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„German-Austrian Electricity Price Bidding Zone. A Synthetic Control Approach"

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Content

List of Tables

List of Figures

Abbreviations

ACER – Agency for the Cooperation of Energy Regulators

BBP – Bundesbedarfsplan

BnetzA - Bundesnetzagentur

CACM – Capacity Allocation and Congestion Management

CEE – Central and Eastern Europe

DE-AT – German-Austrian Bidding Zone

DSO – Distribution System Operator

EEG – Erneuerbare Energien Gesetz

ENTSO-E – European Network of Transmission System Operators for Electricity

EnWG – Energiewirtschaftsgesetz

NABEG – Netzausbaubeschleunigungsgesetz Übertragungsnetz

NEP - Netzentwicklungsplan

NRA – National Regulatory Authority

PL – Poland

SL – Slovakia

TSO – Transmission System Operator

“Ideally, a congestion management method is economically efficient in the short term and also provides efficient long-term incentives to both the network managers and to generation companies. None of the compared methods combines these goals.” (de Vries & Hakvoort, 2001, p. 21)

1. Introduction, Motivation and Research Question

This Master's Thesis is motivated by ACER's last year suggestion to split the only European-wide joint electricity price-bidding zone between Germany and Austria due to substantial grid congestion in the CEE region. The Polish NRA introduced the allegation of congestion and a subsequent opinion has been requested in 2014. By the end of September 2015, ACER confirmed the Polish request and suggested the implementation of permanent capacity allocation measures at the DE-AT border, which is equal to splitting the unique bidding zone. According to ACER (2015), unscheduled loop flows represent the main obstacle for market integration in the CEE region. In particular, the increasing cross-border flows between Germany and Austria, which represent 40 percent of the flow volume in the CEE region, cause substantial congestion and associated loops flows resulting in expensive curative measures within the respective region.

Alleged reasons for the congestion issues caused by the DE-AT bidding zone stem mainly from Germany rather than Austria. First, the German Energy Transition towards renewable energy increases wind feed-in to the transmission grid, whereas the present network cannot cope with the substantial amount of renewable energy. Hence, the German grid cannot accommodate the incoming power such that produced energy in the North cannot be transported directly via German transmission lines to the South, but evades to neighbouring countries Poland and the Czech Republic intensifying present loop flows. Compared to the accelerated pace of power landscape changes and the amount of renewable feed-in, the network expansion process is more than backward. (Morecroft, 2012; Wetzel, 2015)

Since the splitting is supposed to increase the electricity price significantly in both countries, BnetzA and E-Control filed a complaint at the European Court of Justice against ACER's decision to split the joint bidding zone. Albeit the fact that both countries already engage in substantial re-dispatching and countertrading measures, BnetzA and E-Control suggest the problem not be solved until

Germany, Poland and the Czech Republic engage in rapid grid expansion. (ACER, 2015)

Ever since ACER's opinion was published in September 2015, the media presence of this issue is steady. Two major opinion streams can be identified. First, splitting the DE-AT price-bidding zone equals going backwards, since it is the only efficient larger transnational bidding zone. For a fact, the DE-AT bidding zone is highly welcomed by the European Commission. The ultimate goal of the European Union has been to create a united electricity market with an integrated electricity market price, yet the unification of national markets is lagging far behind. Second, the energy industry predicts significant increases in electricity prices in Germany and Austria. The CEO of Austria's prominent energy supplier Verbund, Wolfgang Anzengruber, for instance predicts a price increase of 15 percent. (Auer, 2015; Kowalcze, 2015) Thus, the motivation for this Master's Thesis's topic is not only driven by the medial presence, but also by the suggested price increase in case the reconfiguration of the DE-AT bidding zone actually takes place.

The intention of this thesis is twofold. First, a general and profound overview of the German electricity market with focus on the DE-AT bidding zone is given as well as the theoretical and practical overview of congestion management measures is presented. Considering congestion management, this thesis builds on existing literature e.g. Kumar et al. (2005), Oggioni and Smeers (2010) or Kunz and Zerrahn (2013). Second and foremost, the intention is to examine the scenario of a counterfactual Germany that did not enter into a bidding zone with Austria in 2001. In particular, the electricity price within the scenario that Germany and Austria are two separate bidding zones is investigated. This Master's Thesis is, thus, aimed to critically examine the predicted price increase by German and Austrian energy stakeholders in case the joint bidding zone is split and contributes thereby to existing research in this field.

Therefore, the research question is:

Does the German electricity price change in case of no bidding zone with Austria? If the price changes, how large is the magnitude of the price increase respectively decrease?

The research is embedded in and guided by the Synthetic Control Method (SYNC). The structure of this Master's Thesis is as follows. Section 1 provides an overview of the German electricity market and discusses the impact of the Energy Transition on the current German grid situation. In section 2, the theoretical framework is delineated by providing a literature review in the field of congestion management methods in theory and practice. Moreover, ACER's resolution to split the DE-AT bidding zone is examined. Section 4 covers the empirical part, in which the SYNC method is applied separately for German wholesale and household electricity prices to create a synthetic control unit. In addition, placebo tests are conducted to examine the robustness of the empirical findings. Eventually in section 5, results are discussed and limitations to the study are drawn.

2. German Electricity Market

2.1. Electricity Market Structure and Energy Players

With the creation of a legislative strategy, the European Commission took the first step towards a unified European electricity market in the 1980s. The German electricity market was liberalised with the transposition of the EU Directive to the amended Energy Act in 1998. Formerly vertically integrated energy companies were supposed to unbundle, i.e. generation, distribution and retail must be separated. The German NRA, BnetzA, regulates the field of distribution and transmission. According to the Third Energy Package and the European Directive 2009/72/EC, TSOs and DSOs must be independent and unbundled in the sense of either functional, legal or ownership separation from the formerly integrated company. (BnetzA, 2005; RAP, 2015)

Germany has four TSOs – TenneT, 50Hertz, Amprion and Transnet BW. The first two TSOs cover the largest parts of Germany and are ownership unbundled, whereas the latter ones are functionally unbundled. TSOs calculate and contract capacities for scheduled and a rough percentage of unscheduled electricity flows in advance. In case trading of electricity volumes deviates from physical flows, balancing capacities are used to countermeasure. The ultimate goal is to keep generation and consumption of electricity in equilibrium. Given the delicate peculiarity of electricity, i.e. no storage, TSOs must calculate the necessary capacity for system security to keep the possibility of outages at minimum. In order to keep deviations from scheduled capacities as low as possible, the balancing group in need of balance capacity must bear the costs for it, i.e. imbalance settlement system. The latter system in combination with balancing groups and capacities assures physical and scheduled electricity capacity to be in equilibrium. (BMWi, 2014; RAP, 2015)

Compared to the transmission system, the German distribution system is with approx. 890 DSOs and 20.000 served municipalities, by far the most complex within Europe. The four largest DSOs are E.ON, RWE, EnBW and Vattenfall, which also represent the four largest energy suppliers and generators. Apart from these four, around 700 municipality-owned utilities (*Stadtwerke*) cover the distribution system as well as a handful of regional companies. Although the four largest DSOs cover a substantial part of the German distribution grid, municipality-owned utilities are supposed to take up a significant part of the distribution grid, since the concessions granting monopoly distribution rights will expire in near future. Turning to energy suppliers, Germany has a remarkable amount of over 900 suppliers. Nevertheless, the largest four companies (E.ON, RWE, EnBW and Vattenfall) have a combined market share of 45 percent (60 percent) in retail (generation). (RAP, 2015)

Electricity is traded either on the exchange, i.e. at EEX in Leipzig, EPEX SPOT in Paris, EXAA in Vienna, or OTC, i.e. directly between electricity producers and suppliers. Although bi-lateral OTC contracts cover the majority of contracts, a rising proportion of contracts are dealt with at the individual exchange markets. A simplified version of the German electricity market is subdivided into submarkets for market participants, which trade electricity, and TSOs contracting scarce transmission capacity. Electricity volumes for the next day can be traded at the day-ahead market until midday of the previous day. Any shortfalls or surpluses can be traded at the intra-day market until gate closure. (BMWi, 2014; RAP, 2015)

Ideally, the electricity price signals demand and supply effectively. Since 2001, Austria and Germany have a common electricity price bidding zone obtaining a uniform wholesale price across both countries. Electricity between Austria and Germany flows completely free, disregarding any bottlenecks. Hence, the electricity price within the bidding zone does not reflect congestion properly and blurs price signals. The German electricity market is further coupled with 15 other countries such that exchange prices for transnational electricity flows are determined jointly for all coupled markets. The price corresponds to the lowest price bid in case of available interconnector capacity. In contrast to the DE-AT bidding zone, exchange prices take into account congestion issues. In general, the market follows the merit-order-principle, i.e. the generator producing electricity at lowest costs is the first to cover demand. The exchange price, however, is determined by the marginal costs of the most expensive power plant. Ordinarily, wholesale market prices are declining steadily due to increased energy efficiency and low-marginal cost generation. Household electricity prices, on the other hand, are the second highest within Europe, mainly due to increased renewable energy charges as part of network costs. (BMWi, 2014; RAP, 2015)

2.2. Towards Renewable Energy

Building on the Energy Concept from 2010 and its resolutions from 2011, Germany adopted the Energy Transition (*Energiewende*). The expansion of renewable energy and the increase in energy efficiency establish two main pillars of the Energy Transition. In detail, the German electricity consumption is supposed to be covered by 80 percent renewable energy until 2050. Until then, the electricity consumption is to be cut by half. A further special focus of the German Energy Transition is the phasing out of nuclear energy. Originally, the Energy Concept postponed the phase out by twelve years until the nuclear incident happened in Fukushima in March 2011. As a consequence, Germany decided to foster the nuclear phase out promptly. Out of eight nuclear power plants, two had been already shut down due to technical reasons. Of the remaining six nuclear plants, five are still operating. By 2022 all plants are supposed to be shut down. (BnetzA, 2016; BReg, 2015)

Given Germany’s substantial country-size, energy intensity as well as the energy-related strategic position in the midst of Europe, eight legislations e.g. EEG, EnWG or NABEG were necessary to assure sustainability as well as profitability of the transition process. (IEA, 2013)

2.3. The Impact of Energy Transition and Grid Expansion on Congestion

According to Frontier and Consentec (2011) as well as BnetzA (2016), the nuclear phase out is next to the simultaneous increase of renewable energy the driving cause for increased structural congestion and loop flows within the DE-AT bidding zone and the CEE region. From the remaining five power plants, only one is located in northern Germany, whereas the rest is situated at southern nods nearby the industrial cluster. Excessive wind generation is situated in the northern area, in which consumption is relative to electricity production low. In southern Germany, however, electricity demand is higher given the location of the industrial sector. The pending closure of southern nuclear power plants causes intensified electricity flows of wind energy from the North to South via already congested transmission lines in the middle of Germany. Subsequently, curtailment measures soared to cope with congestion and loop flows. According to BnetzA (2016a), re-dispatching measures increased in 2011 considerably when compared to 2010, as can be seen in Figure 1.

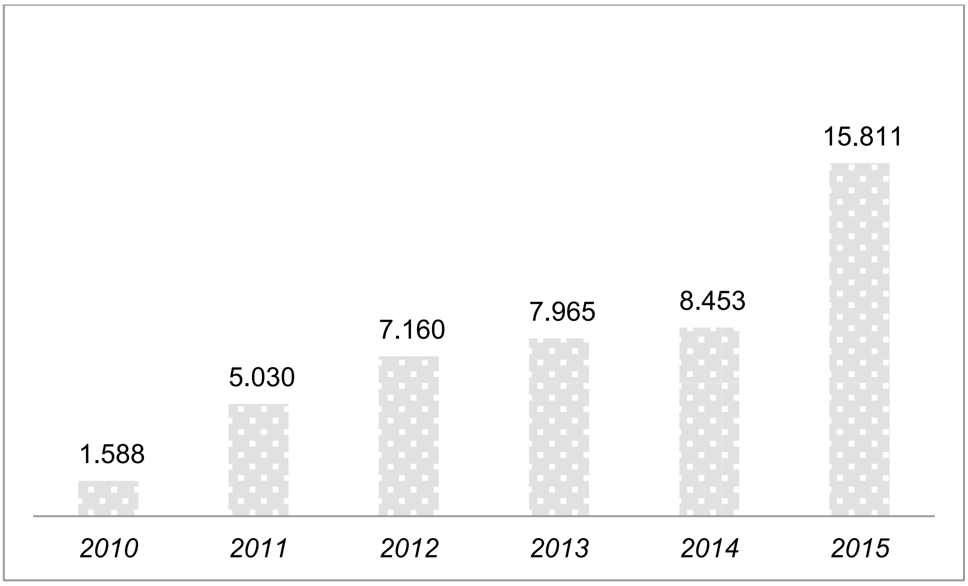

Figure 1. Re-Dispatching Frequency of DE Transmission System in hours. Source: BnetzA, 2016a

From 2014 to 2015, re-dispatching measure tripled up to almost 16.000 GWh, which caused re-dispatching expenditures up to EUR 402,5 Mio. In comparison, in 2014 re-dispatching costs amounted to roughly EUR 185,4 Mio.

The remarkable increase of re-dispatching measures in 2015 was caused by the early shutdown of the nuclear power plant Grafenrheinfeld in southern Germany as well as by the implementation of two conventional power plants, Moorburg and Wilhelmshaven, in northern Germany. These circumstances intensified physical flows from North to South. Further reasons for the increase in necessary curative measures are the expansion of wind energy in the North as well as a wind-intensive year, delayed implementation of network expansion plans and a temporary decommissioning of grid elements in order to pursue the expansion. Briefly said, the main obstacle for Germany is that power plants are connected to the grid too quickly compared to the progress of grid expansion. (BnetzA, 2016; BReg, 2015; IEA, 2013)

Structural congestion has thus intensified substantially, especially at already highly congested lines such as Remptendorf – Redwitz, Brunsbüttel – Hamburg and Vierraden – Krajnik to Poland. In general, highly congested lines are situated in the northern and eastern part of Germany as well as in the middle of the country. (BnetzA, 2016) Furthermore, the substantial expansion of renewable energy causes a massive increase in loop flows posing insecurity threats to the present grid system. Compared to conventional energy, renewable energy has priority access to the grid, which causes physical flows deviating significantly from scheduled ones. Frontier and Consentec (2011) point out, that northeastern transmission lines are congested due to high wind feed-in. In particular, the study shows a clear correlation between increasing congestion and high wind feed-in. (BnetzA, 2016; Thema, 2013)

Consentec (2015) highlights the importance of sufficient and prompt network expansions to accommodate all necessary power flows. As a consequence of the implemented Energy Transition, Germany introduced a nation-wide expansion plan for the national transmission and distribution grids. These network expansion plans are based upon the legislations *Bundesbedarfsplan (BBP)* and *Netzentwicklungsplan (NEP)*, which elaborate on necessary grid investments. Accordingly, new transmission lines up to 2.800 km are to be built and 2.900 km are subject to modernisation. Given the urgent necessity of network expansion, the legislation has been adapted with the *Netzausbaubeschleunigungsgesetz* (*NABEG*) such that the approval process for new transmission lines is reduced from ten to four-six years. (BReg, 2015; IEA, 2013)

3. Theoretical Framework. Literature Review

The following section provides an in-depth review of congestion management methods in theory and in practice. Moreover, the dispute of splitting the DE-AT bidding zone as well as case studies regarding bidding zone reconfiguration are revised.

3.1. Bidding Zones

European electricity wholesale markets are based upon a zonal approach, i.e. electricity is a homogenous good and its exchange is limited in terms of cross-zonal capacity and congestion management measures. A zonal approach divides a geographical area into distinct areas, i.e. bidding zones, with unlimited power trade between various generators and loads. (Consentec, 2015)

In Europe, national borders correspond to bidding zone boundaries, i.e. one country represents one bidding zone. Exceptions to this specification are Sweden, Norway, Denmark and Italy, which are split into several zones and Germany-Austria, which represent one common unit. (Consentec, 2015) Within each bidding zone the electricity price is the same and power can be contracted regardless of the physical state of the transmission network. Although this simplification facilitates intra bidding zone trading, it comes at the expense of cross-border exchanges. In contrast to cross-zonal exchanges, intra-zonal trading is neither restricted nor limited by calculation and allocation procedures of TSOs. (ACER, 2013)

According to Thema (2013, p. 7) the European electricity market is characterized as follows:

Indirect buyer-seller connection. Generation, transmission and consumption of electricity are defined disregarding grid configuration.

Transmission obeys physical laws. Electricity flows follow Kirchoff's law and take thus the path of least resistance. Hence, physical flows do not necessarily follow market schedules.

Grid organization, allocation of costs. Bidding zone grids correspond mostly to national borders and TSO control areas. Costs can be therefore distributed accordingly. Since electricity flows do not follow market schedules, the path of least resistance causes external effects such as loop flows and congestion, causing difficulties of cost distribution.

3.2. Congestion

In cases where demand capacity exceeds transmission capacity, congestion occurs. Congestion is legally described as a situation in which "an interconnection linking national transmission networks cannot accommodate all physical flows resulting from international trade requested by market participants, because of a lack of capacity of the interconnectors and/or the national transmission system concerned." (Regulation (EC) No 714/2009, Article 2(2)(c)) According to ACER (2015), congestion can be either structural or physical. Structural congestion is predictable, geographically stable and occurs under usual network conditions. Physical congestion, by contrast, materialises when scheduled flows violate thermal network limits, voltage or overall grid stability.

In general, cross border exchanges need to be scheduled by TSOs at interconnection points, i.e. scheduled flows. Since electricity flows according to Kirchhoff's laws, physical flows may deviate from scheduled ones. Such flows are termed unscheduled flows or more commonly loop flows. Unscheduled physical flows can cause congestion and thus constitute impediments to grid security. Moreover, loop flows can occur in external bidding zones even if the flow was originally caused and scheduled within another control area. As these flows cannot be planned by TSOs, scheduled cross-border capacity must be reduced at each interconnection point to account for possible unscheduled loop flows in order to avoid grid instability. Loop flows further increase the necessity of expensive re-dispatching and countertrading measures to secure flows within network limits. (ACER 2015; Thema, 2013)

Loop flows are thus characterized as negative external effects increasing congestion, system costs and posing challenges to grid security. Further negative aspects include decreased market efficiency, reduced market supply, insufficient incentives and adverse distribution effects. Market efficiency is lacking, since customer costs and generation compensations do neither reflect actual consumption nor delivery. Furthermore, resources are not employed optimally in case loop flows exceed scheduled transit. The major reason for reduced market supply security is the absence of efficient price signals and thus also the absence of incentives for generators, consumers and grid operators. Another reason is the increase in remedial actions necessary to deal with congestion and grid security limits. Lastly, adverse distribution effects are caused by costs incurring to market areas through which loop flows transit, whereas those bidding zones that scheduled the flow save costs. Limiting available capacity at interconnection points to account for unscheduled flows causes foregone revenues of potential scheduled flows. (Thema, 2013)

3.2.1. Congestion Management Measures in Theory

The literature on congestion management measures is versatile. It stretches from pricing techniques to market designs and coordination techniques of remedial actions taken by TSOs. Given the focus of this thesis on bidding zone re-configuration and the magnitude of theoretical congestion methods, the following literature review provides a thorough overview of studies concentrating primarily on coordination, market splitting, curative measures, transmission contracts and price/market designs.

Kumar et al. (2005) provide an overview of existing literature dealing with congestion management techniques categorized as follows: sensitivity factor based methods, auction based congestion, pricing based methods, re-dispatch and willingness to pay methods. To give a brief overview of the breadth of theoretical remedial actions, these four sections are shortly explained in the following.

Linear sensitivity factor based methods propose the calculation of crucial parameters allowing TSOs do deal efficiently with congestion e.g. imposition of transparent and facile indices reporting the efficient level of load curtailment to cope with congestion. Other examples include power transfer distribution factors suggesting the appropriate level of transmission loading relief. Auction based methods are composed of transmission rights, i.e. firm transmission rights or flow gate rights. These can be used to hedge against financial risk of congestion induced price volatility or otherwise to price explicitly congested transmission lines. Pricing based methods include congestion cluster pricing techniques, nodal, local or path-base marginal pricing. The underlying assumption of price-based mechanisms is that congestion costs must reflect the actual degree of congestion such that price signals can be efficiently used to decrease congestion during the dispatch period. Re-dispatch and willingness to pay methods endorse bilateral contracts between consumers and generators, in particular real time operations as well as optimal dispatch agreements under congestion restrictions. (Kumar et al., 2005)

Price-based congestion measures as well as market designs are prominently discussed by a magnitude of scholars e.g. de Vries and Hakvoort (2001), Ding and Fuller (2005) or Oggioni et al. (2012).

Ding and Fuller (2005) study the economic surplus distribution of nodal, uniform and zonal pricing. Particularly, the authors distinguish between a single price charged for all nodes in a transmission network (Uniform Marginal Price, UMP), a set of nodal prices with different prices for each node (Nodal Marginal Price, NMP) and a set of zonal marginal prices with different zonal, but same node prices (Zonal Marginal Price, ZMP). In theory, NMP is the only economically efficient market design, as it takes into account physical laws of power flows and line constraints within the network during dispatch. To the contrary, UMP and ZMP typically ignore such flows as well as constraints and must therefore be modified after dispatch, which in turn increases costs. NMP is thus considered to increase the social surplus compared to UMP and ZMP and is as such more desirable as a market and pricing design. In practice, however, NMP leads to a large set of nodes and thus also to a magnitude of different prices increasing complexity making it thereby less appropriate for reality.

Similarly, Green (2014) introduces a simplified model of the English and Welsh electricity market, in which he compares prices, profits and social surplus in case of nodal, uniform and hybrid prices. The study's results propose an increase in social welfare in case of nodal pricing compared to hybrid and uniform pricing. Furthermore, nodal pricing improves price signals necessary for investments in network expansion and generation as well as it decreases the degree of exercisable market power.

The market design of contract networks takes into account Kirchoff's laws, i.e. "electricity follows the path of least resistance" (Hogan, 1992, p. 215) and thus also resulting loop flows and grid constraints such as congestion or voltage. According to Hogan (1992) contract networks provide an efficient building block for short-term pricing and long-term firm use of transmission grids. While short-term efficiency in terms of transmission prices can be achieved with calculating optimal spot prices, long-term efficiency is guaranteed with contracts attributing firm rights to the transmission system. Grid constraints are dealt with congestion rentals such that the capacity-right holder is indifferent between electricity delivery and payment receipt during settlement.

Another dominant literature branch e.g. Fang and David (1999), Oggioni and Smeers (2010) or Kunz and Zerrahn (2013), discusses the coordination of TSOs and remedial actions within and across bidding zones. Taking into account the European goal of a unified electricity market, efficient coordination among different national TSOs across borders is inevitable.

Given recent developments in electricity transmission such as the increase of renewable energy entering national grids, Kunz and Zerrahn (2013) suggest trans-border coordination among TSOs to decrease congestion costs. Applying a Nash equilibrium model, the authors clearly show that the larger the degree of coordination, the lower the congestion costs. Overall costs increase significantly in case of no coordination, i.e. each TSO is only responsible for its own transmission zone. The authors suggest implementing a common market when coordination needs to be implemented among multiple TSOs. (Kunz & Zerrahn, 2013)

Based upon the currently applied European zonal market design, Oggioni and Smeers (2010) evaluate different degrees of coordination between energy market players and national TSOs. The authors discuss one of the major issues related to zonal market designs being the unequal access to remedial actions such as re-dispatching and countertrading. The study shows that in case of market coupling one integrated TSO represents an efficient market solution. Another option is the provision of multilateral arrangements granting different TSOs equal access to remedial actions with a simultaneous internal market for curative measures. In case of uncoordinated countertrading, TSOs can only take remedial actions in terms of network expansion. Practically, however, national network expansion omitting loop flows can affect other network elements dramatically and thus restrict market integration.

Similary, Oggioni et al. (2012) analyse the degree of coordination in countertrading in more detail by applying a General Nash Equilibrium setting to three different coordination scenarios. As the theoretical optimum of global countertrading, i.e. one or more fully coordinated and integrated TSOs, is politically not applicable, the authors study the alternative, i.e. grid is operated by disparate TSOs. An internal market of countertrading resources represents full coordination providing non-discriminatory access to congestion remedies and equals therefore full optimization. In case the internal market is restricted, line capacity for each TSO can relieve congestion although it might not restore efficiency fully. Eventually, a completely segmented market for countertrading leads to the least efficient results, which in turn can be partially counteracted with a common market for remedial actions.

Further studies such as Fang and David (1999) or Linnemann et al. (2011) take the zonal market approach as given and accordingly discuss congestion measures e.g. re-dispatch and market splitting in more detail to curtail congestion as efficiently as possible.

Fang and David (1999) propose a two-stage model based on coordination and re-dispatch measures to reveal congestion. In detail, the authors suggest transmission dispatches to be measured according to the degree of congestion produced by the flow itself. Based on spot prices, a methodology for transmission dispatch is developed that considers the willingness to pay of avoiding congestion. Thereby, congestion can be counteracted with competition among market participants. In case of congestion those market participants with the highest willingness to pay are granted transmission services. Moreover, the authors give insights into prioritization procedures of transmission flows as well as they emphasize the importance of coordination between market participants, especially TSOs.

De Vries and Hakvoort (2001) provide an economic analysis of congestion management methods, which are split into congestion pricing methods e.g. market splitting and corrective methods e.g. countertrading and re-dispatching. From a short-term efficiency perspective all methods are efficient. In the long run, however, these methods differ in cost distribution, long-term incentives and practical feasibility. Whereas corrective methods are preferable for unexpected congestion and desirable in addition to other congestion curtailment methods, the main disadvantage is the proper allocation of congestion costs. Generators have thus no incentive to adjust their investment behaviour. On the contrary, TSOs are more incentivised by corrective than pricing measures. The authors conclude that neither pricing nor corrective measures can yield the necessary long-term investment incentives. They admit, however, that regulated areas such as the transmission system are easier to incentivise than private generators.

Whereas de Vries and Hakvoort (2001) review the currently major discussed congestion management methods, Linnemann et al. (2011) complement the discussion by analysing network expansion as a congestion curtailment method in addition. While market splitting is regarded as a medium-term method, in which congestion represents the exceptional case, network expansion is considered to be a long-term approach. This way grid stability can be endorsed and the transmission capacity increased. Re-dispatching is deemed a short-term curtailment measure. Given the recent increase of re-dispatching measures, the authors provide an optimization method resulting in optimal constrained transmission dispatch and load generation.

3.2.2. Congestion Management Measures in Practice

Congestion management can be either preventive or curative. Preventive measures limit congestion before it disperses e.g. re-dispatching, counter-trading. Curative measures modify the network topology up to the extent of changing the whole market design e.g. market splitting. Deemed cheaper, safer and quicker to implement, preventive measures are currently predominantly applied. (ACER, 2014) Furthermore, congestion measures can be classified according to the duration of their implementation. Short-term measures are for instance countertrading, re-dispatching and Phase Shifting Agreements (PSTs), medium-term measures include market splitting and change of market design and grid reinforcement and expansion is termed long-term. (Thema, 2013) Based upon this classification, the subsequent overview can be made (Table 1).

Table 1. Overview Congestion Management Measures

Preventive	**Curative**	
Short-Term	***Medium-Term***	***Long-Term***
Re-Dispatching	Market Splitting	Grid investment
Countertrading	Market Design	
PSTs		

The following section provides an in depth overview of congestion management measures taken in practice. Reports and position papers of energy experts within the European electricity industry including amongst others publications of ACER, ENTSO-E, Frontier and Consentec served for this overview. Considering the question of whether or not to refigure existing bidding zones, the findings are ambiguous. The majority of published papers and case studies e.g. Frontier & Consentec (2011; 2013) or BDEW (2013) argues against market splitting, fostering traditional congestion measures based on re-dispatching and countertrading in addition to long-term grid investment. A smaller part of studies e.g. Thema (2013) or Green (2014) claims conventional measures to be insufficient, making market splitting or market design modification inevitable. The following section assesses the individual measures according to market efficiency, market power, liquidity and price signals. Starting from preventive short-term measures, the overview continues to medium- and long-term curative measures.

Briefly said, re-dispatching is the adjustment of generation output made by TSOs. (de Vries & Hakvoort, 2001) Generators whose power plants contribute significantly to congestion must reduce their power contribution upon request by the incumbent TSO. Conversely, generators whose plants relieve congestion are instructed to increase production such that the energy balance remains constant. Depending on the selection criteria for choosing the generator subject to re-dispatch, the congestion measure is termed market-based or cost-based re-dispatch. (Frontier & Consentec, 2011) The latter approach is more commonly used as it reflects costs of available generation and opportunity losses and is thus easy quantifiable. Market-based approaches, on the other hand, are used less as they increase locational market power of individual generators especially in smaller bidding zones. (ACER, 2014)

In case of countertrading, TSOs initiate a cross-border exchange between two adjacent bidding zones to cope with congestion. For this exchange, TSOs buy and sell electricity at the intraday market such that the amount of power within the individual TSO’s bidding zone decreases congestion. (ACER, 2014; Frontier & Consentec, 2011)

Although ENTSO-E (2012) claims re-dispatching and countertrading to be already exploited completely, Frontier and Consentec (2013) argue in favour of re-dispatching. From a regulatory perspective, re-dispatching causes substantial costs and social welfare losses and is thus not desirable as a primary remedy against structural congestion. BMWi (2014) for instance argues that re-dispatching and countertrading are only an interim solution for the current congestion issue in Germany. Market players, however, suggest bidding zone and market design not to be judged on the extent of re-dispatching costs. Accordingly, reducing re-dispatching and countertrading measures cannot increase social welfare. (Frontier & Consentec, 2013) On the other hand, re-dispatching and countertrading may entail substantial costs in case of serious congestion issues. Both measures do neither provide efficient price nor economic signals. Moreover, they fail to provide efficient investment incentives, since re-dispatching and countertrading costs can be passed on directly to end-customers via an increase in network tariffs. Although both measures may remedy congestion and increase dispatch efficiency, it is deemed unlikely that the present European congestion issue can be optimally solved with solely curative measures. (ACER, 2014; Thema, 2013)

A Phase Shifting Transformer (PST) is supposed to control cross-border electricity flows, it “creates a phase shift between primary (source) & secondary (load) side”. (McIver, 2016, p. 3) The installation of PSTs directly influences physical flows of electricity. It can be thus used to control and limit critical flows at interconnection points thereby securing overall grid stability despite the introduction of new transmission lines. Limiting transit flows through already congested networks means increasing flows on the other side of the installed PST. This increase of physical flows needs to be tackled with additional remedial actions such as countertrading or re-dispatching. (ENTSO-E, 2012) PSTs may impact market prices as the restriction of available transfer capacity increases the price for cross-border exchanges at interconnectors subject to virtual or physical PSTs. From a critical perspective, PSTs are not considered to provide sufficient incentives for efficient alteration of generation and load, as well as they do not provide long-term investment incentives. In conclusion, PSTs are considered a short-term remedial action installed in addition to other remedial actions to decrease congestion and loop flows at critical lines with the major detriment of shifting these problems elsewhere in the network. (Thema, 2013)

Turning to medium-term curative congestion management measures, the reconfiguration of existing bidding zones provides a viable solution to decrease congestion. Being not very popular amongst market players, it is currently widely and prominently discussed in the energy field since ACER's resolution in 2015 to split the German-Austrian bidding zone. (ACER, 2015) Opinions on and possible consequences of a reconfiguration of one larger bidding zone to several separate ones are ambiguous. Supporters of splitting bidding zones argue that a new zone configuration is better able to address the loss of social welfare due to congestion and loop flows. The delineation of existing borders may reduce discrimination amongst network users stemming from limited cross-border capacities. It further allows cost transparency in case countertrading and re-dispatching measures are applied. The reconfiguration further allows efficient market prices and signals, especially locational ones, leading to more efficient dispatch of generation and load. Any kind of price differences between disparate bidding zones can be hedged against with financial transmission rights. (ACER, 2014; Frontier & Consentec, 2011; Thema, 2013)

Opponents of the market splitting idea argue that smaller bidding zones increase market concentration by providing room for locational market power. Larger bidding zones foster competition in the retail market such that hedging against locational price differences becomes obsolete. Smaller bidding zones are associated with less market liquidity. Even if the new bidding zones are connected by efficient interconnection points, the number of market participants as well as the level of electricity supply and demand decrease within the new bidding zones providing room for locational market power. The decreasing market depth and trust may further have a negative impact on investment signals. Moreover, the reconfiguration implies substantially higher transaction costs than the merger of existing bidding zones. Another line of argumentation is that splitting zones cannot alleviate loop flows, which in turn means that expensive curative actions will still be necessary. (BDEW, 2013; Consentec, 2015; Frontier & Consentec, 2011; 2013)

A more rigorous congestion management measure is to alter the market design, i.e. pricing scheme. Currently, the European electricity markets apply zonal pricing. Congestion is mainly tackled with the calculation and allocation of cross-zonal transfer capacities, remaining congestion is coped with curative management measures. Whereas zonal pricing defines limited geographical areas in which trading takes places without constraints, nodal pricing restricts trading at each node, i.e. physical location within the network at which energy is either injected or withdrawn. The price at each node thereby equals the locational value of electricity. In a nodal system each quantity and bid price of every single generator is weighted against its impact on the physical transmission network. Zonal pricing, by contrast, takes only export and import amounts into consideration. (ACER, 2013; Phillips, 2003)

Nodal pricing is considered first best, because the electricity price at each node in the network represents marginal costs of electricity provision at this specific node. Nevertheless, it has been seldom adopted in practice. Only New Zealand, Chile and a handful of US power pools endorsed nodal pricing, whereas the magnitude of markets, especially the European, adopted the simplified market design of zonal pricing. (Green, 2014) Due to its nodal generation approach, nodal pricing is theoretically the ideal measure to relieve congestion where necessary. Power plants near congested lines have for instance a stronger impact on congestion. In case the market design is nodal such congested lines can be easily detected and tackled with congestion relief. The zonal approach, by contrast, does not include this information in its merit order. Although nodal pricing constitutes first best pricing and thus an optimal congestion management method, it contradicts the European target model of an integrated electricity market. (Frontier & Consentec, 2013)

A more long-term congestion management measure is grid investment, which is considered by almost every stakeholder to be a mandatory process. (ACER, 2014; BDEW, 2013; Frontier & Consentec, 2011; 2013) Since it exhibits a tedious measure, other remedial actions are necessary at the same time to cope with pending structural congestion. Investments in the transmission network need to be coordinated on a regional and European level according to the dependency of physical flows on disparate interconnection points within the area. (Thema, 2013)

3.3. Resolution to split the DE-AT Bidding Zone

Due to the strategic geographic position of the German-Austrian bidding zone in midst Europe, the bidding area hosts a substantial amount of cross-border flows. Apart from its locational importance, the bidding zone's strategic importance is fostered by its size and market liquidity. In comparison to other European electricity markets such as France, Italy or the NordPool market, the DE-AT bidding zone exhibits the highest churn rates, i.e. "volume of traded products divided by annual demand" (Frontier & Consentec, 2011, p. 24) Churn rates are commonly used to measure market liquidity as well as the number of market participants and market depth in terms of derivate product ranges. (Frontier & Consentec, 2011)

In regard to electricity demand, the DE-AT bidding zone represents the largest zone within the CEE region e.g. electricity consumption amounted up to 65 percent of total annual consumption in the CEE region in 2013. Considering cross-border trade, the joint bidding zone represents again the largest trading zone in the CEE region. In relation to other cross-border exchanges in the CEE region, intra-zone trading amounted to 26 percent (2011) and 40 percent (2014). (ACER, 2015)

In its opinion report whether or not to split the joint bidding zone, ACER (2015) shows the extent to which the increasing intra-bidding zone trade causes loop flows and congestion in other network elements by calculating the Pearson correlation coefficient. The statistical analysis clearly shows that the cross-border exchanges between Germany and Austria correlate significantly with unscheduled flows at the Polish-German border.

According to ACER's Market Monitoring Report (2015a) unscheduled flows increased at the following borders between 2013 and 2014 as shown below in Figure 2.

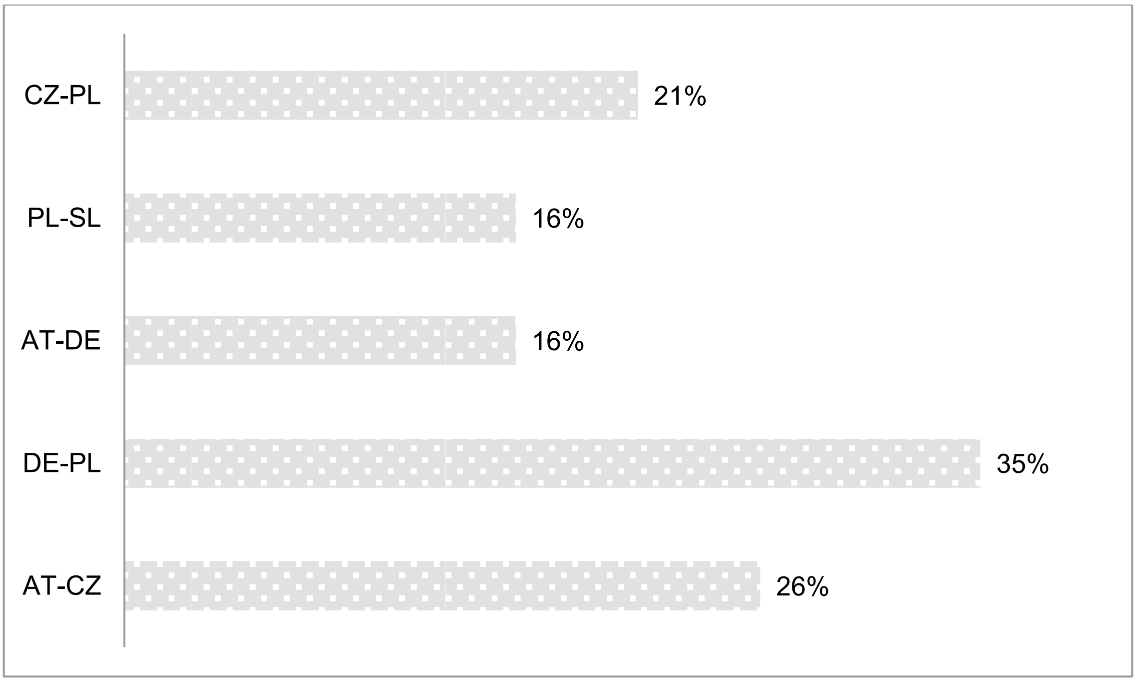

Figure 2. Increase of Unscheduled Loop Flows between 2013-2014 in %. Source: ACER, 2015a

These unscheduled loop flows curtail available net transfer capacity and increase uncertainty considerably whilst planning. Especially the DE-PL, PL-CZ and AT-CZ borders are affected by the absolute value of unscheduled flows. Loop flows at the German-Polish border restricted available cross-border capacity up to

1.780 MW in 2014. The Czech-German cross-border trade capacity was also reduced by roughly 1.150 MW. Another major curtailment of available transfer capacity can be detected at the Austrian-Czech border, decreasing available capacity by 1.837 MW in 2014. Although the calculated welfare loss attributed to unscheduled flows decreased from 2013 and 2014 by 10 percent, the welfare loss at the GER-POL border still increased by 129 million euros. (ACER, 2015a)

In its resolution opinion, ACER (2015) examines the severity of trade consequences between Germany and Austria on neighbouring network elements. The agency concludes that a significant amount of DE-AT intra-zonal trade was realized through neighbouring network elements in the CEE and CWE region. On average, only 51.8 percent of German-Austrian cross-border flows were realized at the respective border, ceteris paribus slightly less than 50 percent of flows result in bypassing other countries.

ENTSO-E (2014) defines critical congested areas in the CEE region. For the purpose of this Master's Thesis, only the necessary congested lines are presented to evaluate according to ACER (2015) the decision to split the DE-AT bidding zone. Notably, the most congested lines appear to be at the German-Polish, Czech-Austrian and Czech-Polish border e.g. Krajnik (PL) – Vierraden (DE) in both directions or Slavetice (CZ) – Dürnrohr (AT) in both directions.

The reasons for congestion within the respective clusters are various. Congestion directly at the borders of Germany stem mainly from steep increases in physical flows from German TSO 50Hertz to Poland in correlation of high generation periods within the TSO's control area. Another reason pose unscheduled transit and loop flows from 50Hertz to the Czech to accommodate for physical flows from northern to southern Germany. Increased production in northern Europe combined with high load from southern Europe such as Hungary, Balkan and Austria cause loop and transit flows at the Czech-Austrian border. Another threat causing congestion in various areas is the high import level of southern CEE countries such as Austria, Hungary and Slovenia. (ACER, 2015; ENTSO-E, 2014)

The point is, that the joint bidding zone not only causes congestion at the respective borders to neighbouring countries, but also in network elements within the neighbouring country itself and at their borders to other countries. In contrast to Austria, Germany struggles further with congested inner lines. These include transmission lines Wolmirstedt – Helmsted, Remptendorf – Redwitz and partially Mecklar – Vieselbach. (ACER, 2015; 2015a; ENTSO-E, 2014)

To summarize, the German-Austrian bidding zone unintentionally increases structural congestion in the CEE region as well as it causes loop and transit flows within the common zone itself, at borders to neighbouring countries and within neighbouring countries and at their respective borders. The reasons for this are ambiguous, yet the most discussed and probable is the German Energy Transition from nuclear towards renewable energy and the subsequent increase of renewables in particular feed-in tariffs from the North. Another cause for congestion is the insufficient transmission network within Germany as well as its slow expansion procedures relative to the rapid increase of renewable energy. (BnetzA, 2016; Consentec, 2015; Thema, 2013) These two causes are discussed in more detail in section 2.3.

Given the critical situation of already persistent congestion within the CEE area and the fact that the common bidding zone causes unscheduled flows in neighbouring and further countries, led ACER to the resolution to split the DE-AT bidding zone. Although there is actually no physical congestion at the national borders between Germany and Austria, the joint bidding zone is supposedly causing tremendous congestion in neighbouring network elements. ACER, therefore, suggests the implementation of coordinated capacity allocation measures at national borders between Germany and Austria to ease the tense situation within the CEE region and tackle structural congestion more efficiently. (ACER, 2015) The introduction of capacity allocation measures at the DE-AT borders equals splitting the only functioning European transnational electricity price zone. (BnetzA, 2015)

3.3.1. Implementation of Coordinated Capacity Allocation Measures

Based upon Regulation (EC) No 714/2009 and Annex I CACM Guidelines, coordinated congestion measures need to fulfil the following requirements to be enacted. (ACER, 2015)

Competition Enhancing. Requests for cross-border flows with the highest monetary value must be granted. In case of lacking capacity to accommodate all requested cross-border flows, exchanges with the lowest monetary value shall be denied.

Economic Signals. Depending on congestion contribution, every cross-border request is imputed congestion costs. The allocation of congestion costs appropriate to congestion contribution is indispensable for efficient economic signals relating to network investment, electricity consumption and generation.

Non-Discrimination. Interconnection points that are not congested hold priority rights for cross-border exchange requests. Exchange requests at congested interconnectors are granted based on capacity calculation, which in turn depends on the degree of congestion within the specific network.

Transparent Congestion Management. Congested network elements must publish information regarding their capacity calculation, limitation of cross-border trade and allocation of scarce capacity to requested flows. This way transparency can be assured as well as coordinated capacity allocation measures can be implemented objectively and proportionally to network and monetary value of cross-border exchanges.

ACER (2015) justifies its decision to split the DE-AT zone by arguing that since there is no actual physical congestion at the German-Austrian border, cross-border exchanges may flow unconditionally and regardless limited capacity. Although the requested cross-border flows contribute to congestion in the CEE region, each requested cross-border flow is granted irrespective of its monetary value. Consequently, congested networks have to deny flows due to lacking capacity, which might have a higher monetary value than flows granted at the DE-AT border. Moreover, the absent congestion at the DE-AT border blurs the efficiency of economic signals of congestion costs.

Whereas exchanges between Germany and Austria are granted assuming no congestion costs, other cross-border exchanges are denied due to inordinate higher costs. Subsequently, the disproportionate allocation of congestion costs results either in over-investment or in omissions of necessary investments. Furthermore, the absence of capacity allocation measures at the German-Austrian border fosters discrimination against exchange requests at other borders in the CEE region. The lack of actual congestion gives DE-AT priority rights to carry out cross-border exchanges within the scarce CEE transmission network. Congested network elements, however, can thus only use the remaining capacity. This imbalance results in discrimination of market participants requesting cross-border flows at different interconnection points in the CEE region and those requesting flows at the DE-AT border. Concerning transparency of congestion management, the common bidding zone reports congestion and critical levels of load flows scarcely. ACER has, therefore, major concerns regarding transparency at the DE-AT border. (ACER 2015)

3.3.2. Case Studies on Bidding Zone Reconfiguration

The reconfiguration of existing bidding zones within the European electricity market has been already discussed before ACER announced the implementation of capacity allocation measures between Germany and Austria. Multiple reports and opinions including case studies were published examining possible bidding zone formations e.g. Frontier and Consentec (2011), Drees et al. (2012), Thema (2013) or Consentec (2015). This section gives an overview of existing case studies in the field of market splitting.

Ofgem (2014) argues that the reconfiguration of existing bidding zones should be carried out depending on the market design. In case of nodal pricing, the number of bidding zones is extreme. This is because any generator represents an individual node and thus also one bidding zone at which the price reflects the short-run marginal costs of electricity generation and transmission as well as congestion. Zonal market designs, on the other hand, are clustered according to similar prices in different regions. The number of bidding zones depends eventually on the dispersity of prices between disparate regions as well as on grid constraints.

Moreover, the authors conduct a literature review, in which they delineate crucial factors to be considered in case of existing areal reconfigurations. Accordingly, splitting existing zones triggers a trade-off between meshed and complex factors such as price signals, investment incentives, efficient network usage, market power and cross-border flows. Eventually, the study poses further crucial questions for future research covering topics such as treatment of existing interconnection points after bidding zone delineation, treatment of access rights between previously common zones, reference prices and implementation costs. (Ofgem, 2014)

Frontier and Consentec (2011) examine the consequences of splitting Germany along the most congested line Remptendorf – Redwitz into a northern and a southern bidding zone, excluding Austria for analysis purposes. Given distribution of electricity generation and load patterns, i.e. demand-exceeding production in the North and demand-inferior production in southern Germany, the northern bidding zone is expected to be a low-price area and the southern a high-price area. Any congestion within the two zones is tackled with cost-based re-dispatching, as market splitting cannot eliminate internal congestion fully. The assessment of splitting Germany into two zones is negatively afflicted. Starting with market power, the study concludes that market concentration ratios will approach the 50 percent threshold of the EU Merger Guidelines in both zones. Considering locational signals, the study supposes that a reconfiguration would result in regionally different price signals favourable for locating new gas- and coal

–fired power plants along the Rhine, albeit the strength of such price signals remains unclear. The reconfiguration will cut current incentives for congestion cost reductions and network expansion. Further consequences suggested are neutral to negative effects on market liquidity and an increase in transaction costs due to changes in market design. Expected favoured groups will be low-price consumers in the North and high-price producers in the southern zone and vice versa. The reconfiguration will, thus, provoke political discussion and resistance from affected stakeholders. (Frontier & Consentec, 2011)

Drees et al. (2012) quantify the impact of a DE-AT split on the transmission grid in the CEE region for 2016 and 2022. Based upon market and network simulation and hourly determination of feed-ins and loads, the study shows that a resolution of the common bidding zone will not solve the congestion problem within the area. In case of no network expansion and no reconfiguration, the authors argue that the already substantial exchanges between northern and southern Germany as well as the flows from southern Germany to Austria will soar dramatically compared to 2010. Unscheduled flows via the Czech Republic and Slovakia are supposed to increase too. Even if the split takes place, the authors cannot prove that it will result in a reduction of exchanges between Germany and Austria as well as it might not prevent unscheduled and transit flows via neighbouring countries. Overall, the changes in flow patterns and transfer volumes are not supposed to change significantly. Therefore, the authors suggest re-dispatch issues and congestion be mainly solved with large-scale transmission line upgrades from 220 kV up to 380 kV lines and further development of electrical super highways within Germany. This might have a lowering impact on electricity prices, since decreased re-dispatching expenditures simultaneously imply a reduction in end-customer network tariffs.

Thema (2013) conducted a market simulation model examining optimal dispatch subject to a set of constraints for the year 2013. As the simulation model tracks scheduled flows, it is possible to estimate consequences of market changes. The authors modelled four scenarios of which one was the reconfiguration of the common bidding zone in three separate ones, i.e. Austria, northern and southern Germany. The underlying assumption is that current spot prices do not reflect local demand and supply such that the North generates more energy than the South resulting in lower (higher) northern (southern) prices. In contrast to no market splitting, a reconfiguration would initially lead to a price increase, but in the long-term be lower than the price in case of no splitting. A clear price increase (decrease) for southern (northern) Germany in case of lower available transfer capacity is identified. The price difference, however, decreases with larger available transfer capacity values. These findings support the results of Frontier and Consentec (2011).

In contrast to Thema's (2013) approach, which considers efficient price signals a fundamental reason for market splitting, Frontier & Consentec (2013) argue that price signals are only one of many decision criteria that must be taken in to account. The authors conduct an economic evaluation to assess major trade-offs of market splitting. The results propose market splitting to cause substantial welfare losses by decreasing market liquidity due to smaller bidding zones and thus less trading partners. This may result in inefficient or even less of crucial investments. Similar to Frontier and Consentec (2011), the authors predict an increase of market concentration in the spot and forward market and impediments to retail competition causing market exits and creating entry barriers to bidding zones. Creating smaller bidding zones inherits transaction costs and cannot assure efficient price and investment signals. A reconfiguration of an existing bidding zone may, thus, affect the electricity price due to decreased market liquidity, a simultaneous increase in transaction costs and risks and especially by limiting retail competition and increasing market concentration. (Frontier & Consentec, 2013)

The negative effects of market splitting are further discussed by Consentec (2015), which qualitatively assess a potential redefinition of bidding zones in Germany according to liquidity, market power, static and dynamic efficiency. The authors conducted numerical simulations of scheduled dispatches and re-dispatches under uncertainty. Similar to Frontier & Consentec (2011; 2013), the study results in overall negative consequences e.g. increased market power or reductions in liquidity. From a static efficiency point of view, the consequences of a reconfiguration are supposed to be modest, since smaller bidding zones still need curative measures to manage congestion. Dynamic efficiency yields mostly negative results. Network expansion can be affected, as already planned network expansion plans may not be synchronised with actual reconfiguration lines. Furthermore, a split may result in substantial transition costs and lead to less efficient investment incentives as smaller bidding areas with less congestion do not provide the same need for grid expansion as larger zones. Overall, a split may entail significant distribution effects. In general, larger bidding zones have an optimised outturn dispatch within the zone itself, which in case of splitting becomes a cross-zonal exchange area. The study projects increased wholesale prices and thus also a surge in consumer end-prices. (Consentec, 2015)

In the Nordic market, bidding zone reconfiguration is commonly used as a congestion management method in case re-dispatching and countertrading becomes too costly. The Norwegian power market is split in five, Sweden in four and Denmark in two bidding zones. Although prices between bidding zones may differ, the spread is minimal. Within the Swedish bidding zones one to three equal prices can be observed in 95 percent of hours, the fourth bidding zone has slightly different hourly area prices differing up to 10 percent relative to other bidding zones. Accordingly, the average price difference between the third and fourth bidding zone amounts to EUR 1,60/MWh. In case of Norway however, the average price difference between the third and fourth bidding zone is more significant amounting to EUR 3,60/MWh. In all other Norwegian bidding zones, the average price is equal in 90 percent of hours. Given the large Norwegian price spreads, the Nordic Pool countries are discussing zonal reconfiguration again. (Thema, 2013a)

Previous studies examining the potential consequences of splitting Germany and Austria concentrate rather on economical factors such as competition, liquidity and transaction costs, than on electricity prices. The research is further versatile, since each study has different market splitting simulations making comparisons difficult. There is also no clear consensus on the effect a delineation of existing zones may have on electricity prices. As shown with the case of Nord Pool, delineations may entail smaller and larger price dispersions between different bidding zones within one country.

4. Empirical Framework. German-Austrian Bidding Zone

Given the magnitude and ambiguity of disparate research designs, current studies and reports lack comparability of potential consequences resulting from bidding zone reconfiguration. An in-depth review of recent dominating literature has been given in section 3, which clearly showed that electricity prices were seldom referred to as the main variable of interest. This section is therefore mainly dedicated to examine possible impacts a split of the joint DE-AT bidding zone might have on German wholesale and household electricity prices by applying the Synthetic Control Method (SYNC).

The following section starts with an introduction of the SYNC method and a short overview of studies applying the method. Data and variables used to examine German electricity prices on household and wholesale level are explained afterwards. After conducting the SYNC method, the results are presented.

4.1. Methodology. The Synthetic Control Method (SYNC)

The Synthetic Control method (hereinafter SYNC) was established in light of two upcoming methodological strands in comparative empirical research in political science. The first debate in recent literature aimed for a connecting point between quantitative and qualitative approaches towards empirical research. In particular, it is demanded to use quantitative methods to simplify qualitative analysis. The second strand in political science literature requested a research design dedicated to select comparison units more effectively to reduce the upcoming of bias. (Abadie et al., 2015)

The SYNC method provides a possibility to complement comparative case studies by enabling quantitative inference without precluding a qualitative analysis with the same dataset. Depicting the method briefly, it is aimed to compare a pre-selected outcome variable between one unit, i.e. country A exposed to a specific event, with similar units unaffected by the particular event, i.e. counterfactual country A. The comparison unit, which is supposed to reconstruct the unit in the absence of the specific event, is comprised of a weighted average of all potential comparison units that best resemble the determined unit, i.e. country A. Special attention is given to the selection of comparison units. Abadie et al. (2015) allege that the SYNC method circumvents the main barrier to quantitative inference, which is the "absence of an explicit mechanism that determines how comparison units are selected" (Abadie et al., 2015, p. 496), by providing a systematic way for the selection procedure of comparison units. The significant importance given to the selection of best resembling units is based on the consequence that not accurately chosen comparison units distort the outcome of the comparative case study. If the units, thus, are not chosen properly, any difference between the units may result from their discrepancies in similarity and may lead further to inconsistent and erroneous conclusions. Whereas previous comparative studies chose units based on aggregate countries or regions, the SYNC method selects comparison units as a weighted average of all potential comparison units that best resemble the unit of interest. (Abadie et al., 2015)

The systematization of the comparison unit selection procedure allows conducting falsification tests, which Abadie et al. (2015) term "placebo studies". The authors distinguish between *in-time placebos* and *in-space placebos*, where the intervention is either reassigned in time or to members of the comparison unit. These falsification tests are applied to test the robustness of the empirical findings. Exercising in-time placebo tests, the SYNC method with the same data set is applied to another time period when the event did not occur. Assuming that for this time period the SYNC method estimates the same or larger effects, the previous findings would result in a non-validation. Applying in-space placebos the intervention is assigned artificially to comparison units not exposed to the intervention of interest. If the test results in same or larger effects, the previous findings would result again in non-validation. (Abadie et al., 2015)

Comparing the SYNC method to a multiple regression analysis, both methods are based upon a linear combination of potential comparison units. In contrast, the SYNC method restricts the sum of comparison units' weights to one preventing extrapolation, whereas the regression analysis allows extrapolation by not inhibiting the sum of weights. The SYNC method further displays the contribution of each comparison unit to the synthetic control. (Abadie et al., 2015)

Abadie et al. (2015) highlight the numerous advantages of the SYNC method. First of all, the systematic procedure of choosing comparison units similar to the unit of interest allows substantial falsification tests as well as qualitative and quantitative examination with the same data set. Moreover, the weighted average of comparison units between zero and one prohibits extrapolation outside the data set. Choosing a set of comparison units instead of an aggregate region or country assures an effective depiction of units best resembling the unit of interest. Despite these substantial advantages, the SYNC method has its limitations as well. Although the method circumvents extrapolation, interpolation bias may occur if the pool of comparison units contains countries or regions substantially different from the unit of interest. Another major limitation is that the method requires a sizeable amount of pre-intervention periods. Otherwise the method cannot assure the comparison units tracking the unit of interest properly.

The most prominent studies using the SYNC method are Abadie et al. (2015), Abadie et al. (2010) and Abadie et al. (2003). Starting chronologically, Abadie et al. (2003) conducted a study using the SYNC method to examine the economic costs of the Basque terrorist conflict. Particularly, the authors showed that the Basque conflict caused substantial decreases in GDP per capita compared to the counterfactual Basque country in absence of the terrorist conflict. The second study by Abadie et al. (2010) assessed the effect of California's Control Program in 1988. The authors prove that the absence of the Tobacco Control Program would have led to a higher consumption compared to the actual case in which the program had been introduced. Finally, Abadie et al. (2015) use the SYNC method to examine the economic costs and the effect of the German reunification in 1990. The economic effect is measured by GDP per capita. The conducted study significantly proves that the reunification lowered GDP per capita for West Germany when compared to synthetic West Germany without a reunification.

4.2. Data Set and Preparatory Empirical Work

The following section provides an overview of data and variables. Given the importance of well-chosen donor pool countries for empirical results and the viability of the method, this section focuses on the selection process of donor pool countries.

4.2.1. Data

The research question of this Master's Thesis is, whether or not the German electricity price changes at wholesale and household level in case of splitting the joint bidding zone. In a next step the magnitude of potential price increases is examined. For this purpose half-yearly German net electricity prices are investigated between 1991 and 2014. Electricity prices are drawn from the Eurostat databank for each country separately and exclude taxes and levies. Given the largest time period of 1991-2014 for which data on household and wholesale electricity prices for most of European countries are available, the dataset consists of the following countries: Belgium, Denmark, Greece, France, Luxembourg, Portugal, Spain and Netherlands (solely for household level).

In order to construct the counterfactual, the following two pre-intervention characteristics are chosen: GDP per capita expressed as constant purchase power parities (PPS) in US Dollars with base year 2010 and electricity consumption per capita measured in kWh per capita. Data for GDP per capita has been taken from the OECD statistics databank. For electricity consumption per capita, data has been drawn from the World Data Bank, except for 2013 and 2015. For these two years, data on electricity consumption and population has been taken from the Eurostat databank and calculated by dividing electricity consumption by population. According to Abadie et al. (2015) the sum of pre-intervention characteristics can include values of the outcome variable in advance of the event in question. Therefore, household and electricity prices are taken as pre-intervention predictors as well. The variables used in the selection procedure are chosen to best resemble Germany in terms of energy related predictors (Abadie et al., 2003). As the joint electricity bidding zone came into effect in 2001, the time span 1991-2001 is termed pre-intervention period and the time span 2001-2014 post-intervention period. This results in 21 pre- and 27 post-intervention periods respectively. Due to the restricted time span only two predictors in addition to the electricity price have been chosen.

4.2.2. Variables

Following the terminology from Abadie et al. (2010; 2015), real Germany is referred to as the *treated unit*, i.e. unit exposed to the event or intervention. The *donor pool* is “a reservoir of potential comparison units” establishing the counterfactual scenario, i.e. Germany representing a single bidding zone. (Abadie et al., 2015, p. 497). Potential comparison units are in this case the pre-selected countries BE, DK GR, FR, LUX, PT, ES and NL. The comparison units are supposed to resemble Germany as closely as possible before the intervention took place. Three pre-intervention indicators, i.e. electricity prices, GDP per capita and electricity consumption per capita, are thus applied to restrict the donor pool and construct a counterfactual Germany as similarly as possible to the treated unit. The intervention of interest constitutes the absence of the joint bidding zone formation between Germany and Austria in 2001. An overview of used variables and data is given below in Table 2.

Table 2. Overview Data and Variables

Variables	Description	Source
Treated Unit	Germany Net Electricity Household and Wholesale Prices in €	Eurostat
Potential Comparison Units	BE, DK GR, FR, LUX, PT, ES, NL (only household) Net Electricity Household and Wholesale Prices in €	Eurostat
Potential Donor Pool Countries	BE, ES, FR, PT, NL (only household) Net Electricity Household and Wholesale Prices in €	Eurostat
Donor Pool (SYNC)	BE, PT Household and Wholesale Level	
Pre-Intervention Predictors	Net Electricity Prices Household and Wholesale Level	Eurostat
	GDP/capita PPS base year 2010 in USD	OECD
	Electricity Consumption/capita in kWh/capita	World Data Bank (1991-2012) Eurostat (2013, 2014)
Intervention/Event	Formation of DE-AT joint bidding zone in 2001	
Pre-Intervention Periods	21 Half-yearly, 1991-2001	
Post-Intervention Periods	27 Half-yearly, 2001-2014	

4.2.3. Selection Process of Donor Pool Countries

The number of countries subject to potential comparison units is restricted by data available in advance to this study. In order to choose an efficient donor pool, the following preselected steps suggested by Abadie et al. (2015) are followed. First of all, countries affected by a similar intervention must be excluded from the donor pool. Second, any country that has been subject to substantial idiosyncratic shocks due to the intervention of interest needs to be excluded. Third, the donor pool must be restricted to comparison units similar to the treated unit. The last steps preclude interpolation bias and overfitting issues.

Concerning the first two steps no country from the potential comparison units was subject to similar or the same intervention and none of them suffered any idiosyncratic shocks due to the intervention in case. For the third step all three pre-intervention characteristics were plotted individually against German data with Excel to evaluate on deviations and their magnitude.

Plotting in a first step electricity prices, Belgium, Spain, Netherlands and Portugal showed the least deviations compared to German electricity prices. Greece, Denmark and France, on the other hand, showed major divergences. Figure 3 shows the plotting of wholesale electricity prices in EUR per kWh for Belgium and Denmark in relation to Germany. As delineated, Belgian wholesale electricity prices are more similar to German wholesale electricity prices than Danish ones.

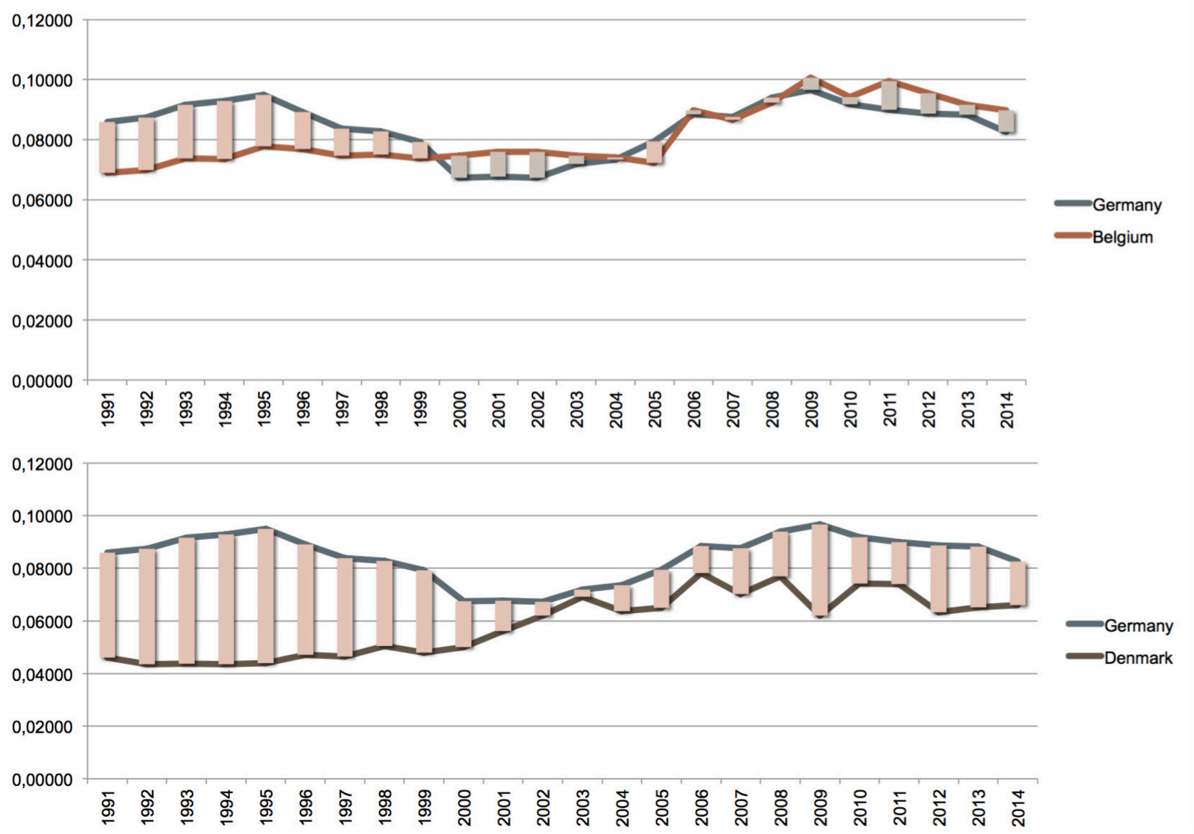

Figure 3. Deviations of Wholesale Electricity Prices in EUR/kWh

Plotting respective data for GDP per capita, the results show that Belgium, Spain, Denmark, Netherlands and France were significantly similar to German GDP per capita than Luxembourg or Portugal. Concerning electricity consumption per capita the same countries as in GDP per capita showed the least deviations when compared to German data.

Eventually, the final donor pool consists of Belgium, Spain, France, Portugal and Netherlands (only for household electricity prices). Although France has significantly lower electricity prices compared to Germany, its GDP per capita as well as electricity consumption are substantially similar to Germany. Portugal, in comparison, has a similar electricity prices, but differs in terms of GDP and electricity consumption per capita. Compared to Luxembourg, Greece and Denmark, the overall deviations of Portugal and France are minor.

Following the three steps of the selection procedure for donor pool countries suggested by Abadie et al. (2015) I assume the selection process of donor pool countries to be reasonable.

4.3. Empirics and Results. Applying the SYNC Method

The SYNC method can be best describes as a method “to use the control group’s outcome to approximate the outcome that would have been observed for the treated group in the absence of the treatment” (Abadie et al., 2011, p.11). Its major advantages are the selection procedure of donor pool countries and the assignment of appropriate weights such that the control unit best approximates the treated unit within the pre-intervention period. Post-intervention characteristics of the proxy are then used for outcome estimations for the unit of interest in absence of the event.

Let J+1 be a sample of units, in this case countries, indexed by j. Taking from Abadie et al. (2015) let j=1 be the “treated unit”, i.e. Germany, and j=2 to j=J+1 the potential comparison units termed in the following *donor pool*. According to the authors, the data set needs to fulfil two major prerequisites. First, all units are observable over the same period of time. In this study the time period spans half yearly from 1991 to 2014. Since all electricity prices have been drawn from Eurostat, the assumption of a balanced data panel set is taken. Second, the sample must include a significant number or pre- and post-intervention periods, which include in this study 21 pre- and 27 post-intervention time slots.

The donor pool is further comprised of a vector (Jx1) of weights W (1) subject to restrictions that the sum of each weight must be either zero or larger than zero (2) and the sum of all weights must be one (3). (Abadie et al., 2015)

(1) $W = (w2 + \cdots + wj + 1)'$

(2) $wj \geq 0\, for\, j = 2, \ldots, J + 1$

$$(3) \qquad w2 + \cdots + wj + 1 = 1$$

Each W represents a particular weighted average of control units thereby representing a potential synthetic control unit. In order to resemble Germany according to the pre-intervention characteristics, appropriate weights are assigned to the each donor pool country. Let X1 be a (kx1) vector comprised of pre-intervention characteristics of the treated unit and X0 the respective for donor pool countries, the minimization of the distance between X1-X0W yields the perfect synthetic control unit W* (4). The predictive power of each pre-intervention variable is pooled in the matrix V, which is chosen such that it minimizes the mean square error of the outcome variable, i.e. electricity price. (Abadie et al., 2011; 2015)

$$(4) \qquad \|X1 - X0W\|v = \sqrt{X1 - X0W)' \, V \, (X1 - X0W)}$$

In order to track the unit of interest properly, a substantial amount of pre-intervention periods is necessary. For the purpose of this thesis, a half-yearly data set is used to enlarge the pre-intervention observations. For the weight selection procedure, yearly data are used because of a lack of proper half-yearly data regarding the pre-intervention predictors GDP and electricity consumption per capita. After the appropriate weights and the synthetic control unit W* is found, the dataset will be stretched half-yearly again under the assumption of constant weights for one year.

The SYNC method will be applied separately for wholesale and end-customer electricity prices with the statistical software R. Following the line of argumentation by Ofgem (2014), any delineation of existing bidding zones carries distributional effects. Accordingly, the average German household electricity price is supposed to decrease given rising net market efficiencies. Considering wholesale prices, the effect depends on the newly drawn borders between bidding zones, but is considered overall allocatively positive given prices reflecting scarcity values better and increasing social surplus. The average wholesale electricity price is, thus, supposed to decrease in export-constrained areas and conversely rise in high-demand areas.

4.3.1. Wholesale Electricity Prices

Applying the SYNC method for German wholesale electricity prices half-yearly during 1991 – 2014, the synthetic control unit is best approximated by Belgium and Portugal given the pre-intervention characteristics wholesale electricity prices, GDP per capita and electricity consumption per capita. Accordingly, 55 percent Belgian and 45 percent Portuguese data best approximate synthetic Germany (Table 3).

Table 3. Synthetic Control Weights, Wholesale Electricity Prices

Country	**Synthetic Control Weight**
Belgium	0,55
France	0
Spain	0
Portugal	0,45

Unfortunately, the synthetic control and the treated unit do not correspond very well to each other as can be seen in Figure 4.

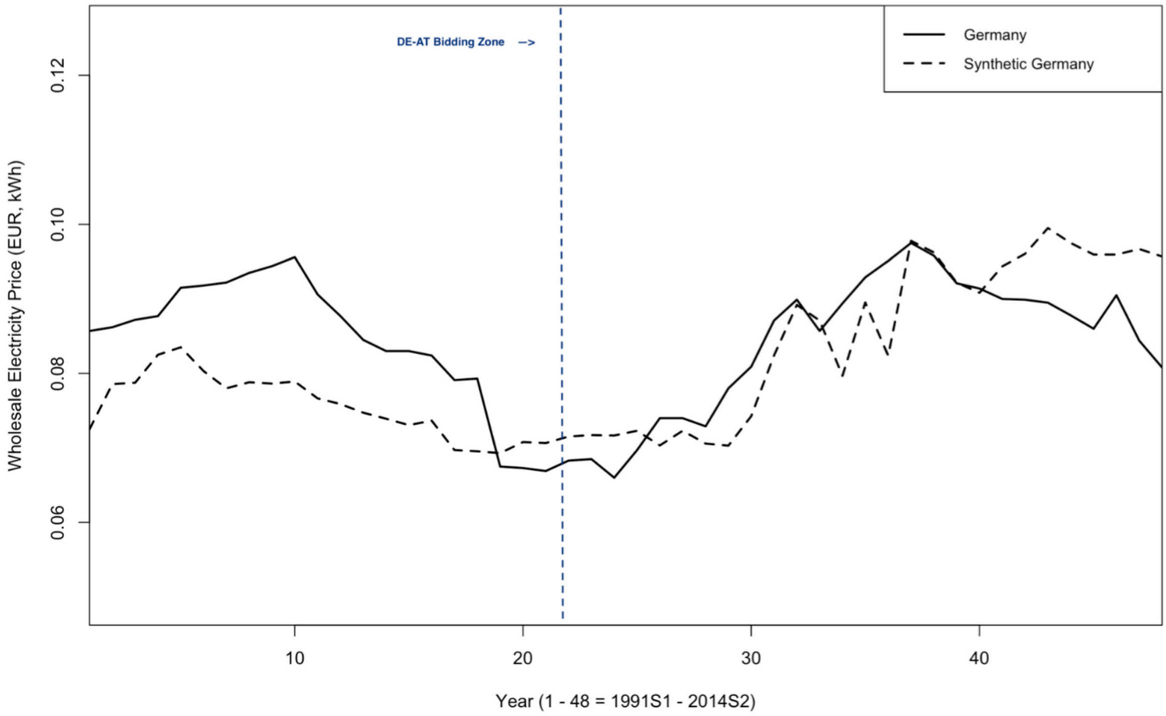

Figure 4. Trends in Wholesale Electricity Prices per kWh

For the pre-intervention period, i.e. until 2001 S1 = 21, the dotted line and the full line are not near each other, but rather characterized by significant interruptions. This means, that the present data set and resulting control unit cannot approximate the treated unit very well. Therefore, the following statements regarding the wholesale electricity price are to be read with great caution. After the event of interest in 2001 S1 (21), the wholesale electricity price is at first higher for synthetic Germany than for the treated unit. From 2003 S2 (26) to 2008 S2 (36) the synthetic price is roughly lower than the real German electricity price, until it increases after 2009 S1 (37) again and remains persistently higher than the actual electricity price.

4.3.2. Household Electricity Prices

Conducting the SYNC method to half-yearly household electricity prices during 1991-2014, Germany is again best approximated by Belgium and Portugal as can be seen in Table 4 showing the weights attributed to the synthetic control unit.

Table 4. Synthetic Control Weights, Household Electricity Prices

Country	Synthetic Control Weight
Belgium	0,426
France	0
Netherlands	0
Spain	0
Portugal	0,574

Compared to the analysis of wholesale prices, the synthetic unit approximates household electricity prices slightly better than wholesale prices (Figure 5). The two lines, however, do not fit each other perfectly. Hence any statements regarding the household prices must be read with great care. The synthetic electricity price is almost always below the real electricity price, except for two peaks in 2007 S1 (33) and 2009 S2 (38). A noticeable increase after 2014 S1 (47) can be observed.

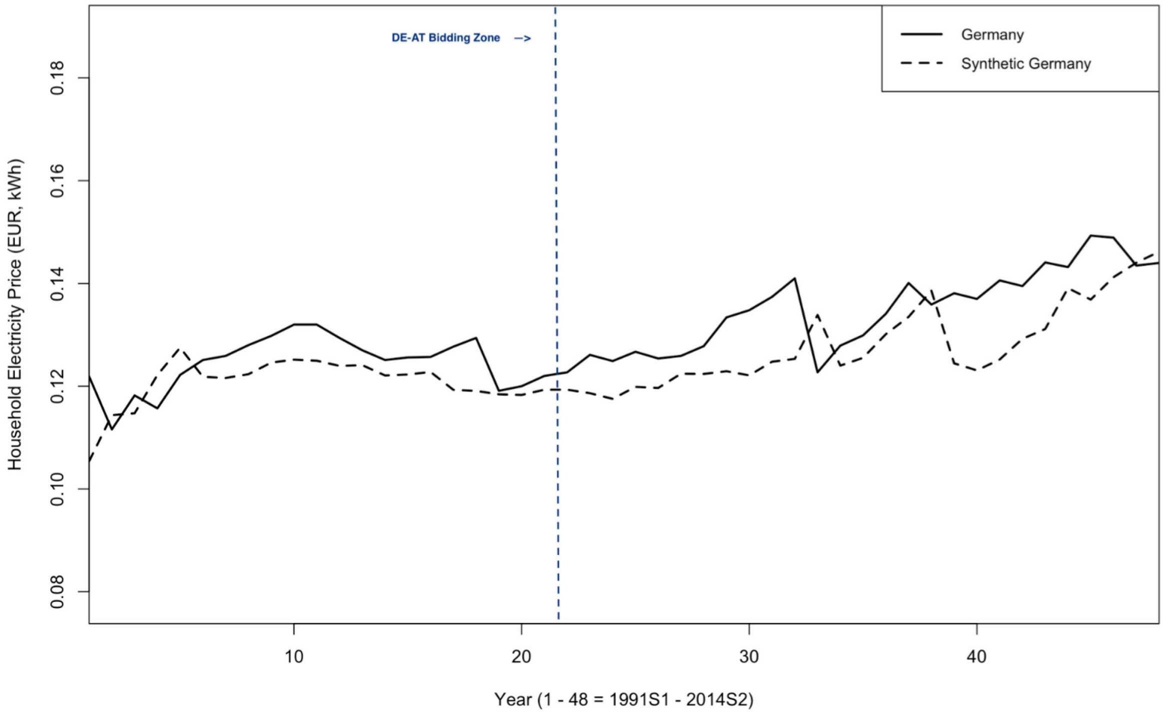

Figure 5. Trends in Household Electricity Prices per kWh

4.4. Placebo Tests

The credibility of the results from section 4.3.1 and 4.3.2 are tested with falsification tests, i.e. placebo studies. For this purpose the event of interest will be first reassigned to each comparison entity of the synthetic control unit. Since the synthetic control unit is best approximated by Belgium and Portugal for wholesale and household electricity prices, the in-space placebos will be done for treated unit being once Belgium and then Portugal. Second, in-time placebo tests separately for wholesale and household prices for the intervention time being 1998 S1 (15). A similar or even larger placebo estimate undermines the results of the previous section, since it cannot be said for sure that the price estimations after 2001 S1 (21) can be attributed mainly to the introduction of the DE-AT bidding zone. (Abadie et al., 2015)

4.4.1. In-Space Placebos

In this section the intervention is reassigned in space, i.e. a different treated unit is selected. Applying the SYNC method to the same dataset of wholesale electricity prices, with the only difference of taking Belgium as the treated unit instead of Germany, the placebo test estimates a larger effect than for the results in 4.3.1., which means that the results are not significant (Figure 6). The same holds when the second comparison unit Portugal is assigned as the treated unit (Figure 7).

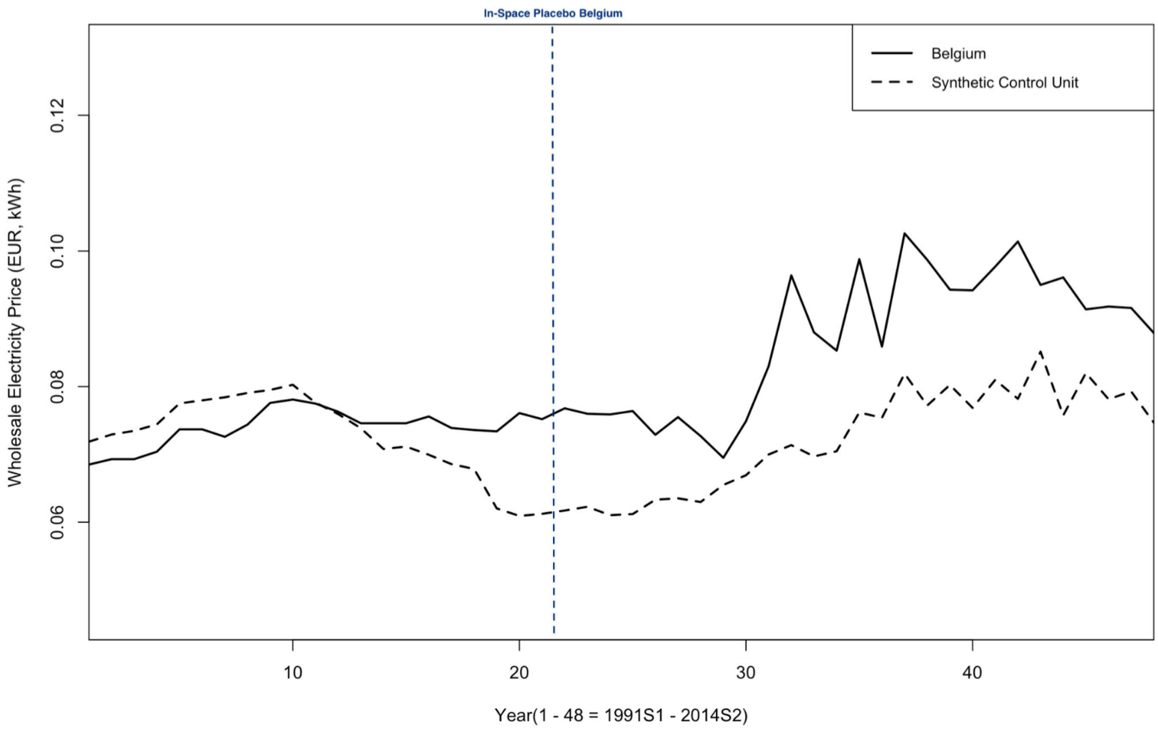

Figure 6. Placebo Trends in Wholesale Electricity Prices per kWh, Belgium

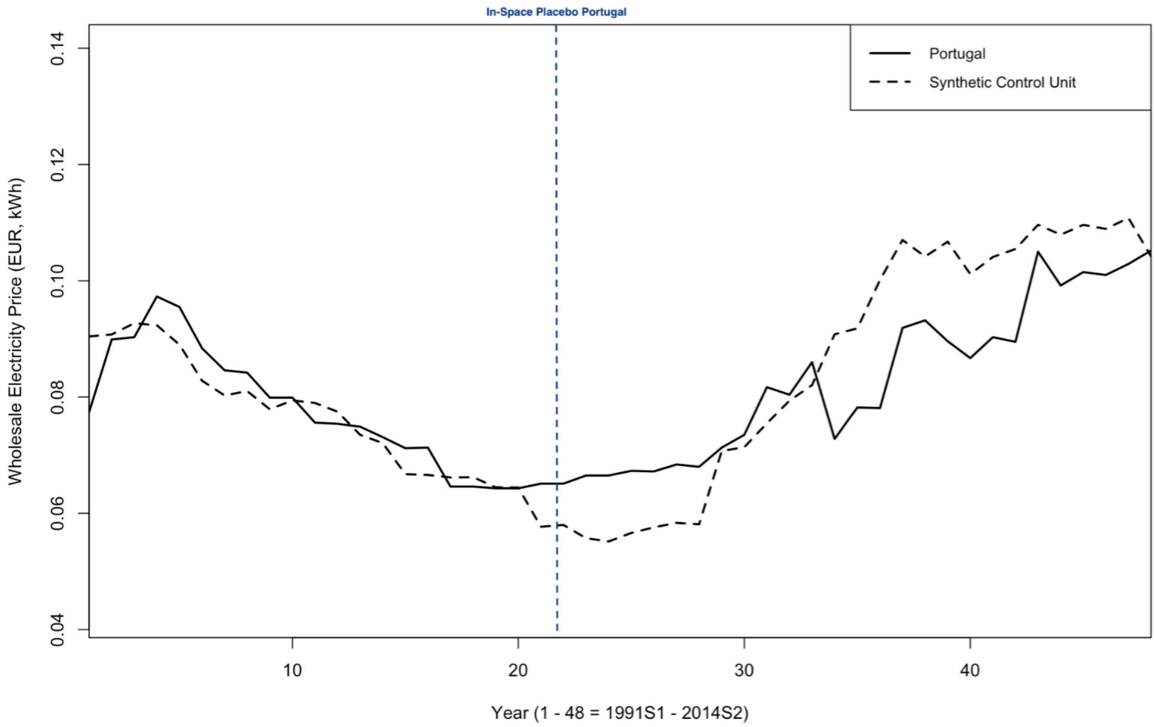

Figure 7. Placebo Trends in Wholesale Electricity Prices per kWh, Portugal

Applying the same placebo tests with the same comparison units to household electricity prices, the placebo tests show larger effects for Belgium (Figure 8) and no clear effect in case of Portugal, as the approximation does not fit properly (Figure 9).

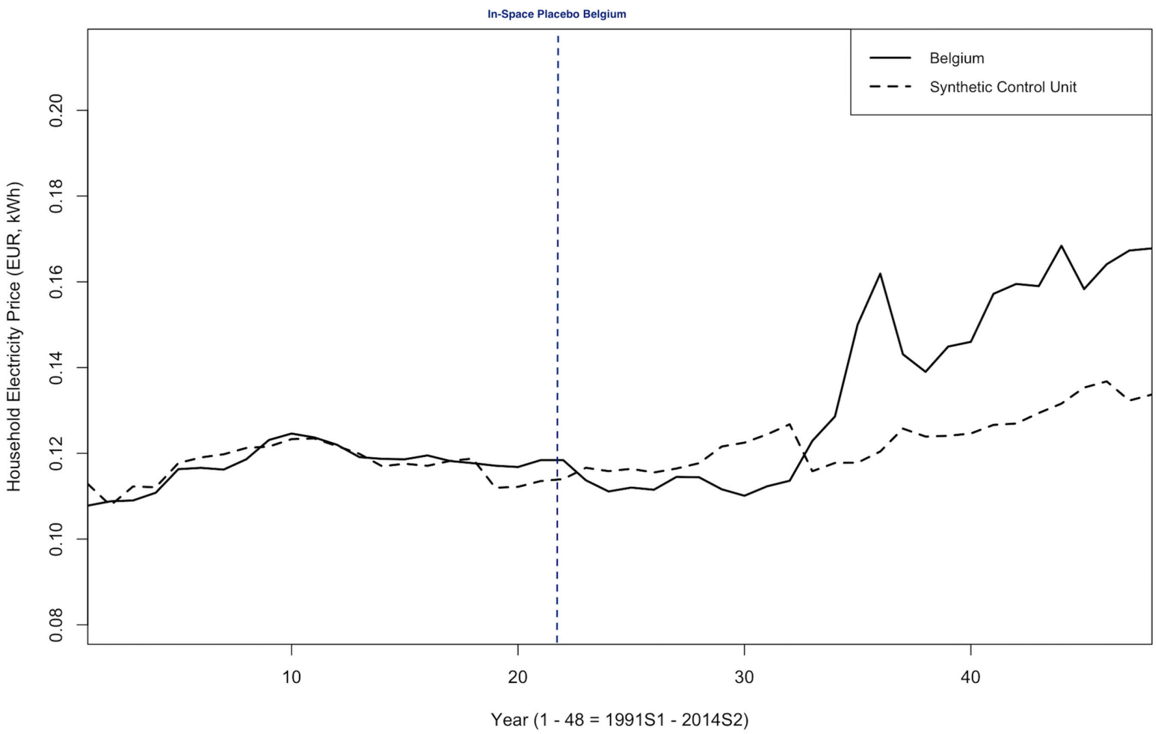

Figure 8. Placebo Trends in Household Electricity Prices per kWh, Belgium

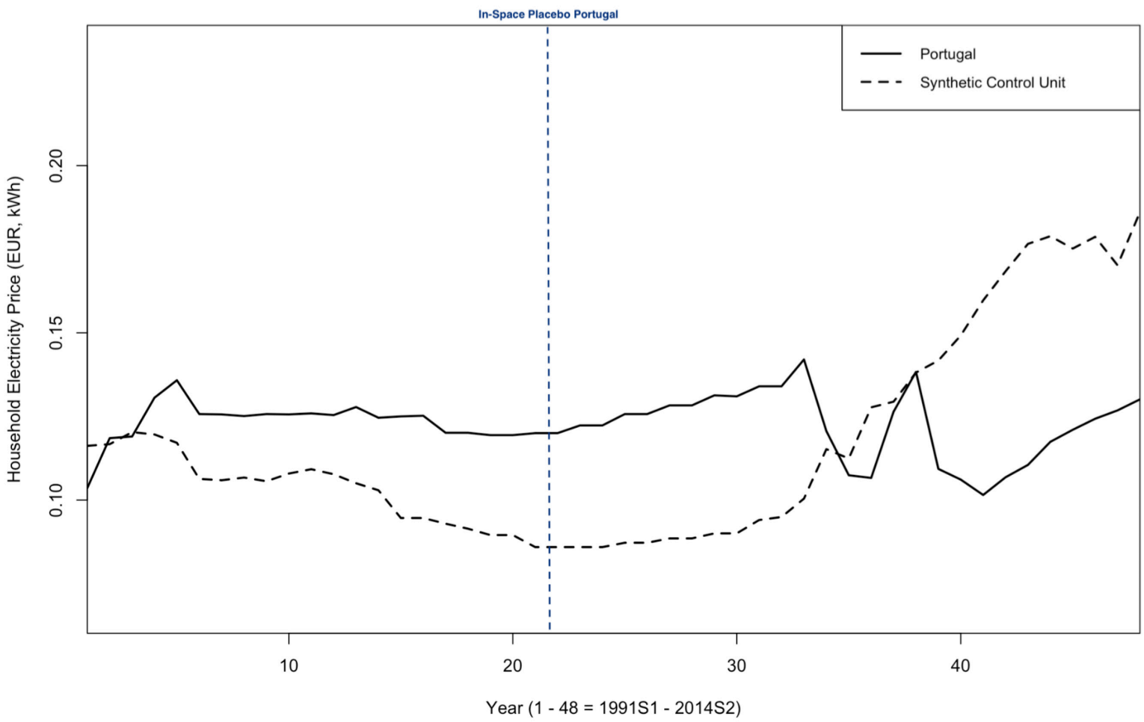

Figure 9. Placebo Trends in Household Electricity Prices per kWh, Portugal

4.4.2. In-Time Placebos

In this section, the intervention is reassigned in time. Conducting the SYNC method with the same dataset for wholesale prices with the only difference of reassigning the time of intervention to 1998 S1 (15), the placebo estimates similar effects for wholesale electricity prices (Figure 10). Therefore, the results in section 4.3.1. are not significant as price estimations after the intervention cannot be surely attributed to the implementation of a joint bidding zone in 2001 S1.

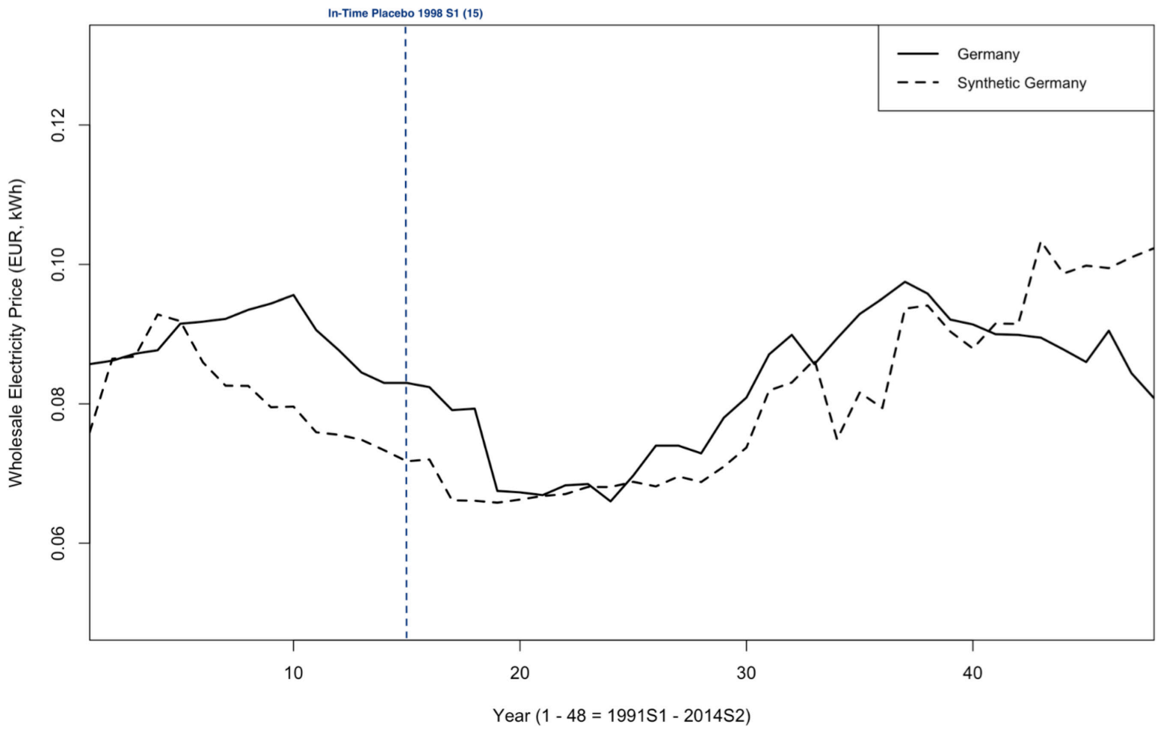

Figure 10. Placebo Trends in Wholesale Electricity Prices per kWh, 1998 S1 (15)

The same procedure and intervention time is tested for household electricity prices (Figure 11). For intervention period 1998 S1 (15), the placebo estimates different electricity prices, which would suggest that the results in 4.3.2. are significant.

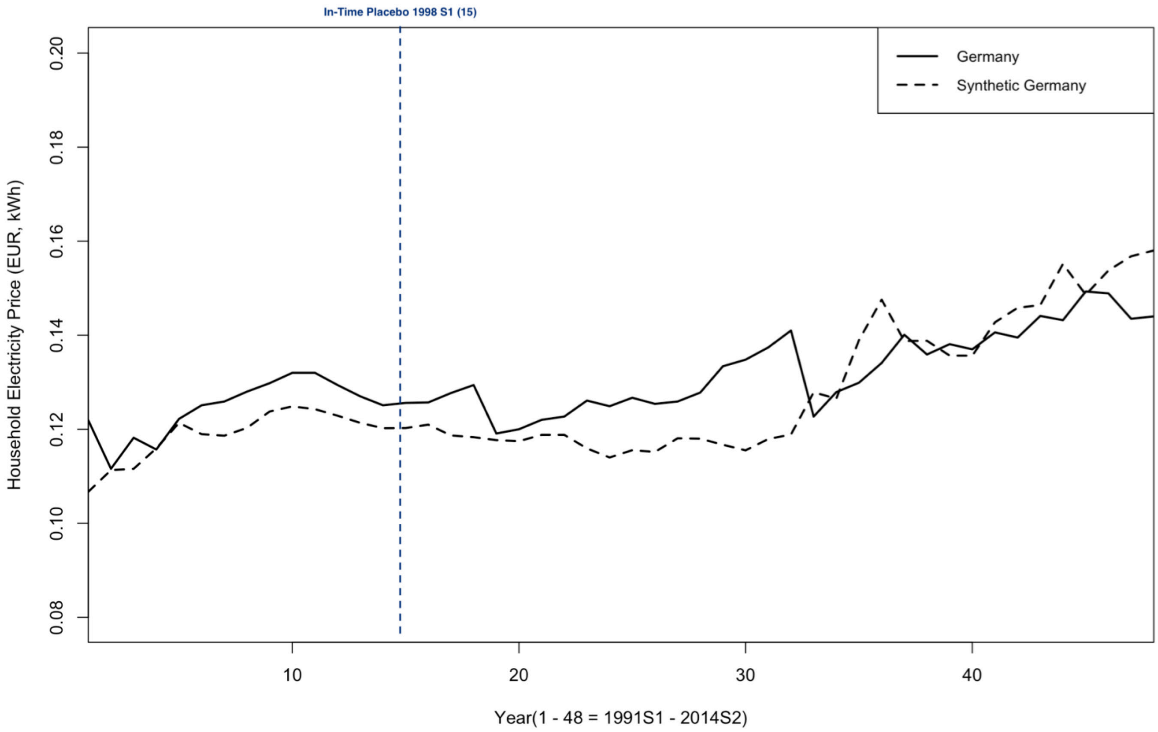

Figure 11. Placebo Trends in Household Electricity Prices per kWh, 1998 S1 (15)

5. Discussion and Limitations

The medial discussion of the pending issue, whether or not the DE-AT bidding zones is to be separated, suggests an increase of electricity prices in case the splitting actually takes place. (Kowalcze, 2015) Unfortunately, the empirical results of this thesis cannot refute the statement of increasing prices, as no significant results could be obtained.

In case of wholesale electricity prices, the approximation of a synthetic Germany did not resolve in expected results, whereas the approximation in case of household prices revealed better results. Considering the falsification tests, wholesale prices failed to provide significant results in terms of in-time and in-space placebo tests. In comparison, household prices result in confident results regarding in-time placebo, whereas the in-space placebo suggests no significant results.

Although none of the results are reasonably significant, household prices are approximated best and the in-time falsification test for household electricity prices is valid, a statement with great caution may be drawn. Considering the expectations of rising electricity prices up to 15 percent, Figure 12 shows gaps as well as the magnitude of price dispersions in EUR per kWh between Germany and synthetic Germany. Albeit higher prices in 2007 S1 (33) and 2009 S2 (38), the synthetic control unit has steady lower prices compared to real household prices, which assumes that the implementation of a joint bidding zone increased electricity prices. The magnitude of the price difference ranges from -0,01 EUR/kWh to +0,015 EUR/kWh.

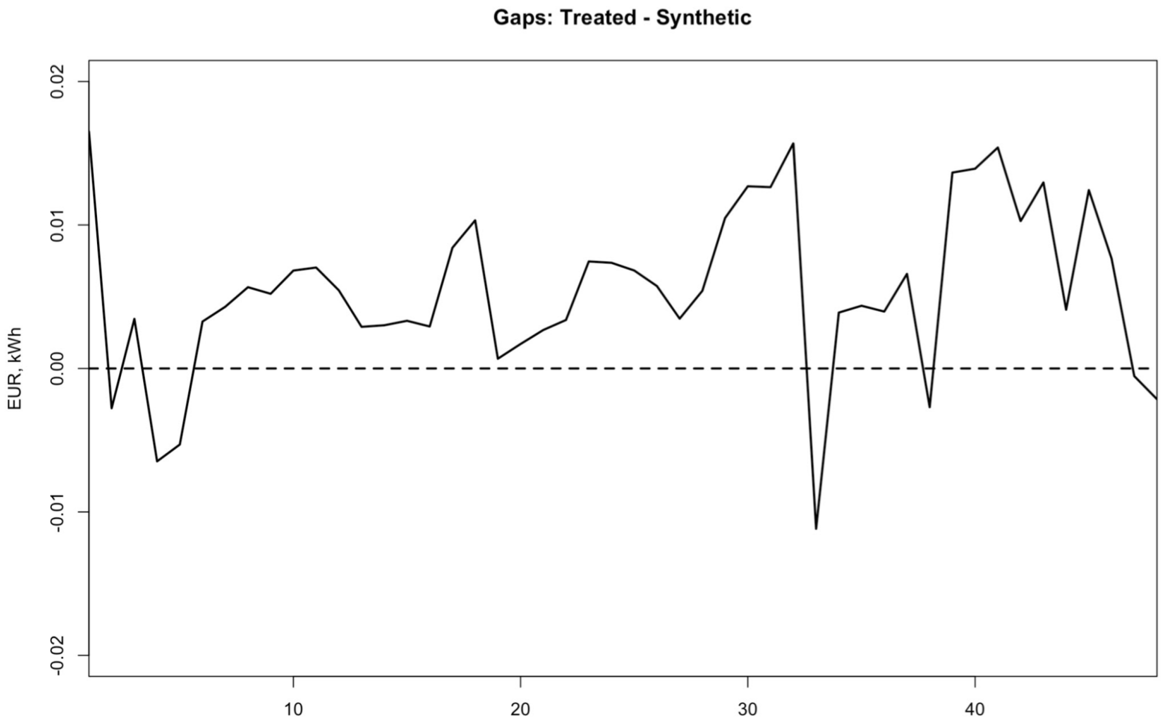

Figure 12. Gaps in Household Electricity Prices per kWh between Synthetic Germany and Germany

It should be noticed that in 2014 S1 (47), the electricity price of the synthetic control unit rises above actual household electricity price. Comparing the results of household prices with the theoretical argumentation by Ofgem (2014), the resulting prices are in line. On average, the German household electricity price is supposed to decrease, which can be observed in general in Figure 5, despite two higher price peaks in 2007 S1 (33) and 2009 S2 (38). Given the fact that the results for household prices are generally in line with the theoretical argumentation in case of bidding zone reconfiguration, the results suggest the opposite of the predicted price increases in case of splitting the DE-AT bidding zone. Moreover, it shows that after 2001 S1 (21) the synthetic electricity price is steadily lower than the actual German electricity price.

The conclusions drawn above are, however, not completely significant. Therefore, they must be read with great caution and care. The insignificance of the results may be given due to the following possible limitations.

First of all, the synthetic control unit obviously lacks predictive power. Table 5 and 6 below show the pre-intervention predictor means before the implementation of the bidding zone. Looking firstly at wholesale prices, Table 5 shows that the calculated values for synthetic Germany do not correspond well to values of real Germany. In case of GDP per capita the sample mean achieves values closer to real Germany than the synthetic unit, which is detrimental. In terms of household predictors means (Table 6), the mean value for GDP per capita is again closer to real Germany than the approximation by the synthetic control unit. In contrast to wholesale prices, the electricity consumption per capita for household prices is lower for the synthetic unit than the sample mean. Only the household electricity price is closely approximated.

Table 5. Pre-Intervention Predictor Means, Wholesale Electricity Prices

	Germany	**Synthetic Germany**	**Sample Mean**
GDP/capita	33.748,095	27.863,500	27.956,726
Electricity Consumption/capita	6.448,024	5.572,382	5.435,843
Wholesale Electricity Price	0,085	0,076	0,072

Note: Wholesale Electricity Price is averaged half-yearly, other predictors are averaged yearly over 1991 S1 (1) - 2014 S2 (48).

Table 6. Pre-Intervention Predictor Means, Household Electricity Prices

	Germany	**Synthetic Germany**	**Sample Mean**
GDP/capita	33.748,095	26.693,093	29.524,733
Electricity Consumption/capita	6.448,024	5.047,886	5.535,601
Household Electricity Price	0,124	0,121	0,106

Note: Household Electricity Price is averaged half-yearly, other predictors are averaged yearly over 1991 S1 (1) - 2014 S2 (48).

The lack of predictive power may stem from bad data. Arguably, the data set consists of half-yearly electricity prices, whereas the two pre-intervention predictors GDP per capita and electricity consumption per capita provide only yearly data. The poor approximation of a fitting synthetic control unit may therefore be caused by the data stretch in case of the two predictors. Leaving out any of the three chosen pre-intervention predictors, however, does not result in better estimations. Further limitations concern the restricted amount of pre-intervention periods, which may have caused the SYNC method to not approximate the control unit well. This limitation may be outweighed by the fact that Abadie et al. (2010) studied with 18 pre-intervention periods even less than this Master's Thesis and achieved significant results as well as a good approximation of the synthetic unit.

This thesis demonstrates the limitations of the SYNC method in case perfect data are not obtainable. Despite the fact, that the amount of pre-intervention periods might be small, the method was not able to attain a reasonable synthetic control unit consisting of other countries than Belgium and Portugal, which eventually failed to resemble Germany. An interesting point is that Portugal was part of the synthetic control unit, although it did not resemble Germany well in case of the predictors GDP and electricity consumption per capita. Even if Portugal is excluded from the potential donor pool, however, the approximation of German electricity prices fails (see Appendix).

Hence, the main limitation to this study is probably bad data concerning electricity prices and the pre-intervention predictors. A large amount of free accessible data on electricity prices for multiple countries covering the same period of time is almost impossible to find. This Master's Thesis covers the largest time period and largest number of countries for which electricity prices can be found with unrestricted access. Another point is that diversified data considering GDP per capita and electricity consumption per capita cannot be found roughly before 2000.

Despite the fact that the empirical results of this study were not significant, cautious conclusions were drawn in term of wholesale prices. As said above, testing end-customer prices showed that the bidding zone might have had an increasing impact on electricity prices. This suggests, that in case of no bidding zone the price would have been persistently lower, except for 2014. Given Germany's decision towards Energy Transition in 2011, two factors may cause price increases, which might also explain the steady increase of the synthetic household electricity price from 2011 S1 (41) in Figure 5. First, the increase of renewable feed-in from the North and second the slow grid expansion compared to the rapid expansion of renewable energy input to the grid. Both reasons have a substantial impact on structural congestion, which even in case of no DE-AT zone would probably have caused an increase in German electricity prices. Hence, a potential increase in German electricity prices in case of splitting the DE-AT bidding zone might not result from the split itself, but rather from the drawbacks of the current German transmission network and the magnitude of renewable feed-in fostering structural congestion.

The effect of splitting existing zones is, thus, a multifactor issue. Manifold interdependent determinants have to be taken into account such as transition costs, market liquidity and concentration, interconnector changes, coordinated grid expansion, impacts on price signals and electricity prices. The magnitude of possible determinants shows the complexity of a delineating decision. Probably the most important determinant is the distributional effect in the sense of electricity price changes. Although this Master's Thesis is not able to present significant results regarding electricity prices, it shows the importance and necessity of a more thorough and in-depth research in this field.

References

Abadie, A., Diamond, A., & Hainmueller, J. 2010. *Synthetic Control Methods for Comparative Case Studies: Estimating the Effect of California's Tobacco Control Program*. Journal of the American Statistical Association, 105(490): 493-505.

Abadie, A., Diamond, A., & Hainmueller, J. 2011. *Synth: An R Package for Synthetic Control Methods in Comparative Case Studies.* Journal of Statistical Software, 42(13): 1-17.

Abadie, A., Diamond, A., & Hainmueller, J. 2015. *Comparative Politics and the Synthetic Control Method*. American Journal of Political Science, 59(2): 495-510.

Abadie, A., & Gardeazabal, J. 2003. *The Economic Cost of Conflict: A Case Study of the Basque Country*. The American Economic Review, 93(1): 113-132.

ACER. 2013. *The influence of existing bidding zones on electricity market.* Consultation document PC_2013_E_04.

ACER. 2014. *Report on the influence of existing bidding zones on electricity markets*. Report R_2014_E_01.

ACER. 2015. *Opinion of the Agency for the Cooperation of Energy Regulators No 09/2015*. Opinion 09-2015.

ACER. 2015a. *Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2014.* ACER Market Monitoring Report 2015. URL http://www.acer.europa.eu/official_documents/acts_of_the_agency/publication/acer_market_monitoring_report_2015.pdf

Auer, M. 2015. *Keine neuen Grenzen für Europa – auch nicht für Strom*. Available from: http://diepresse.com/home/meinung/kommentare/wirtschaftskommentare/4763846/-Keine-neuen-Grenzen-in-Europa-auch-nicht-fur-Strom-

?direct=4763746&_vl_backlink=/home/wirtschaft/energie/4763746/index.do&selChannel=&from=articlemore (2016-08-20)

Bayer, E. (RAP) 2015. *Report on the German power system.* Agora Energiewende, Version 1.01. URL https://www.agora-energiewende.de/fileadmin/downloads/publikationen/CountryProfiles/Agora_CP_Germany_web.pdf

Bundesnetzagentur (BnetzA). 2005. *History of liberalisation.* URL http://www.bundesnetzagentur.de/EN/Areas/Energy/Companies/GeneralInformationOnEnergyRegulation/HistoryOfLiberalisation/historyofliberalisation_node.html (2016-08-22)

Bundesnetzagentur (BnetzA). 2015. Press Release of 23rd of September 2015. URL http://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/BNetzA/PressSection/PressReleases/2015/150923_GemeinsamePM.pdf?__blob=publicationFile&v=3

Bundesnetzagentur (BnetzA). 2016. *3.Quartalsbericht 2015 zu Netz- und Systemsicherheitsmaßnahmen.* URL https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Energie/Unternehmen_Institutionen/Versorgungssicherheit/Stromnetze/System_u_Netzsicherheit/Quartalsbericht_Q4_2015.pdf?__blob=publicationFile&v=1

Bundesnetzagentur (BnetzA). 2016a. *Redispatch*. URL http://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Versorgungssicherheit/Stromnetze/Engpassmanagement/Redispatch/redispatch-node.html (2016-08-22)

Bundesregierung (BReg). 2015. *Bilanz zur Energiewende 2015.* URL https://www.bundesregierung.de/Content/DE/_Anlagen/2015/03/2015-03-23-bilanz-energiewende-2015.pdf?__blob=publicationFile&v=1

Bundesverband der Energie- und Wasserwirtschaft e.V. (BDEW). 2013. *ACER – Consultation on bidding zones "The influence of existing bidding zones on electricity markets".* Position Paper. URL http://www.acer.europa.eu/Official_documents/Public_consultations/ACER%20Bidding%20Zones%20Responses/BDEW.pdf

Commission Regulation (EU) 2015/1222 of 24th July 2015.

Consentec. 2015. *Economic efficiency analysis of introducing smaller bidding zones.* Report. URL https://www.eex.com/download/en/7412

de Vries, L. J., & Hakvoort, R. A. 2001. *An Economic Assessment of Congestion Management Methods for Electricity Transmission Networks*. Journal of Network Industries, 3(4): 452-466.

Ding, F., & Fuller, D. J. 2005. *Nodal, Uniform, or Zonal Pricing: Distribution of Economic Surplus.* IEEE Transactions on Power Systems, 20(2): 875-882.

Drees, T., Breuer, C., & Moser, A. 2012. *Impact of a German/Austrian market splitting on electricity markets and the transmission grid in CEE*. IAEW RWTH Aachen. URL https://www.apg.at/~/media/C50DB68C7337445C8077FC843B0DECD5.pdf

ENTSO-E. 2012. *Interconnected system operation conditions in Continental Central Europe*. A briefing paper to the European Commission. URL https://www.entsoe.eu/fileadmin/user_upload/_library/news/Briefing_paper_to_EC/120416_Briefing_Paper_TO_EC_ENTSO-E_assessemnt_interconnected_system_operation_in_CCE.pdf

ENTSO-E. 2014. *Bidding Zones Review Process*. Technical Report. URL https://www.entsoe.eu/Documents/MC%20documents/140123_Technical_Report_-_Bidding_Zones_Review__Process.pdf

Eurostat. Wholesale and Household Electricity Prices before 2007. URL http://ec.europa.eu/eurostat/de/data/database

Eurostat. Wholesale and Household Electricity Prices after 2007. URL http://ec.europa.eu/eurostat/de/data/database

Eurostat. Supply, transformation and consumption. Annual Electricity Consumption per kWh. URL http://ec.europa.eu/eurostat/de/data/database

Eurostat. Population on 1st January. URL http://ec.europa.eu/eurostat/de/data/database

Fang, R. S., & David, A. K. 1999. *Transmission Congestion Management in an Electricity Market*. IEEE Transactions on Power Systems, 14(3): 877-883.

Federal Ministry for Economic Affairs and Energy (BMWi). 2014. *An Electricity Market for Germany's Energy Transition.* Discussion Paper. URL http://www.bmwi.de/EN/Service/publications,did=673330.html

Frontier, & Consentec. 2011. *Relevance of established national bidding areas for European power market integration – an approach to welfare oriented evaluation*. A report prepared for Bundesnetzagentur. URL http://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/BNetzA/Areas/ElectricityGas/Special%20Topics/StudyPriceZone/StudyPriceZoneLong.pdf?__blob=publicationFile&v=3

Frontier, & Consentec. 2013. *Bidding zone configuration*. A report prepared for the market parties platform. URL http://www.consentec.de/wp-content/uploads/2013/11/Rpt-Frontier-Consentec-Bidding-zone_06-11-2013-stc1.pdf

Green, R. 2014. *Electricity Transmission Pricing: How much does it cost to get it wrong?* Cambridge Working Paper in Economics. URL http://www.econ.cam.ac.uk/electricity/publications/wp/ep63.pdf

Hogan, W. W. 1992. *Contract Networks for Electric Power Transmission*. Journal of Regulatory Economics, 4: 211-242.

International Energy Agency (IEA). *Energy Policies of IEA Countries. Germany 2013 Review.* URL https://www.iea.org/publications/freepublications/publication/Germany2013_free.pdf

Kowalcze, K. 2015. *Kampf um Strompreiszone mit Deutschland eskaliert*. Available from: http://wirtschaftsblatt.at/home/nachrichten/newsletter/4827923/Kampf-um-Strompreiszone-mit-Deutschland-eskaliert (2016-08-20)

Kumar, A., Srivastava, S. C., & Singh, S. N. 2005. *Congestion management in competitive power market: A bibliographical survey*. Electric Power Systems Research, 76: 153-164.

Kunz, F., & Zerrahn, A. 2013. *The Benefit of Coordinating Congestion Management in Germany.* Deutsches Institut für Wirtschaftsforschung. Discussion Paper. URL https://www.diw.de/documents/publikationen/73/diw_01.c.421155.de/dp1298.pdf

Linnemann, C., Echternacht, D., Breuer, C., & Moser, A. 2011. *Modelling Redispatch for the European Transmission Grid.* Paper for Presentation at 2011 IEEE Trondheim Power Tech.

McIver, J., 2016. Phase Shifting Transformers – Principles, Design Aspects and Operation. PJM Power Pool. URL http://pjm.com/~/media/committees-groups/task-forces/partf/postings/pjm-phase-shifting-transformer-principles.ashx

Morecroft, J. 2012. *German power loop flows threaten EU's internal market: regulators*. Available from: http://www.platts.com/latest-news/electric-power/brussels/german-power-loop-flows-threaten-eus-internal-8878410 (2016-08-20)

OECD.Stat. Gross Domestic Product (Expenditure Approach). URL https://stats.oecd.org/index.aspx?queryid=60702# (2016-08-20)

Ofgem. 2014. *Bidding Zones Literature Review*. URL https://www.ofgem.gov.uk/sites/default/files/docs/2014/10/fta_bidding_zone_configuration_literature_review_1.pdf

Oggioni, G., & Smeers, Y. 2010. *Degree of coordination in market-coupling and counter-trading*. CORE Discussion Paper. URL https://www.uclouvain.be/cps/ucl/doc/core/documents/coredp2010_52web.pdf

Oggioni, G., Smeers, Y., Allevi, E., & Schaible, E. 2012. *A Generalized Nash Equilibrium Model of Market Coupling in the European Power System*. Netw Spat Econ, 12: 503-560.

Phillips, D. 2003. *Nodal Pricing Basics.* Market Evolution Program. URL http://www.ieso.ca/Documents/consult/mep/NodalBasics_2003Dec10.pdf

THEMA. 2013. *Loop flows – Final advice*. THEMA Report 2013-36 prepared for the European Commission. URL https://ec.europa.eu/energy/sites/ener/files/documents/201310_loop-flows_study.pdf

THEMA, 2013a. *Nordic bidding zones*. THEMA Report 2013-27 Commissioned by the Swedish Ministry of Enterprise, Energy and Communications /The Nordic Council of Ministers. URL http://www.thema.no/wp-content/uploads/2013/10/THEMA-report-2013-27-Nordic_Bidding_Zones_FINAL.pdf

Regulation (EC) No 714/2009 of the European Parliament and of the Council of 13th July 2009.

Wetzel, D. 2015. *Die Angst der Bayern vor den Luxusstrompreisen*. Available from: http://www.welt.de/wirtschaft/energie/article146865965/Die-Angst-der-Bayern-vor-den-Luxus-Strompreisen.html (2016-08-20)

World Data Bank. Electric Power Consumption per kWh. URL http://databank.worldbank.org/data/reports.aspx?source=2&series=EG.USE.ELEC.KH.PC&country=# (2016-08-22)

A. Appendix

As it is not possible to include half-yearly timelines in the R package “Synth” for the SYNC method, the time axes spans from 1 (1991 S1) to 48 (2014 S2) for figures 4 to 17.

A.1. Gaps Wholesale Electricity Prices

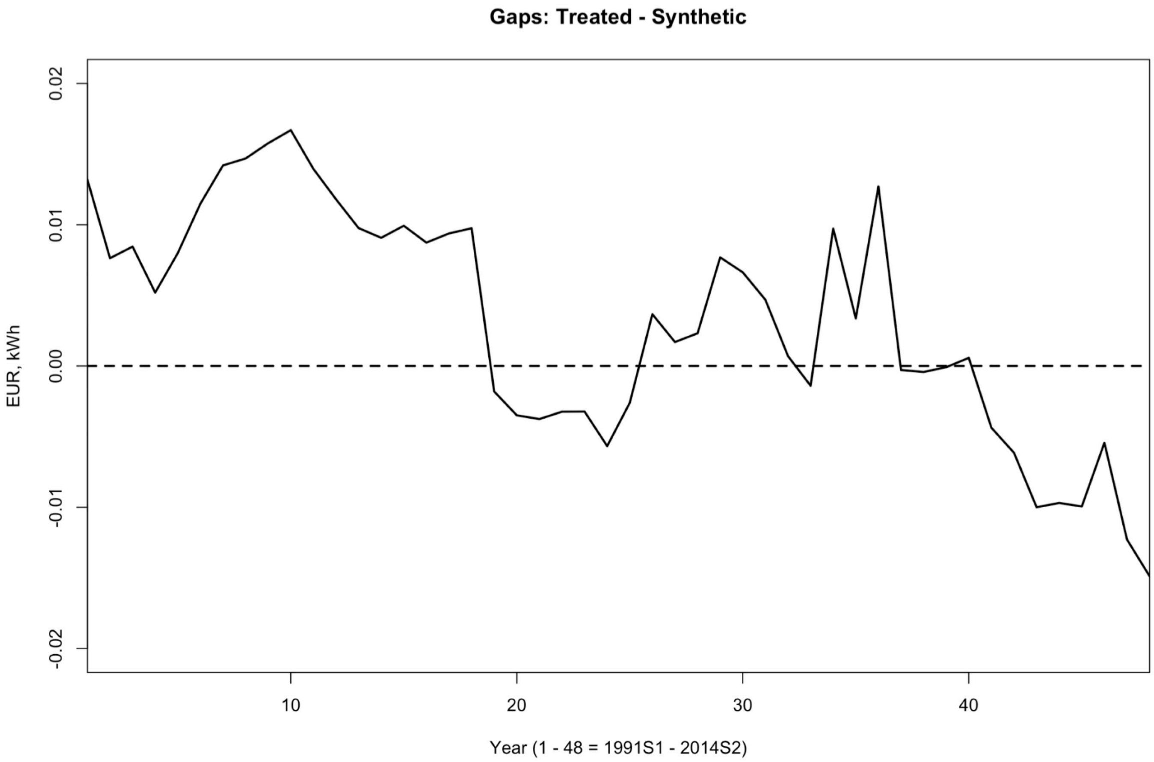

Figure 13. Gaps in Wholesale Electricity Prices per kWh between Synthetic Germany and Germany

A.2. Excluding Portugal from Donor Pool

Table 7. Pre-Intervention Predictor Means, Wholesale Electricity Prices. Excluding Portugal from Donor Pool

	Germany	Synthetic Germany	Sample Mean
GDP/capita	33.748,095	30.188,042	29.711,302
Electricity Consumption/capita	6.448,024	6.439,244	6.162,687
Wholesale Electricity Price	0,085	0,074	0,070

Note: Wholesale Electricity Price is averaged half-yearly, other predictors are averaged yearly over 1991 S1 (1) - 2014 S2 (48).

Table 8. Synthetic Control Weights, excluding Portugal from Donor Pool

Country	Synthetic Control Weight
Belgium	0,682
France	0
Spain	0,318

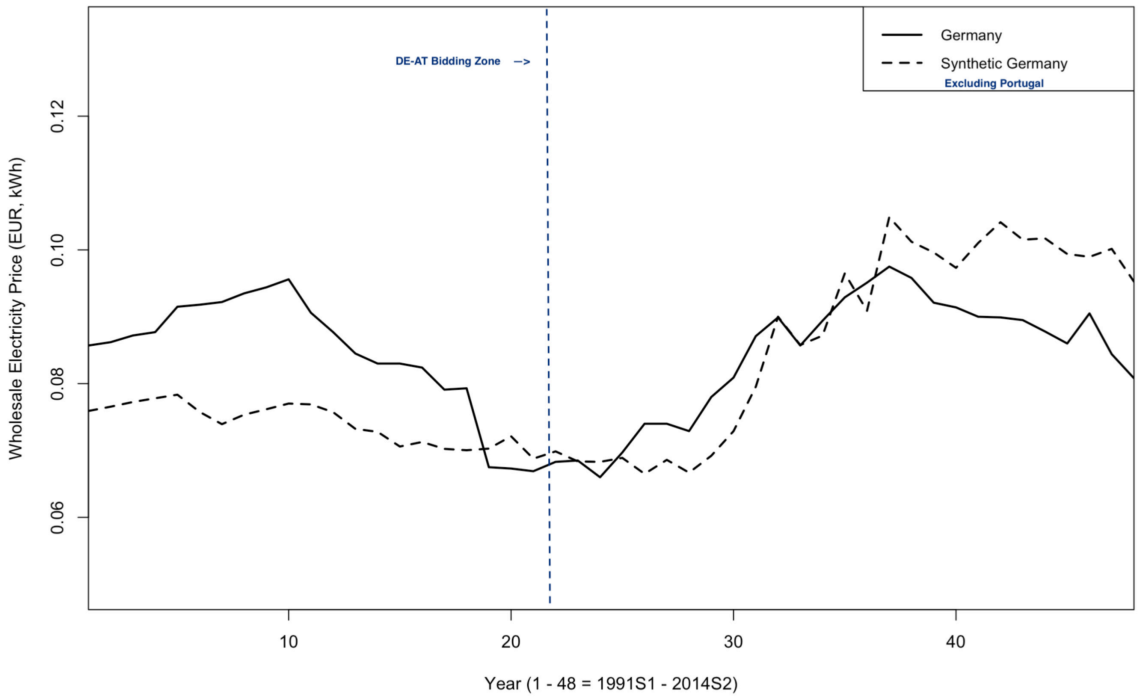

Figure 14. Trends in Wholesale Electricity Prices per kWh, excluding Portugal from Donor Pool

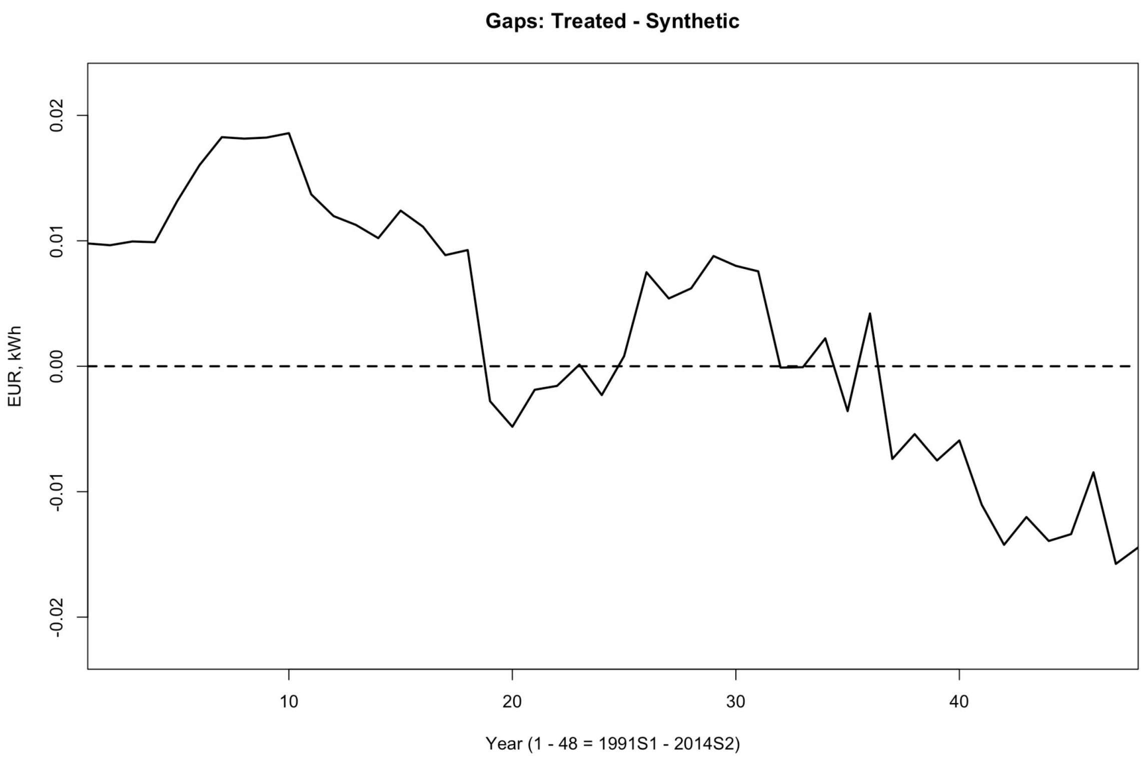

Figure 15. Gaps in Wholesale Electricity Prices per kWh between Synthetic Germany and Germany, excluding Portugal from Donor Pool

Table 9. Pre-Intervention Predictor Means, Household Electricity Prices. Excluding Portugal from Donor Pool

	Germany	Synthetic Germany	Sample Mean
GDP/capita	33.748,095	32.092,853	31.232,667
Electricity Consumption/capita	6.448,024	7.467,701	6.105,674
Household Electricity Price	0,124	0,117	0,101

Note: Household Electricity Price is averaged half-yearly, other predictors are averaged yearly over 1991 S1 (1) - 2014 S2 (48).

Table 10. Synthetic Control Weights, excluding Portugal from Donor Pool

Country	Synthetic Control Weight
Belgium	0,682
France	0
Spain	0,318

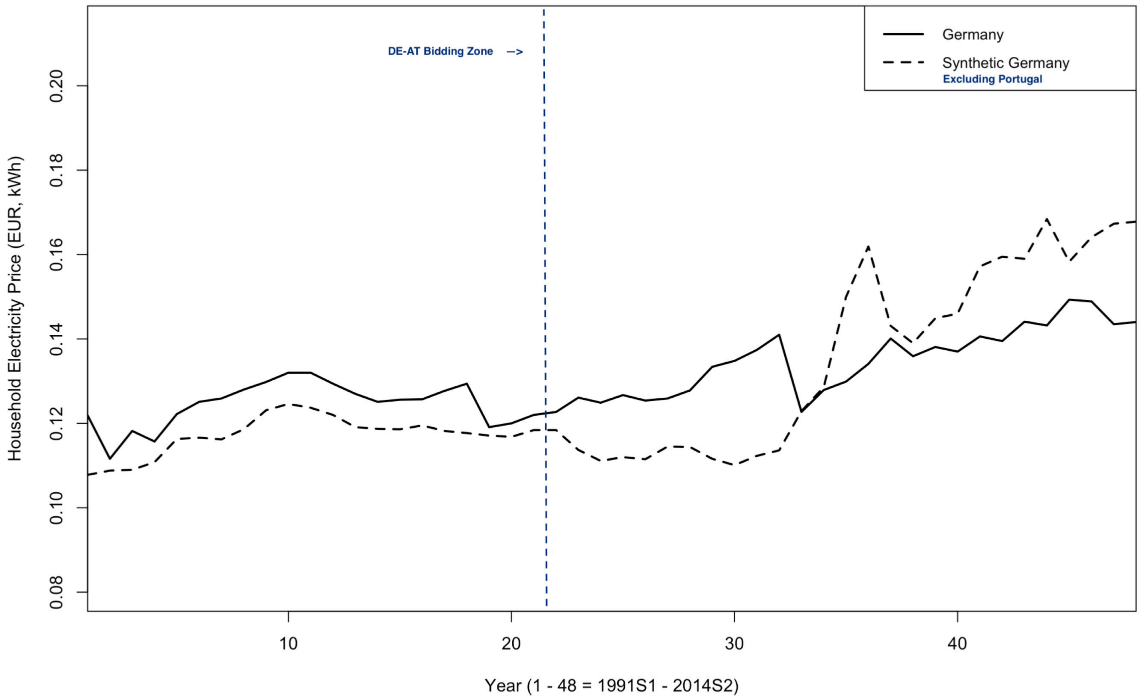

Figure 16. Trends in Household Electricity Prices per kWh between Synthetic Germany and Germany, excluding Portugal from Donor Pool

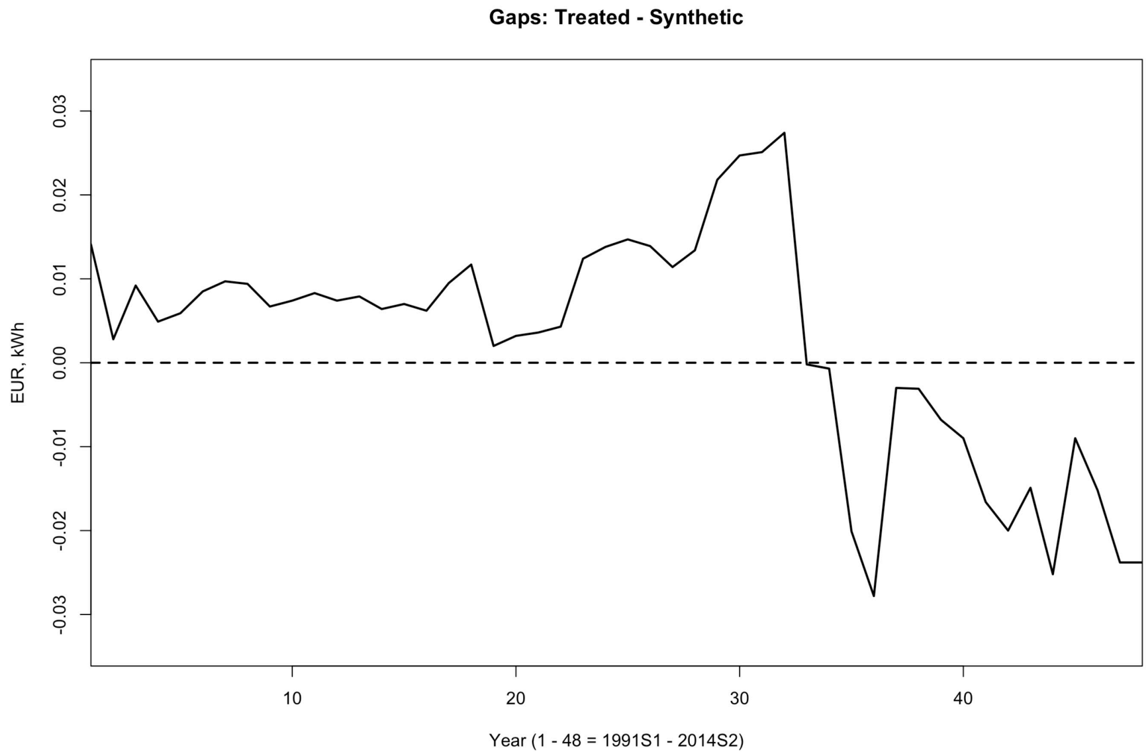

Figure 17. Gaps in Household Electricity Prices per kWh between Synthetic Germany and Germany, excluding Portugal from Donor Pool

A.3. Abstract English

This Master's Thesis is motivated by ACER's last year resolution to split the joint electricity price bidding zone between Germany and Austria due to substantial grid congestion in the CEE region. Subsequent consequences of the splitting will allegedly result in electricity price increases in both countries. The aim of this Master's Thesis is twofold. First, a general overview of the German electricity market with particular focus on the DE-AT bidding zone as well as congestion management alternatives to bidding zone reconfiguration are given. Second and foremost, this thesis investigates the effect of the joint bidding zone on German wholesale and household electricity prices. For this purpose, a counterfactual scenario is conducted with the Synthetic Control Method (SYNC), in which Germany represents a sole bidding zone. Although generally lower synthetic electricity prices can be identified, no significant results were obtainable when applying the SYNC method.

A.4. Abstract German

Die Motivation für diese Masterarbeit zieht sich aus der Entscheidung ACERs, die deutsch-österreichische Strompreiszone aufgrund von struktureller Überlastung im Übertragungsnetz der CEE Region aufzulösen. Als Konsequenz nennt die Energiewirtschaft eine direkte Preiserhöhung am Strommarkt. Die Intension dieser Arbeit ist zweifach. Einerseits soll ein Überblick über den deutschen Strommarkt mit Fokus auf die deutsch-österreichische Strompreiszone, sowie ein Überblick über Methoden zum Management von Überlastungen im Übertragungsnetz gegeben werden. Andererseits soll die Auswirkung der gemeinsamen Strompreisezone auf deutsche Industrie- und Haushaltspreise untersucht werden. Hierfür wird ein kontrafaktisches Szenario mit der Synthetischen Kontrollmethode (SYNC) konstruiert, in welchem Deutschland seit jeher eine eigene Strompreiszone repräsentiert. Obwohl grundsätzlich niedrigere synthetische Strompreise zu beobachten sind, konnten keine signifikanten Ergebnisse mit der angewandten Methodik erzielt werden.