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Assessing distorted trading incentives of balance responsible parties based on the example of the Swiss power system

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HIGHLIGHTS

- We investigate distorted incentives that stem from loopholes in the market design.
- Cross-border trading that undermines electricity balancing principles is evaluated.
- Little effort is necessary to make a good profit at the expense of system security.
- We examine historical data from the Swiss power system.
- We outline remedies to limit the possibilities of profiting from potential loopholes.

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ABSTRACT

Power systems require a continuous balance of supply and demand. In Europe, this task is shared between Balance Responsible Parties (BRPs) and Transmission System Operators (TSOs). For this purpose, the European electricity sector consists of several markets. Objective of this paper is to investigate distorted incentives that stem from loopholes in the market design which BRPs can use to undermine electricity balancing principles in favour of gaming opportunities between the domestic imbalance energy pricing and international wholesale markets. These incentives are evaluated using historical data from the Swiss power system which features a typical European imbalance pricing mechanism. The results imply that little effort would have been needed to make a good profit at the expense of system security. The major loophole arises from the interdependence between cross-border trading and national imbalance energy pricing. Bearing in mind the European Union's Third Energy Package, the importance of national balancing mechanisms will increase strongly. In this context, national remedies to cope with distorted incentives are outlined and the importance of harmonising balancing markets on an international level is elaborated.

1. Introduction

The successful operation of interconnected power systems requires balancing electricity generation and consumption. Power imbalances cause frequency deviations in the system that can lead to equipment damage, loss of infrastructure, and eventually blackouts. Hence, balancing power deviations is important and determines the level of security of electricity supply. It is related to all three economic, political and regulatory aspects.

1.1. Focus, objective, positioning, and structure of this paper

We target a contribution in the area of electricity balancing by generally examining distorted incentives of Balance Responsible Parties (BRPs). We evaluate these using the example of the Swiss power system. We consider as distorted incentives all BRP motives for intentionally breaking or exceeding their electricity balancing responsibility. The objective of our paper is to answer the following questions, which can be read as individual contributions:

1. What are possible distorted profit strategies for BRPs to exploit the imbalance energy pricing of a country?
2. What is the maximum impact expressed in money quantities of these distorted profit strategies of BRPs?

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3. What are the proper remedies for trading strategies that undermine balancing principles?

We focus on Continental Europe and Switzerland. We describe distorted incentives in a general manner, where our evaluations are based on historical data from the Swiss power system from 2011 and 2012. Our main intention is to show how straightforward it can be and what knowledge is needed to engage in gaming opportunities that undermine electricity balancing principles.

It depends on the respective market designs to what extent the qualitative findings can be transferred to other countries. For example, the German and the Austrian balancing systems are very similar to the Swiss one, even if they have slightly different pricing schemes: All three systems feature a quarter-hour scheduling and rely on the requirement that BRPs be balanced in real-time. By that, the Transmission System Operators (TSOs) are supposed to only compensate the remaining residual power imbalance in real-time. This overall setup is in line with the current European trend which is towards shorter trading and product intervals in the current work in progress discussion of a European-wide harmonisation of electricity balancing and frequency control. In particular, countries with a one hour settlement and imbalance period will be affected by such a development, and our findings can be of particular interest for those with access to several foreign markets.

The structure of the paper is as follows: Section 2 briefly reviews the current concept of energy balancing as well as frequency control in Continental Europe and identifies possible distorted strategies. Section 3 applies possible strategies to historical data from the Swiss system and calculates potential financial impacts. Section 4 describes the measures taken to cope with some distorted incentives in Switzerland, discusses the policy implications and closes with further recommendations as well as the conclusion.

1.2. Background and related topics addressed in the literature

Large interconnected power systems show similar control schemes across Europe, although they differ in terminology and market design: The task of matching load and production has been assigned to two entities. First, the BRPs are responsible for keeping their own generation and consumption portfolio balanced over a defined imbalance settlement period. Second, the TSOs compensate the remaining real-time power imbalance in their respective country, which is a result of the overall instantaneous energy imbalance.

There are several markets available for the BRPs' energy trading. These differ not only on the basis of the traded products, but also in reference to the corresponding deployment time. Their diversity allows for financial optimisation which may even favour an increased risk of instability, i.e. energy imbalances that destabilise the power system. TSOs do not usually have any generation capacity but must have access to active power reserves in real-time: They use market-based mechanisms for the acquisition of reserves within the framework commonly referred to as ancillary services and respective national or regional ancillary service markets.

It is obvious that the overall operational effectiveness in a system depends on the market design and the physical circumstances. Several studies have been carried out comparing market and product designs in Europe (Rivero et al., 2011; Rebours et al., 2007a,b). Tractebel Engineering and Katholieke Universiteit Leuven (2009) discussed the interdependency between the balancing and control responsibility. Frunt et al. (2012) as well as van der Veen and Hakvoort (2009) evaluated design variables such as the imbalance settlement period, whereas Weißbach and Welfonder (2009) identified the latter as being related to the decreasing frequency quality in the Continental European power system. Costs for electricity balancing have mainly been investigated with respect to the penetration of intermittent sources or to regional initiatives (Abbasy et al., 2009; Farahmand et al., 2012).

Furthermore, Wawer (2007) as well as Boogert and Dupont (2005) discussed gambling strategies for the German and the Dutch pricing mechanisms, respectively. However, most of these considerations focus on the spread between day-ahead and real-time markets. Seen from a bottom-up perspective, we are interested in understanding distorted incentives of BRPs to maximise profit by means of cross-border trading and misuse of imbalance energy, as described in detail in the next section. Our paper reveals the straightforwardness of such approaches: The presence of loopholes in the market design should not be surprising at all if one considers the sheer number of different markets and products, but the little effort it takes to persistently profit from these loopholes is remarkable. This paper emphasises the necessity for tackling design flaws in the system. Not only should the possible practices be explicated, but their implications need to be quantified: An extrapolation of the Swiss example indicates possible financial impacts in the three-digit million range for the European power system.

2. Methods for electricity balancing and regulatory boundary conditions in Europe

Compared to power system operation, energy trading and wholesale markets are a relatively young but strongly developing business. Up to now, three legislative packages on energy liberalisation have entered into force in Europe in order to enhance the liberalisation of the electricity sector. In 1996 the "Directive 96/92/EC of the European Parliament and of the Council" set the basis for a European-wide unbundling of the electricity market (European Commission, 1997). It was superseded by the "Directive 2003/54/EC of the European Parliament and of the Council" in 2003 (European Commission, 2003). The directives provide a non-discriminatory access to the power grid, the so-called third-party access. System operators have to grant access to dependent and non-resident energy suppliers for which the system operator receives a transport fee. In 2009 the "Directive 2009/72/EC of the European Parliament and of the Council" entered into force which included further rules for the ownership unbundling and the establishment of regulating authorities in the European Union (European Commission, 2009a).

Moreover, the Agency for the Co-operation of Energy Regulators (ACER) and the European Network of Transmission System Operators for Electricity (ENTSO-E) was established. ACER has been appointed to develop "Framework Guidelines" on which basis ENTSO-E has to write "Network Codes". "Framework Guidelines" are legally non-binding by nature, whereas "Network Codes" are legally binding after the approval of the European commission.

The stipulated unbundling of network activities from production and supply activities ensures that producers or distribution companies may not act as a system operator in parallel. Thus, they cannot give privileged transmission rights to their production units or cross-subsidise production by third-party grid usage tariffs. As a consequence of this on-going liberalisation process, energy and ancillary service markets have a chronological dependence which is depicted in Fig. 1. The fields of BRP and TSO responsibility are referred to as energy balancing and frequency control, respectively.

2.1. Energy balancing: The BRP responsibility

On electricity wholesale markets, participants, i.e. BRPs, have two possibilities to sell and buy electricity, either Over The Counter (OTC) or through energy exchanges. On OTC markets, electricity is

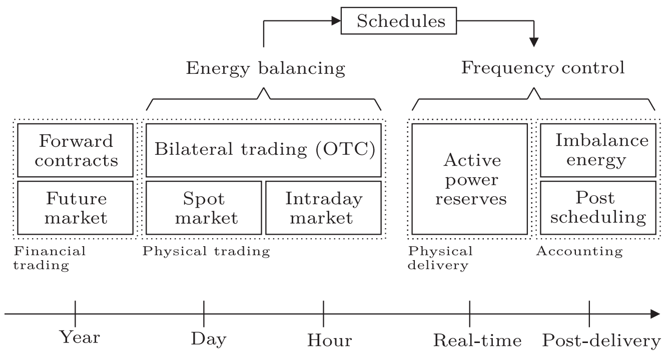

Fig. 1. The European energy market model; not all markets necessarily exist in each country (figure based on Dieckmann, 2008).

traded bilaterally between two parties, which negotiate individual products consisting of a volume, a price and an arbitrary delivery period. In contrast to these non-standardised contracts, trading on energy exchanges is based exclusively on predetermined products for different time horizons such as one year or month ahead, quarter-hourly or hourly. As depicted in Fig. 1, there are purely financial markets for derivatives, for example, futures or options, and physical markets, i.e. spot or intraday markets.

As generation and system operation are unbundled, TSOs are not provided automatically with information regarding production and load. Hence, BRPs send schedules to the respective TSO containing the net energy trade a BRP intends to carry out. Depending on the market design, schedule notifications, i.e. the imbalance settlement period, may have a granularity of 15 minutes (Switzerland, Germany, and Austria), 30 minutes (France and United Kingdom), or one hour (Scandinavian countries, South and East Europe). For each production schedule, there is a consumption schedule and vice versa. This means a BRP has to pay so-called imbalance energy – also referred to as "balancing energy" or "balance energy" – for the aggregated deviations between scheduled and physical net energy during an imbalance settlement period[1]. Each market participant is part of a BRP, for example, utility, trader, consumer, and generator. Hence, there are three possible types of BRPs:

1. BRPs comprising load and production, i.e. both feed-in and feed-out metering points are assigned to such BRPs. This is the case for a classic utility, i.e. managing a power plant portfolio and providing full service provision to consumers.
2. BRPs which comprise either load or production. The entire production or demand has to be brought to the market and the only link between demand and supply is schedule notifications.
3. BRPs without any metering points. Such a BRP is reduced to a virtual construct for the purposes of billing and accounting: traders and trading companies belong to this type. Their schedule, i.e. sum of all their trades, must be zero.

2.2. Frequency control: The TSO responsibility

As every transaction on a spot or intraday market leads to a physical flow in the system and as TSOs are responsible for system stability, there has to be a certain moment close to real-time where the responsibility is transferred to the TSO. This is referred to as gate closure. From this moment on the TSO is obliged to balance generation and load in its country. This procedure is commonly referred to as frequency control since active power is closely related to the power systems' frequency (Kundur et al., 1994). Frequency control is a three-tiered approach whose reserves can be divided into frequency containment reserves, frequency restoration reserves and replacement reserves. The associated resources are referred to as active power reserves, whereas the amount of deployed reserves commonly corresponds to control power.

Based on the nomenclature used in Continental Europe, the corresponding control types are primary, secondary and tertiary control (OpHB-Team, 2004, 2009):

1. Primary control stabilises the frequency after a disturbance. All control areas located in Continental Europe contribute jointly to primary control as frequency deviations are a system wide problem; an imbalance between generation and consumption in any control area will therefore cause the power exchanges to deviate between the areas from their scheduled values.
2. Secondary control is to restore both the system's frequency and the control areas' cross-border power flow to its target values. Hence, secondary control acts in the area causing the deviation and is meant to re-establish primary control power in all areas.
3. Tertiary control adjusts the set point of the secondary controller and reacts as a supplement to the secondary control reserves after a large incident or the persistent use of secondary control power.

Tertiary and secondary reserves have the same objective: to bring the exchange schedule of an area and therefore the frequency in the interconnected power system back to their set values. Both are related to reserve capacities co-ordinated by and available to the TSOs, whereas the activation of primary control cannot be directly influenced as there is no communication between the TSO and the units participating in primary control. Therefore, when it comes to distorted trading incentives, primary control is irrelevant.

2.3. The Swiss imbalance pricing mechanism

Before classifying and evaluating distorted trading incentives, we introduce the principles of the Swiss BRP model, which features a typical European imbalance pricing mechanism. Furthermore, we discuss a case example to illustrate the potential physical risk of distorted trading.

2.3.1. Principles of the Swiss BRP model

Until the end-2012, the Swiss imbalance pricing mechanism was a dual-price system in which the prices of imbalance energy were classified according to the direction of a BRP's discrepancy; the price paid by BRPs with a shortage was higher than the one the Swiss TSO paid to the BRP for a surplus within the same time period. In addition, the pricing mechanism takes into account the effect of the BRP on the control area: It rewards BRPs with a stabilising imbalance on the system and punishes BRPs with a destabilising imbalance. Fig. 2 outlines the Swiss imbalance pricing mechanism.

The following example clarifies this principle: In case the control area is short and simultaneously a BRP's infeed is lower than its scheduled energy, the BRP has a destabilising imbalance. Hence, due to this behaviour, the TSO has to activate control power, for example secondary control. The price the BRP has to pay for its imbalance in the aftermath is based on the price of the deployed control energy (P_{cp}) affected by the lever α_1. As the BRP is short of energy, $\alpha_1 > 1$, implying that the BRP always pays more for imbalance energy than it might have received for the provision of control power in advance. Until end-2012, there were no negative prices in Switzerland and the price for secondary control

[1] To avoid misunderstandings, it should be expressly stated that "imbalance energy" is referred to as control energy whereas an aggregated deviation is simply referred to as an "imbalance" in the draft version of the "Network Code on Electricity Balancing" (ENTSO-E, 2013).

		Control area	
		Shortage	Surplus
BRP	Shortage	BRP pays[1] $P_{cp} \cdot \alpha_1$ $(\approx 1.2 \cdot P_{spot} \cdot 1.3)$	BRP pays[2] $P_{spot} \cdot \alpha_4$ $(= P_{spot} \cdot 1.3)$
	Surplus	BRP receives[2] $P_{spot} \cdot \alpha_2$ $(= 0.7 \cdot P_{spot})$	BRP receives[1] $P_{cp} \cdot \alpha_3$ $(\approx 0.8 \cdot P_{spot} \cdot 0.7)$

[1]destabilising effect [2]stabilising effect

Fig. 2. The Swiss imbalance energy mechanism between 2009 and 2012 (numbers and approximations in brackets for 2011 and 2012).

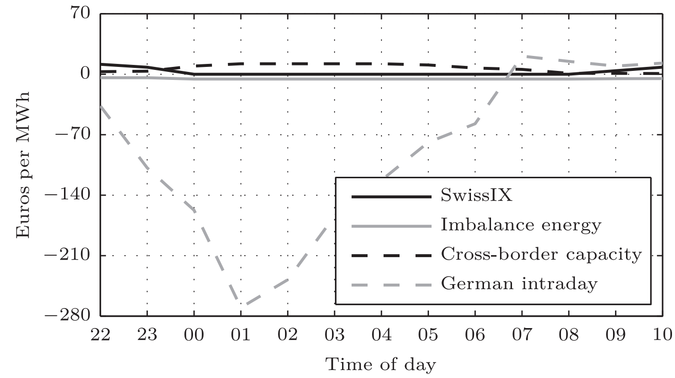

Fig. 3. An incident which occurred in 2012 and caused physical imbalances of up to 700 MW.

energy was calculated as the Swiss day-ahead spot price $P_{spot} \pm 20\%$. Therefore, Swiss BRPs generally have a financial incentive to keep their portfolio best balanced, i.e. no open positions, as they pay at least 20% times α_1 more for imbalance energy than for the same amount on the domestic spot market: The imbalance pricing mechanism is meant to inherently motivate a BRP to support the Swiss TSO in balancing the system. This principle can be transferred to other imbalance situations accordingly: If the BRP behaviour is increasing the overall imbalance, the imbalance price is based on control energy prizes and, furthermore, if the BRP is short (long), the respective lever is $\alpha_1 = \alpha_4 > 1$ ($\alpha_2 = \alpha_3 < 1$). The four levers have been changed only once since the pricing mechanism was introduced. Between 1 January 2009 and 30 June 2009 $\alpha_1 = \alpha_4 = 1.01$ and $\alpha_2 = \alpha_3 = 0.99$. Between 1 July 2009 and 30 November 2012 $\alpha_1 = \alpha_4 = 1.3$ and $\alpha_2 = \alpha_3 = 0.7$.

When it comes to gambling, one aspect has to be considered: Spot market prices result from the day-ahead trading, and thus, are known to all market parties the evening before the day of delivery. By this, the imbalance energy price is determined by the spot price as long as solely secondary control energy is activated. Therefore, the imbalance energy price is known at the same time the spot prices are known. As opposed to this, tertiary control energy is auctioned separately by the Swiss TSO according to a merit order. The prices are published the week after the delivery. Neither price curve nor time and amount of activated tertiary control reserves are known before real-time. However, as the proportion of time when tertiary control is activated is comparably small, BRPs often have a robust guess of imbalance energy prices after gate closure of the Swiss day-ahead market. But to what extent can this setup be used to create gambling opportunities on foreign wholesale markets?

2.3.2. Historical case example

To illustrate potential physical threats of distorted trading to system security, we briefly discuss a severe incident that occurred end-2012 in the Swiss power system. The ex post analysis of this incident made evident that this had not been a coincident but rather a consequence of the price setup of international wholesale markets and the domestic imbalance pricing mechanism.

The incident occurred when several traders had large open positions at the same time, i.e. there was no demand for the produced energy. Fig. 3 shows the prices of the Swiss spot and the German intraday market as well as the Swiss imbalance energy and the day-ahead cross-border capacity. For the early morning hours, which are typical base load hours, the already low Swiss spot price converged to zero. At the same time the intraday market price in Germany was strongly negative, as there was a large amount of energy offers due to intermittent infeed. During these hours, several BRPs of traders (without load or production responsibility) had large open positions. These traders were not able to sell their energy on the Swiss spot market, and they did not take actions to sell the energy in the German intraday market at a negative price. As the imbalance energy price in Switzerland remained positive, they made a profit: In retrospect, they even had a clear incentive to accept these open positions. This situation caused a physical power deviation of up to 700 MW for eight hours in the Swiss control area. Together with regular forecast errors of load supplying BRPs this imbalance summed up to roughly 1 GW. Such an imbalance surpasses the active power reserves available to the Swiss TSO, as those reserves are dimensioned only for forecast errors and forced unit outages.

This incident questioned whether such situations could be anticipated and, if so, what remedies could prevent these adverse price setups. Both will be discussed in detail after a general classification of different types of distorted strategies.

2.4. Identifying distorted incentives

Fig. 4 classifies distorted strategies of BRPs related to the imbalance pricing mechanism: It is a non-exhaustive classification and the application of such a strategy possibly depends on the regional market design. We see four fields of distorted incentives a market design may reveal. All but risky arbitrage require a BRP to have access to a production or load portfolio, and all can be related to an intentional surplus (over-supply) or shortage (under-supply) position of a BRP. Such behaviour is generally not in line with current abuse-clauses, as BRPs should not be allowed to financially optimise in favour of an intentional imbalance. But in reality it is not easy to distinguish whether a BRP is intentionally provoking an energy surplus (or shortage) or inadvertently deviating from the scheduled net energy balance. The only setup in which this can clearly be identified is one where BRPs have no metering points, only trading, i.e. mere traders. Theoretically, their net energy balance must always be zero as elaborated in Section 2.1.

2.4.1. Risky arbitrage

Arbitrage is the practice of taking advantage of price spreads between two or more markets. Textbook arbitrage is self-financing trading that has a positive current payoff and a zero payoff at a known future point in time, i.e. arbitrage is meant to be riskless. In practice, risky arbitrage is more common; it is self-financing trading with a positive current payoff but a zero payoff at an unknown future point. Within the scope of distorted incentives in electricity balancing, arbitrage is possible between wholesale market trading and the imbalance energy pricing if the price for imbalance energy is known: Market participants can have open positions and accept to pay for imbalance energy. Obviously, that is not the intention of an imbalance pricing scheme as it is supposed to incentivise BRPs not to have open positions. Hence, the wholesale energy price is generally higher than the imbalance

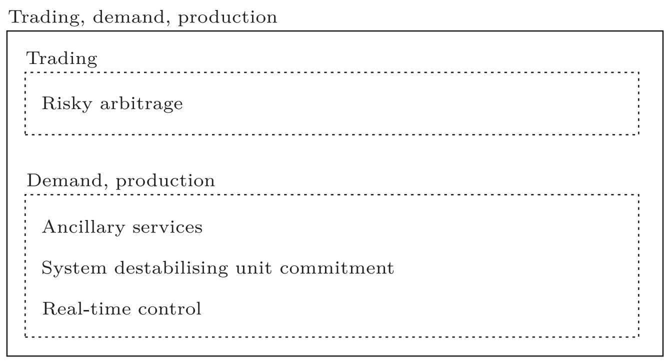

Fig. 4. Classification of fields of distorted strategies that can facilitate gaming opportunities for BRPs in the imbalance pricing mechanism.

energy price; however, arbitrage is possible if markets with energy prices below the domestic imbalance energy can be accessed. As imbalance energy prices are mostly settled after real-time, a BRP will not know the precise amount of energy that can be traded before the imbalance energy price converges, and inherently, only risky arbitrage is possible.

Different strategies with different levels of complexity related to imbalance energy can be identified: Not all countries have negative prices for energy, i.e. delivering energy may cost money. This may lead to situations in which energy can be purchased in a country for a negative price and an intentional surplus position of a BRP in a neighbouring country does not get priced or even results in additional winnings. The same can apply to the price difference between imbalance energy and intraday prices as pricing mechanisms differ from country to country. However, in any case a market participant has to have access to BRPs in different countries.

2.4.2. Ancillary services

With regard to ancillary services, manual control reserves in particular, i.e. tertiary control, can be subject to distorted trading. The activated amounts are generally higher compared to automatic reserves, and their deployment time is longer. A market participant managing a BRP and offering ancillary services with the same power plant portfolio is a prerequisite: A BRP may trigger an activation of reserves by an intentional shortage, which is incentivised if the imbalance energy price is below the control energy price. Alternatively, there is an incentive to not deliver requested reserves if the penalty for a non-delivery is below the imbalance energy this additional deviation causes.

2.4.3. System destabilising unit commitment

A BRP which does not offer ancillary services can nonetheless be the source of a system destabilising unit commitment: A power plant portfolio allows BRPs flexible production and non-standardised products; however, this flexibility can also cause imbalances. In this context, system destabilising unit commitment refers to the capability of triggering imbalances that require the activation of active power reserves by TSOs. A common example is market-induced imbalances at the full hour in order to minimise the imbalance energy resulting in very fast ramping gradients that cannot be compensated by active power reserves (de la Torre Rodríguez et al., 2014).

Flexible hydropower in particular is predestined for gambling with price correlations. For example, if the wholesale energy price drops below the forecasted production price, power plants stop producing. A pump-storage hydro power plant could switch from turbine to pump mode without buying energy for this change in demand, which creates a shortage for the BRP. Another opportunity arises if there is no market liquidity or incentive for a BRP to compensate a loss of load or production within the requested time frame. In this case it will intentionally not take measures to compensate the loss but cover it with imbalance energy.

2.4.4. Real-time control

The following approach is different from the ones explained above. So far all outlined approaches aim at intentionally breaking the balancing responsibility. In addition, the balancing responsibility could be exceeded. We refer to this as real-time control. It takes place if a BRP sets up a control structure to operate its individual load-frequency control, which is actually part of the TSO responsibility. Real-time control is not to be confused with load-following operation, where a BRP uses real-time measurements to compensate for short-term forecast errors. The precise demarcation depends on the real-time data a BRP uses and the control structure it implements. However, we consider real-time control a distorted incentive, as it interferes with the TSO responsibility.

3. Results of evaluating distorted incentives

After a general classification of possible distorted behaviour, we evaluate specific strategies for the Swiss power system and show which of these could have been profitable in the past. We examine historical data from 2011 and 2012, which are Swiss day-ahead prices (SwissIX), Swiss imbalance energy prices, the Available Transmission Capacity (ATC) one hour before delivery on the Swiss-German border, as well as the bids and prices of the German intraday market. Bids and prices are publicly available. The ATC is calculated according to trading records.

3.1. Exploiting price spreads

In a discussion of distorted strategies, the possible markets are of interest. Fig. 5 shows day-ahead and intraday markets of the four neighbouring control areas of Switzerland. We focus on intraday markets as these offer the possibility for short-term trading and optimisation:

- The Swiss day-ahead price is known and therefore most of the possible imbalance energy prices.
- Cross-border capacity is free of charge for intraday trading.

The Italian intraday market is very limited in its possibilities as only two gate closures take place intraday and as only hourly

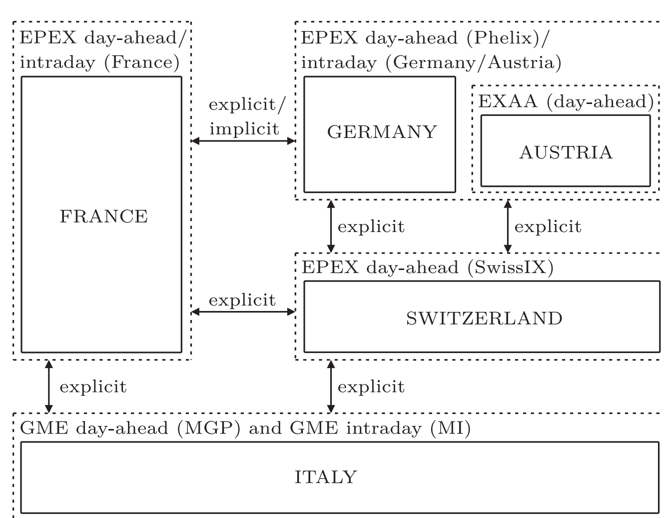

Fig. 5. Assessable markets for Swiss BRPs; cross-border capacity can be allocated implicitly or explicitly (dated 2012).

products are traded. The French intraday market has a low liquidity of approximately 5% of the day-ahead volume and offers only half-hourly products. However, the German intraday market offers quarter-hour products and has a comparably higher liquidity of approximately 10%. Consequently, the German-Austrian intraday market is the market of interest for Swiss BRPs.

In the following, we analyse to what extent a Swiss BRP could have exploited the imbalance pricing mechanism by leaving open positions, i.e. a trade without a countertrade, and accepting to cause a physical imbalance in the system. This could either be done by a trader without physical assets or by a utility that owns a production portfolio. As both have the same physical effect, we refer to these possibilities as gaming opportunities.

3.1.1. Import surpluses to Switzerland

The most obvious incentive for gaming occurs when German-Austrian spot prices are negative. However, in 2011 and 2012 there were only 41 and 38 h of negative prices in Germany, respectively. But obviously, every situation could be financially beneficial in which the German intraday price, P_{DE}, is below the Swiss imbalance energy price. Since most of the time the latter is directly proportional to the day-ahead spot price, P_{spot}, it can be estimated with a coefficient, C_i, and the price spread has to satisfy the following formula:

$$P_{DE} < P_{spot} \cdot C_i \tag{1}$$

In the first place, the control energy price, P_{cp}, is approximated by the secondary energy price as explained in Section 2.3. Therefore, $C_i = 0.56$ for the case of a destabilising BRP, i.e. 0.8 times α_3. Based on this approximation, we assume that whenever Formula (1) is satisfied one hour before real-time delivery, energy is bought on the German market and the resulting energy surplus is left in the Swiss control area. Energy imports are limited by the available market volume and the ATC one hour before delivery on the Swiss-German border.

Table 1 shows the results of this first strategy and compares the numbers to the potential profit BRPs could have made if they knew the real imbalance energy price in advance. A rough projection onto Europe indicates a large possible financial impact, if similar strategies had been applied all over Europe. However, this projection does not consider the difference in market design and is meant to illustrate the expected number for larger market areas.

The results for Switzerland show that a simple strategy results in 35% of the maximum possible winnings for the two years considered. However, in 2011 it was quite a robust approach, whereas in 2012 only 15% of the maximum could have been realised. This is due to the participation of Switzerland in the German Grid Control Co-operation, which influenced the activation of control power (Scherer and Geissler, 2012). Subsequently, the choice of C_i needs further screening: What is the best coefficient for both years? To answer this and to sketch a realistic scenario, more parameters are needed.

Table 1
Comparison between the strategy of importing surpluses with a constant estimation coefficient of 0.56 and the maximum possible profit if the real imbalance energy prices had been known.

Year	Profit based on estimated prices (euros)	Profit based on real prices (euros)
2011	4 360 826	5 316 692
2012	1 853 365	12 454 939
Total	6 214 191	17 771 631
Total projected onto Europe[a]	50 442 718	144 258 420

[a] The extrapolation is done by disproportionately scaling the total to the European peak load of 532.6 GW in 2011 (ENTSO-E, 2012b).

First, we have to decide on a maximum market volume the BRPs can buy: As a rule of thumb the market clearing price is quite inflexible up to a change of 20% of the market volume, i.e. the price would not change significantly. Fig. 6 shows how the choice of C_i influences the overall profit when buying 20% from the market at a maximum.

For both years the profit is at the maximum when C_i is 0.58 which is close to the initial choice of 0.56. However, there is no limit to the overall imbalance of a BRP. A large imbalance is noticeable to the TSO, which normally monitors BRP behaviour. A more realistic ambition is that a BRP limits its maximum intentional imbalance. According to an internal analysis, the imbalance energy of large Swiss BRPs comprising production and demand exhibits a standard deviation of approximately 50 MW. If a long or short position is kept close to the standard deviation, it will be hard to find evidence for its intentionality. Fig. 7 plots the profit against the estimation coefficient, C_i, when limiting the maximum imbalance to 50 MW.

This underscores the results shown in Table 1; the simple estimation lost its robustness in 2012. The best coefficient for 2011 is still the same, whereas the one for 2012 differs significantly: If $C_i = 0.58$ is assumed for both years, the profits are 210 055 euros and 130 260 euros. Both numbers are significantly below the maximum shown in Table 1.

3.1.2. Export surpluses from Switzerland

Section 3.1.1 outlined a plain approach to profit from intentional surpluses in Switzerland by the use of a constant estimation

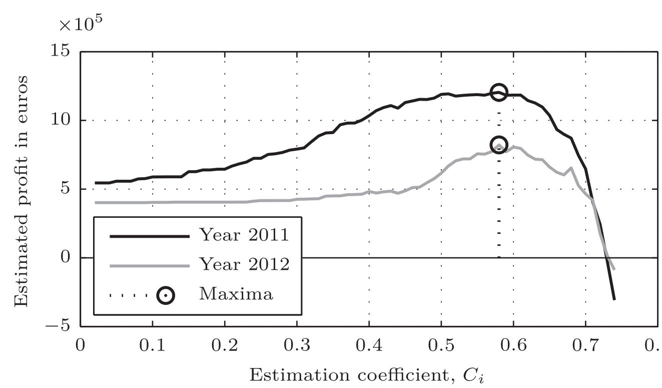

Fig. 6. The yearly profit by importing surpluses as a function of the estimation coefficient, C_i; the maximum energy that can be bought is limited to 20% of the total market volume.

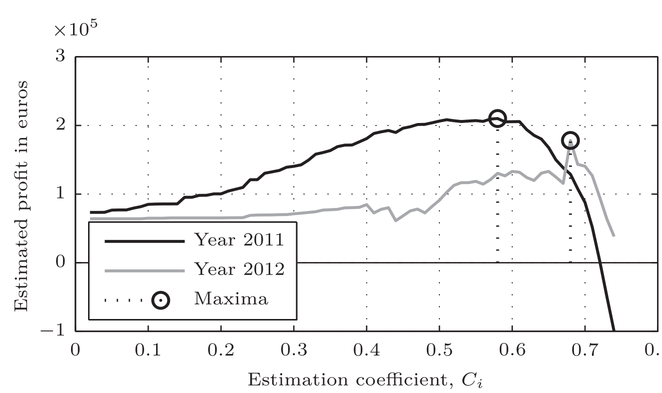

Fig. 7. The yearly profit by importing surpluses as a function of the estimation coefficient, C_i; the maximum imbalance and energy that can be bought is limited to 50 MW and 20% of the total market volume, respectively.

Table 2
Comparison between the strategy of exporting surpluses with a constant estimation coefficient of 1.56 and the maximum possible profit if the real imbalance energy prices had been known.

Year	Profit based on estimated prices (euros)	Profit based on real prices (euros)
2011	693 222	5 057 689
2012	106 066	53 593 230
Total	799 289	58 650 920
Total projected onto Europe	6 488 103	476 089 620

coefficient. Before analysing granularity, we want to investigate the same approach for exporting surpluses, i.e. importing shortages to Switzerland.

Similar to Formula (1), an estimation coefficient, C_e, can be used to find beneficial situations for exporting surpluses:(

$$P_{DE} > P_{spot} \cdot C_e \tag{2}$$

The idea stays the same: If Formula (2) is satisfied one hour before intraday delivery, energy is sold in Germany in favour of an intentional shortage in Switzerland, i.e. the short position will be invoiced according to the Swiss pricing model for imbalance energy.

Again, the simplest choice for C_e is according to Section 2.3, i.e. $C_e = 1.56$ for the case of a destabilising BRP. Table 2 shows the results of this strategy and compares the numbers to the potential profit that BRPs could have made if they knew the real imbalance energy price. Again, a rough projection onto Europe indicates a large possible financial impact.

The difference for Switzerland between strategy (estimated prices) and theoretical maximum (real prices) is even higher compared to the importing approach. However, these results are still tempting numbers. For a more realistic scenario we apply the same constraints as before. We set the limiting market volume to 20%. The results are displayed in Fig. 8.

The difference in the offset between 2011 and 2012 is similar to the one observed in Fig. 6, but both functions are considerably less smooth and therefore less robust. This becomes more salient if we furthermore add the aforementioned limit of the maximum imbalance of 50 MW: Fig. 9 reveals only losses.

This is due to the generally large difference between the imbalance energy price and the SwissIX price if the latter is comparably low. Exporting surpluses leads an activation of negative reserves for which the Swiss TSO has to pay. The price for negative and positive tertiary control reserves is mostly above and below spot prices, respectively, i.e. an ancillary service provider offers low

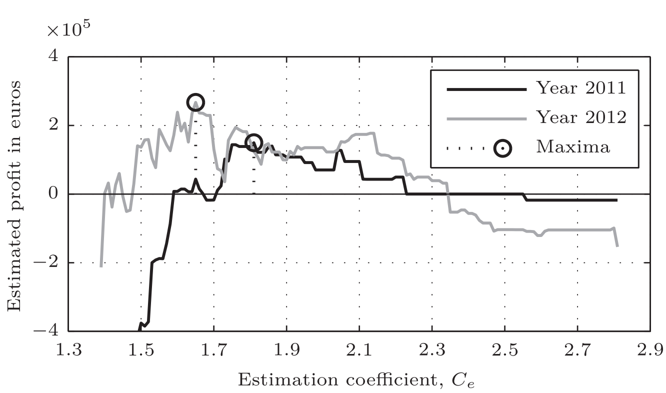

Fig. 8. The yearly profit by exporting surpluses as a function of the estimation coefficient, C_e; the maximum energy that can be bought is limited to 20% of the total market volume.

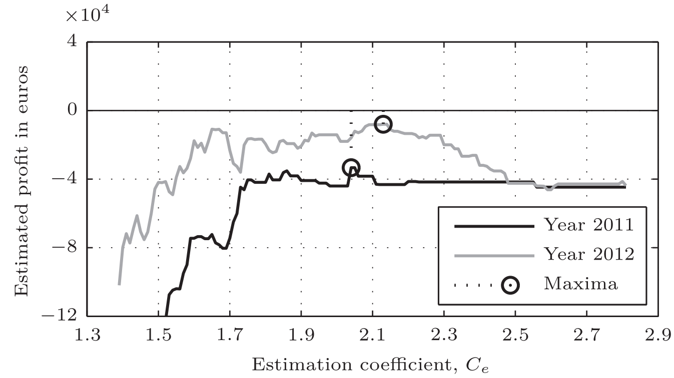

Fig. 9. The yearly profit by exporting surpluses as a function of the estimation coefficient, C_e; the maximum imbalance and energy that can be bought is limited to 50 MW and 20% of the total market volume, respectively.

prices for negative control energy but high prices for positive control energy. Subsequently, the activation of negative tertiary control power has a weak influence on the imbalance energy price whereas the activation of positive tertiary control reserves has a comparably strong impact on the imbalance energy price. This effect gets amplified in case of low spot prices: Solely tertiary control energy determines the balancing price in such a situation. The production structure in Switzerland is dominated by hydroelectricity and nuclear power. Both have little variable costs; therefore, tertiary control energy prices are quite independent of the Swiss spot price: Compared to secondary control, the tertiary control market is large but the proportion of time is comparably small in which tertiary control gets activated. Prices for the tertiary control provision are smaller than for secondary control. Tertiary energy prices are very high for positive reserves and close to zero for negative reserves. That implies that providers are not much interested in deploying energy, i.e. hydropower spares the water and, in opposite to secondary control, money is made by provision not by activation.

Furthermore, it can be observed that in case of low SwissIX prices, the Swiss control area is likely to be short, i.e. exporting surpluses further destabilises the system. At a first glance, this may sound contradictory: Why should load supplying BRPs be short on energy when the price is low anyway? Again, this is owed to the operational flexibility of hydroelectricity: When the spot price is roughly below 20 euros/MWh Swiss power plant operators tend to reduce the output of power stations; producers spare water to utilise it later for expensive peaking power production. However, this is only applied at low spot prices, as the risk of higher balancing prices increases with it. We can overcome this obstacle by choosing an appropriate floor price for the exporting strategy. To find an appropriate limit we performed an in-depth analysis of the 2011 data: Fig. 10 shows the estimated profit plotted as a function of the estimation coefficient and price floor. The profit is largest at an estimation coefficient of $C_e = 1.9$ and a floor price between 8 and 11 euros, which results in 14 519 euros for 2011. Applying the same parameters for 2012 results in 41 119 euros. These numbers are comparably small compared to those for importing surpluses: This strategy does not offer much profitability. Furthermore, this shows a limitation of our estimation approach: The impact of a constant estimation factor is small if it is multiplied by a low price: With the exporting strategy, a BRP wants to profit from low prices but the estimation coefficient has a poor effect. By contrast, for the importing strategy high prices are of interest and the estimation factor considerably impacts the profit.

3.1.3. Daily patterns

Up to now, we aimed at long-term profits; therefore, we only used yearly estimation coefficients. In order to understand the

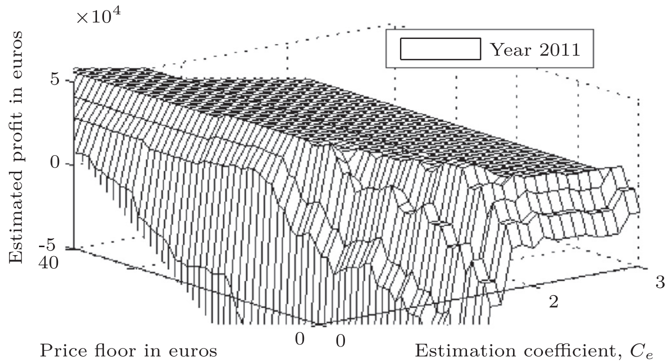

Fig. 10. The yearly profit by exporting surpluses for 2011 as a function of the estimation coefficient, C_e, and the price floor; the maximum imbalance and energy that can be bought is limited to 50 MW and 20% of the total market volume, respectively.

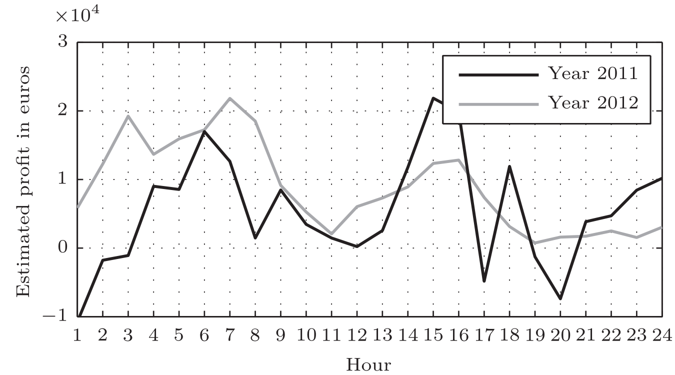

Fig. 12. Estimated profit per hour by importing surpluses for an estimation coefficient, C_i, of 0.58; the maximum imbalance and energy that can be bought is limited to 50 MW and 20% of the total market volume, respectively.

dynamics behind our strategies and the reason for their success and failure, we further analyse and compare the importing and exporting strategies.

The results in Section 3.1.2 already indicate that the exporting strategy may not offer much potential for short-term profits: There had only been 11 h and 26 h in 2011 and 2012, respectively, where this strategy could have been successful. The numbers for the importing strategy are significantly different: 1649 h (2011) and 1410 h (2012). Thus, only the importing strategy can be reasonably analysed for a pattern.

Fig. 11 shows the average estimation coefficients per hour for both years. A certain daily pattern is visible but differs for both years due to the tertiary control activation pattern and the participation in the German Grid Control Co-operation (see Section 3.1.1). Theoretically, the profit would be 225 744 euros and 382 259 euros indicating an increase of 78% compared to the use of a constant coefficient. But as the correlation between the years is weak, it is virtually impossible to forecast hourly coefficients: If the 2011 values are applied to 2012 data, we end up with a profit of 103 605 euros, which is largely below the profit based on a constant yearly coefficient.

Fig. 12 shows which parts of the day offer a potential for profit with a constant estimation coefficient of 0.58. Obviously, for certain hours the strategy is robust, whereas the possible profit is small or even negative for midday and evening hours. These hours should be avoided in order to minimise the risk of losses, i.e. the imbalance energy mechanism is robust in these hours.

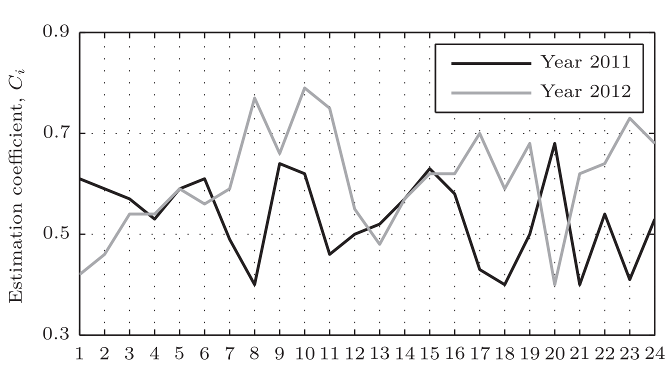

Fig. 11. Average estimation coefficient, C_i, per hour for 2011 and 2012; the maximum imbalance and energy that can be bought is limited to 50 MW and 20% of the total market volume, respectively.

4. Conclusions and policy implications

We investigated possible impacts of system destabilising trading activities in the Swiss power system, and a rough extrapolation indicated a large possible financial implication for the European power system. Consequently, we conclude that there is a strong interdependence between cross-border electricity trading and national electricity balancing. For this reason, we discuss operational and contractual measures to cope with potential loopholes and elaborate what aspects need to be considered in future regulations for the electricity sector.

4.1. Remedies on a national level

There are different approaches to cope with distorted trading incentives between energy trading and the BRP responsibility that undermine electricity balancing principles. We elaborate three basic adjustments and illustrate respective measures implemented for the Swiss wholesale electricity trading and imbalance pricing mechanism:

Competitive imbalance pricing: The pricing mechanism for imbalances should reflect real market prices or, if not, its prices must not be predictable. In Switzerland, BRPs in surplus (long) still receive a credit note, while billing units in deficit (short) are charged accordingly. But additionally, the price for surpluses is now linked to the lowest price out of the spot and control energy price, whereas the price for shortages is linked to the highest price out of the spot and control energy price. In both situations the price forecasting partly loses its predictability and BRPs have to accept the most inconvenient price independent of the amount of activated control energy.

Robustness against traders: Imbalance pricing has to suit the needs of traders. Lately, there have been more traders than energy suppliers for end consumers. Historically, imbalances only referred to national energy utilities as a result of a mismatch between demand and production. Today, most BRPs are mere traders which naturally focus on business cases rather than load covering of end consumers. In Switzerland, a zero imbalance requirement has been introduced for BRPs without metering points, i.e. traders. These BRPs are now monitored for imbalances of large amounts. In such a case they must pay a fine for their violation of system security. However, the zero imbalance requirement is only reasonably applicable to traders. BRPs coping with load and production are not yet covered by this regulation.

Compatibility to neighbouring markets: In particular, non-negative price markets adjacent to markets with negative prices lead to gaming opportunities between national balancing and cross-border trading. As negative prices are allowed in the French and German wholesale markets, the introduction of negative prices for the SwissIX has been investigated by the Swiss TSO in close co-operation with Swiss BRPs. Negative prices have been implemented in the beginning of 2014. Additionally, the introduction of the continuous intraday market on the Swiss-German and Swiss-French borders in mid-2013 affirms such a step, as negative prices mainly occur in the intraday trading.

These measures limit the possibilities of profiting from gaming opportunities between imbalance pricing and wholesale markets. More importantly, certain distorted incentives can be abandoned. In Switzerland, experience will show the robustness of these balancing mechanism adjustments. Nonetheless, the intrinsic feasibility to profit between markets with different pricing systems stays the same. Due to European-wide developments, this can be considered as the very core challenge of future balancing mechanisms.

4.2. European-wide regulations

The financial crises in 2008, and the American "Dodd-Frank Act" in particular, gave rise to several new regulations for financial markets such as REMIT, EMIR, MiFIR, and MAR. However, they do not deal with electricity balancing and imbalance pricing, but affect the electricity sector as they cover data reporting as well as national reporting requirements and have to be duly considered for the drafting of the "Network Codes". The purpose of the latter is to set up European-wide rules for harmonisation of electricity markets and system operation: They aim at providing effective and transparent access to the transmission systems across national borders. The drafting of these codes started in 2010, whereas the number and precise scope has not been predefined; "Regulation 714/2009/EC" only sets out the areas in which these codes will be developed and a process for developing them (European Commission, 2009b). However, as these codes will involve the future regulations for electricity balancing and power system operation, particular attention should be paid to the impact of harmonising cross-border regulations on local electricity balancing and its national imbalance pricing mechanism.

On the one hand, the Third Energy Package stipulates a competitive and integrated European electricity market with extensive cross-border trade facilitation. The implementation of the corresponding "Network Code on Capacity Allocation and Congestion Management" already started on a regional level with a stepwise integration of regional initiatives (ENTSO-E, 2012a). For example, the Central West Europe (CWE) region was successfully coupled with the Nordic countries in February 2014, resulting in the so-called North-Western Europe (NWE) day-ahead market coupling. Hence, market participants' access to new markets is gradually facilitated. On the other hand, the future generation mix according to the European Union's 20–20–20 targets[2] will be characterised by an even higher amount of intermittent generation than today. These developments lead to both volatile electricity prices caused by unpredictable infeed and therefore continuously occurring erratic imbalances. Hence, intraday markets' significance will increase on a national and cross-border level. However, our investigations showed that system destabilising trading is among other factors subject to the interaction between national imbalance pricing mechanism and neighbouring wholesale market rules, i.e. cross-border day-ahead and intraday trading.

The "Network Code on Electricity Balancing" aims to promote a higher degree of co-ordination and integration of European balancing markets (ENTSO-E, 2013). According to its regulations, market participants in general shall support system security, and more specific settlement principles for imbalance energy shall take into account interdependencies with intraday and day-ahead markets. Additionally, the code requires the definition of common principles for the procurement of balancing capacity and balancing energy "to ensure that distortions within the internal market and in particular between adjacent markets are avoided" (ENTSO-E, 2013). Nonetheless, the crucial issue of aligning cross-border wholesale electricity market activity and national balancing pricing mechanisms on a European level is only treated on a high level. For example, the code claims that two TSOs are enough to form a co-ordinated balancing area. Hence, the harmonisation of pricing rules has to take place only between those two TSOs; adjacent markets are not taken into account. Obviously, the current development of the "Network Codes" deals with a wide range of cross-border network and market integration issues, whereas imbalance pricing mechanisms are dealt with on a national level.

4.3. Closing remarks

This paper outlined possible loopholes which imply distorted trading incentives of BRPs and analysed these for the Swiss imbalance pricing scheme. The impact of distorted incentives, i.e. gaming opportunities based on risky arbitrage and system destabilising unit commitment, was investigated using historical data from Switzerland. We conclude that little effort and technical means would have been necessary to make a good profit at the expense of system security. The major loophole arises from the interdependence between cross-border trading and national balancing. For this reason, both the Swiss wholesale electricity market rules and the Swiss balancing price mechanism have been adjusted.

Nonetheless, bearing in mind the Third Energy Package and the European Union's 20–20–20 targets, the importance of national balancing mechanisms will increase strongly. As cross-border network and market integration issues form a strong part in the current development of "Network Codes" on a European level, imbalance pricing systems are still dealt with on a national level. The general stipulation of international energy policy harmonisation is not specific enough to prevent loopholes that arise from the differences in national imbalance pricing policies: Market design in one country must take the one in neighbouring countries in consideration, or market participants will exploit flaws and potentially create physical risks. The corresponding European legal framework has to ensure that system security is not jeopardised by market activities.

Future work should examine the detailed applicability of the investigated example to other countries as well as the future robustness with respect to the increasing importance of cross-border intraday markets. The manipulation of electricity prices in combination with design loopholes in the imbalance pricing can create system destabilising gaming opportunities. Switzerland is a comparatively small country: The impact of destabilising system security through gaming opportunities between spot markets and imbalance pricing activities might be more severe in larger areas. At the end of the day, the power system is only as secure and reliable as the financial incentives for market participants are robust and system-stabilising.

[2] The 20–20–20 targets for 2020 in climate and energy policy: 20% reduction in greenhouse gas emissions from 1990 levels, 20% increase in renewable energy of the total energy production, and 20% reduction in energy consumption of projected 2020 levels by improving energy efficiency (European Commission, 2009a).

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