovenian electricity exchange market before and after the simulation of implicit auctions on the Slovenian-Austrian border

Due to the lowest hydrology level in recent history, Slovenia imported a great amount of energy during the last quarter of 2011 and first quarter of 2012 (Orešič, 2012). In such circumstances, efficient CZC allocation, which in the case of implicit auctions is reflected in a larger amount of exchange market transactions, is of great importance (Jullien et al., 2012). The latter is also confirmed by the simulation scenario results for the first quarter

¹² The substantial difference in the quantity of available CZCs in the direction Austria-Slovenia compared to their quantity in the opposite direction is the result of the higher usage of the available quantity of long-term CZCs in the direction Austria-Slovenia than in the direction Slovenia-Austria. Hence there is a smaller leftover of available CZCs in the direction Austria-Slovenia compared to the direction Slovenia-Austria.

of 2012 which reveal that if, during that period, implicit auctions had been used on the Slovenian-Austrian border, a larger number of transactions would have been made in the Slovenian electricity exchange market (up to 30% more) than in the case of the reference scenario. After stabilisation, in all subsequent months a higher number of transactions would still have been made in the Slovenian electricity exchange market than in the reference scenario. However, the difference between both is no longer so noticeable. After implementing implicit auctions on the Slovenian-Austrian border, the volume of trading in the Slovenian electricity exchange market would rise by 715,633 MWh (16%) on the annual level, which confirms our fourth hypothesis (*H4*).

5.4. Comparison of social welfare in Slovenia before and after the simulation of implicit auctions on the Slovenian-Austrian border

The influence of implicit auctions on the Slovenian-Austrian border on social welfare in Slovenia is described in Table 3.

Table 3: *Change in social welfare after simulation of implicit auctions on the SI-AT border*

	Before implicit auctions (€)	After implicit auctions (€)
Producer surplus	146,318,029	119,998,678
Consumer surplus	855,105,950	890,547,561
Total producer and consumer surplus	1,001,423,979	1,010,546,239
Net benefits due to increased import from Austria	/	8,326,379
Net benefits due to increased export to Austria	/	795,881
Total net benefits due to exchange with Austria	/	9,122,260
Congestion rent on the SI-AT border	10,317,924	2,290,102
Congestion rent on the SI-IT border	34,886,765	50,163,851
Total congestion rent	45,204,689	52,453,953
Change in collected congestion rent	/	7,249,264
Change in social welfare in Slovenia	/	16,371,524

Note: Congestion rent accounts for half of the congestion rent acquired annually on the SI-AT and SI-IT border – the other half belongs to the Austrian or Italian TSO.

The results of the analysis show that due to the use of implicit auctions on the Slovenian-Austrian border and the increased imports of cheaper electricity from the Austrian electricity exchange market and the resulting drop in the price in the Slovenian electricity exchange market the net benefits for Slovenia amount to €8,326,379. Due to the use of implicit auctions on the Slovenian-Austrian border and the increased exports of electricity to the Austrian electricity exchange market and the consequential rise in the price in the Slovenian electricity exchange market, the net benefits for Slovenia amount to €795,881.

For Slovenia, the total net benefits from trading between the two markets amount to €9,122,260.

The Slovenian TSO income from the congestion rent after implementing implicit auctions decreased to €2,290,102. The smaller amount of congestion rent on that border is expected when considering all inefficiencies of the explicit CZC allocation due to which the amount of congestion rent from the explicit CZC allocation is too high and does not reflect the real economic value of CZCs.

On the other hand, the Slovenian TSO's income from the congestion rent on the Slovenian-Italian border increased to €50,163,851 after implementing implicit auctions on the Slovenian-Austrian border. The increased congestion rent is expected since the price in the Slovenian electricity exchange market decreased, which results in an increase in the price difference in the northern zone of the Italian electricity exchange market and the acquired congestion rent on that border.

Summarising the net benefits of the Slovenian electricity exchange market from the exports to the Austrian electricity exchange market (in hours, when the Slovenian electricity exchange price was lower than the Austrian electricity exchange price), the net benefits of the Slovenian electricity exchange market from the imports to the Austrian electricity exchange market (in hours, when the Slovenian electricity exchange price was higher than the Austrian electricity exchange price) and the additional congestion rent gained by the Slovenian TSO shows that social welfare increased by €16,371,524 in Slovenia. This also confirms our fifth hypothesis (*H5*), which states that the use of implicit auctions on the Slovenian-Austrian border would increase social welfare in Slovenia. The benefits of the implementation amount to €7.91 per capita. This is in line with a recently published study which estimated that the benefits of allocating CZC at implicit auctions within market couplings, once fully implemented across the EU, would be between €2.5 and €4 billion per year, or about €5 to €8 per capita per year (Booz & Company, Newbery, Strbac, Noël & LeighFisher, 2013).

6. CONCLUSION

Due to the benefits of implicit auctions and the positive influence of this CZC allocation method on social welfare, the European Commission has been trying to legally unify the existing CZC allocation practices throughout Europe. In the last few years we have witnessed considerable progress since implicit auctions within market couplings have already been established on numerous borders of energy systems within the EU. On the Slovenian-Austrian border, CZCs are currently allocated by means of explicit auctions. However, in compliance with the European Target Electricity Model we can expect the implementation of implicit auctions within market couplings in the future.

By simulating trading on the Slovenian electricity exchange market and the allocation of CZCs following the implementation of implicit auctions within market coupling on the

Slovenian-Austrian border for 2012, we demonstrated that in the Slovenian electricity exchange market the electricity price would be brought closer together or even equalise with Austrian electricity exchange market by an average decrease of €6.84/MWh, leading to a 16% increase in the volume of trading in the Slovenian electricity exchange market. The efficiency of CZC utilisation would increase as well. In addition, market coupling on the Slovenian-Austrian border would increase social welfare in Slovenia by €16,371,524.

By implementing implicit auctions within the market coupling on the Slovenian-Austrian border, Slovenia will fulfil its obligations imposed by the pan-European, day-ahead, market-forming process. The Slovenian electricity exchange market will be partly reformed and enable exchange market members to trade in a liquid exchange market that is connected to the Austrian-German and Italian electricity exchange markets.

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