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The analysis of 4M MC electricity market

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Abstract

This paper studies the integration level of 4M in the single European electricity market. The extensive evolution of the European electricity framework and established focus on the interconnectivity imply that there should exit some integrative processes in the eastern part of the continent. Our analysis shows that even though 4M market fails to provide data for attesting convergence with European market under current regulatory framework, it has achieved a high level of integration in the off-peak period. Moreover, our study underlines that 4M countries achieved the desired level of interregional integration required by the European regulatory framework. Therefore, the results of this paper provides empirical evidence of the convergence of 4M market to European one and establishes the foundation for further research of integrative processes in electricity market in the eastern European region.

Keywords: Electricity, Day ahead market, Integration, Europe

CONTENTS

ABBREVIATION

4M MC – 4M Market Coupling

ACER - Agency for the Cooperation of Energy Regulators

ENSO-E - European Network of Transmission System Operators

TSO- transmission system operators

TEM- Target electricity model

CZ –Czech Republic

SK-Slovakia

HU- Hungary

RO- Romania

TPA –Third party access

CEE- Central East European

TSO- Transmission System Operator

PX -Power exchange

NRA- National Regulatory Agency

Euphemia -acronym of Pan-European Hybrid Electricity Market Integration Algorithm

1. INTRODUCTION

This paper investigates the integration level of Central East European (Czech Republic, Slovakia, Hungary and Romania) electricity markets in the European electricity markets. The primary motivation is to determine if the harmonization policies implemented by EU resulted in price convergence of 4Ms' electricity markets to European one and their internal integration.

Even though the evolution of European electricity market is complex, the main objectives of the common market remain the same: security of energy supply, energy efficiency, integration of renewable sources and interconnection of networks (Treaty of Lisbon Art. 197). The primary expectations aimed by European regulation represent: the existence of the standardized regulatory framework throughout the continent and the emergence of an interconnected well-functioning electricity market. Even though EU heavily invested in integration of energy market, the empirical results highlight the desired price convergence on primary stages of integration was not reached: Bower (2002) analysis highlighted only a partial integration of West European markets by 2001, whether Boisseleau (2004) concluded the integration level in European markets is low. Since then, a few investigations have been performed on price convergence, therefore, current research on this topic represents an important step as both regulatory framework and political environment changed. Besides, this analysis is crucial for further integration of the East and Balkan countries in the pan European grid and establishment of an optimal energy mix.

This thesis tries to provide empirical evidence of market integration on the price convergence in the electricity market. The researched questions are: Did harmonization of regulatory framework contribute to integration of the electricity prices of 4M countries? What is the level of integration within the 4M market coupling?

This paper contributes in several ways to the literature. Firstly, it aims to cover the gap of academic literature on CEE market and enlarge the existing knowledge on market integration. Secondly, the thesis provides guidance for assessing the success rate of European regulatory framework of electricity market and determines the pitfalls for a deeper market integration.

The paper is structured as follows. Section 2 outlines the conceptual framework and Section 3 presents the methodology and data used. In Section 4 the results are discussed.

2. LITERATURE REVIEW

The security of electricity supply and optimal management of demand represent the EU cornerstone challenges. It is the third largest electricity consumer in the world has a sizable carbon footprint on climate change. Being aware of its weight on both electricity demand and supply, EU recognizes the importance of sustainable growth and sets as objective to reduce its impact on environment. The main directions of development are: reduction of greenhouse emissions by 20% comparing with 1990 level, increment of renewables' share in energy mix to 20% and improvement of energy efficiency by 20%. The implementation deadline is 2020. The achievement of these goals relies on the ability to upgrade production capabilities and integrate national markets. Consequently, we should observe a standardization of regulatory framework and deeper integration of the European electricity market. Based on these premises, we expect to witness the emergence of a single European market and the strengthening of links with peripheral markets, one of them being the 4M MC. These interactions should not only lead to electricity price convergence due to optimal allocation of resources but also decrease the volatility level due to higher price response from adjacent markets. Therefore, we analyze the evolution of European electricity market framework and 4M compatibility to integrative process, in order to determine whether 4M are currently integrated in European market.

2.1 The evolution of the European electricity market

First stage (1988- 2004):

The emergence of EU electricity market dates several decades ago. Before 1996, as described in table 2.1, electricity generation, transmission and distribution was dominated by state owned enterprises. Lack of other supply options for customers and low cross border trade were also common features of that period. However, situation changed significantly with implementation of Directive 96/92/EC and later 03/54/ EC that established the primary framework of unified European market. Directive 96/92/E C aim was liberalization of the electricity market restructuring the supply side and regulatory framework. Subsequently, former state owned companies were disentangled in separate entities (generation, transmission and distribution). Consumers obtained the opportunity to select their electricity provider. Cross border trading, inexistent until that moment of time, became less restrictive, even though its impact on electricity generation was not sizable. The removal of entry barriers as well as restructure of production facilities led higher market competition and increment in social welfare.

Table 2.1. Evolution of EU electricity market in first stage

	Before 1996	**Directive 1996**	**Directive 2003**
Generation	Monopoly	Authorization Tendering	Authorization
Transmission, Distribution	Monopoly	Regulated TPA Negociated TPA Single buyer	Regulated TPA
Supply	Monopoly	Free	Free
Customers	No choice	Choice for eligible customers	All nonhouseholds(2004) All(2007)
Cross regional trade	Monopoly	Negociated	Regulated
Unbundling of T/D	None	Accounting	Legal
Regulation	Government Department	Not Specified	Regulated Authority

***Source*:** made by author based on Vasconcelos(2003)

A prominent example of electricity market liberalization is UK. As a result of the electricity market reform, the main electricity provider (CEGB) was divided in 4 parts: a transmission operator and 3 generating companies. The unbundling of transmission and generation activities as well as implementation of a 10% threshold on market share led to emergence of power exchange and increment of customers' utility. For example, Newbery, Strbac and Viehoff(2016) found that electricity market reforms reduced the generation and transmission cost by 6% (around £6 billion in 1996). Even though regulation continued with Directive 03/54/ EC which contributed to further liberalization of the electricity market, the main result of these reforms was the transition from state monopolies to free market system. Unfortunately, liberalization occurred mostly on the national level and no measures were implemented for emergence of a common European electricity market. Academic literature highlight this finding as by 2006 European electricity market exhibited signs of fragmentation, and the integration level was reduced. For example, Bower (2002) analyzed the correlation and cointegration of locational prices from different parts of the Europe (Scandinavian countries, UK, Germany, the Netherlands and Spain). He concluded that some markets exhibit signs of integration (Nordpool, German and British markets) whether other counties like the Netherlands peripheral Spain didn't. Moreover, Bower (2002) identified that the relative level of integration is a result of inefficient use of transmission pricing mechanism. For example, regions that adopted an implicit auction mechanism had higher level of integration (Nordpool) than regions that used the explicit auction for electricity trade. Therefore, the integration was not fully achieved in European electricity market by 2001. Later studies like Boisseleau (2004), confirmed the existence of supranational markets that reflect a high level of integration (Nordic countries, German-French market). However, this paper highlighted a low correlation between these markets, concluding that within a single European market the integration was depressed. An important contribution to the electricity market integration literature is Zachman(2008) analysis of European market during 2002-2006 period. He found out that even though 59% of national electricity markets converge, it tended to be present mostly during off-peak hours. Only 25 % of market pairs converge during on peak hours. Moreover, ibidem underlined that out of 93% market pairs which present significant arbitrage opportunities, only 60% led to price convergence. This finding highlighted the presence of limitations in cross-border transmission capacity auction mechanism and realization of arbitrage freeness. It confirmed the Bower (2002) finding regarding implicit auction mechanism superiority over explicit due to increment in liquidity, trades, and lower risk of market congestion. Overall, the implemented market reforms didn’t lead to desired level of integration in European electricity market. Unfortunately, adopted directives resulted in liberalized but isolated electricity markets, thus the emergence of a single European electricity market didn’t happen. A drawback of the academic research during this evolution stage is that authors neglected existing regulatory framework when studying the integration process in the European market. Therefore, there were no strong fundamental preconditions to admit a high degree of price convergence on the continent and the emergence of a single European electricity market.

Second Stage (2004-2014):

The second stage of reforms started in 2004 and resulted in a series of important steps in terms of institutional standardization and mutual cooperation. The main EU objective was final consolidation of institutional and regulatory framework in order to enhance infrastructural development. As a result, 2 new agencies emerged: ACER and ENSO-E. Both institutions are responsible for the elaboration of common framework for electricity networks, development and upgrade of cross border linkages and advisory of market participants. Besides institutional consolidation, in 2009 EU updated previous framework by directive 2009/72/EC and established the basement for the emergence of the so called Target Electricity Model (TEM). TEM represents a market coupling program which primary goal is to facilitate cross-border electricity trade. One of the primary TEM objectives was the shift from explicit to implicit auction mechanism. It aimed to ensure the security of supply, increase competitiveness and minimize market frictions. Furthermore, it targeted the lack of cross border infrastructure and the underuse of existing connections. TEM was designed not only as a solution for security of electricity supply but also aimed to increase the system efficiency and maximize social welfare. For example, market coupling benefits were estimated to range from €2.5bn to €4bn per year. Moreover, Newbery, Strbac and Viehoff(2016) found that increment in interconnections usage can lead to gains up to €3.9 bn/year at current level of coupling of 8% and save additional €1.58bn/year by increasing the cross border electricity capacity flow from 10% to15%.Currently, due to interconnection of Nordic region and NW Europe markets, 58-66% of estimated benefits are already achieved. One prominent example is France-Belgium- Netherlands integration. Before market coupling, only in 10% of the cases the price differentials between French and Dutch markets were €1/MWh and 39% of the cases were more than €10/MWh. After coupling the price differentials of €1/MWh or less increased to 72% and those of €10/MWh dropped to 14% (Newbery et al. 2013). If such developments will continue EU can save yearly up to €40bn for period 2015-2030. Therefore, EU views interconnectivity as a pivotal element in its energy policy and commits to improvement of infrastructural framework in order to achieve higher integration in common market and finally maximize the social welfare of Europeans. All the measures implemented and currently in operation represent adequate preconditions for a future market integration expressed by price homogeneity in the common European electricity market.

2.2 4M MC and integration requirements

The 4M Market coupling is the day ahead electricity trading platform of the CEE region. It started as a bilateral agreement between 2 countries: Czech Republic and Slovakia and expanded further with Hungary (2011) and Romania (2014).Currently, Poland (2019) and Bulgaria (2020) express their interest in joining the regional market coupling. It is important to highlight this tendency as the main goal of the 4M is to harmonize the electricity prices in the Eastern Europe via reduction of congestion and efficient distribution of available transfer capacity (ATC). Furthermore, 4M is expected to integrate both existing EU members that are geographically isolated (Greece and Bulgaria) and future ones (former Yugoslavian republics) in the EU Target Model. Currently, 4M is viewed as an intermediary phase of integrating Eastern electricity market in the European one. In order to smooth the transition to the common electricity market, 4M aligned the infrastructural and regulatory framework of the participating countries with the European standards. Firstly, 4M evolved from an explicit auction mechanism to an implicit one. This change ensured that both the costs of energy and congestion are included in electricity price, therefore electricity would flow from areas with low prices (surplus) to areas with high prices (deficit), resulting in price convergence. For this purpose, 4M uses Euphemia algorithm. This algorithm is used by main European power exchanges for cross border capacity allocation and day ahead price settlement. Secondly, the regulatory framework for electricity trading is in line with European directives. All 4M countries have a strict division in generation, trading (PX) and transmission (TSO) institutions (table C 1.1) as well as the general regulatory body (NRA). Moreover, the partnership of NRAs via ACER and TSOs via ENSTO-E establish common ground for synchronization of decisions and efforts thus contributing to cost effective decisions and an in-depth market integration.

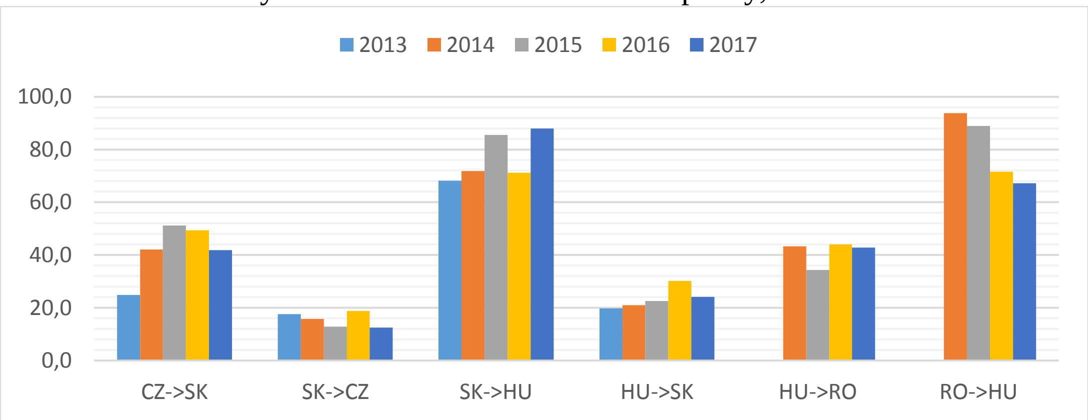
When analyzing integration process we should distinguish between 2 types of integration: static and dynamic (Zachman(2008)). Static integration is the level to which a unified market is realized, whether dynamic integration is the evolution of prices towards a common European price level. Price convergence can be attained if a series of fundamental factors are persistent. Therefore he concludes that convergence in electricity price can be achieved if these factors are present.

- *The convergence of factor and product prices*
- *The harmonization of the institutional framework and convergence of market regulation*
- *The convergence of production technologies and consumption patterns*
- *The increasing international electricity trade*

The converge of factor and product prices is determined by the geographical proximity of the members, the climate similarities, share of common political and economic risks related to membership in EU. All countries reformed their institutional framework and market regulation in order to align to EU standards and should benefit from the harmonization of the internal electricity market. From the perspective of demand and supply patterns, 4M countries share the same dynamics and structure. For example, via analyzing the dynamics of the electricity generation by source for the period 2013-2016(Appendix A) we conclude that no significant changes took place in the 4Ms' energy mixes, except the rise of renewables from 7,4 to 14,1% in Romania. On the one hand, nuclear power plays an important role in energy mix of all countries, being the primary electricity source for Hungary and Slovakia. On the other hand, fossil fuels dominate the Romanian and Czech markets and make them sensitive to international conjuncture. An important role in 4M plays the integration of Romanian market as it offers a series of benefits. Firstly, Romania is a large net exporter of electricity, thus can tackle the excessive demand of Hungarian market and lead to price convergence. Secondly, it has the most balanced energy mix that incorporate generation facilities with the highest market response to demand. Therefore the flexibility of electricity output can mitigate the price volatility of 4M countries and result in price stability. Thirdly, Romania has the second best wind potential in Europe, behind Scotland. This renewable resource is crucial for future electricity supply of the region and stability in prices. From the perspective of demand side, all countries exhibit a relative constant dynamics (appendix B). Industry and agriculture are the largest consumers of electricity, accounting for almost half of the consumption. Services and transportation count the rest of electricity demand. The last source of demand is transportation however its effect is insignificant accounting for approximately 3% of total consumption.

The upgrade of infrastructure in terms of building new interconnections or enhancing the existing ones should also play a role in electricity price convergence. Table 2.3 reveals a series of interesting observations. During the period 2013-2017 the efficiency of cross border flow from central European countries to peripheral one increased. This is observed in dynamics of CZ-SK, SK-HU and HU-RO links. The positive trend is supported by increasing trans-border capacity. Even though all countries do not fulfill currently the 10% interconnection target set by EU, the increment in transfer potential and capacity usage represent good signs of market integration. The reverse flow of electricity doesn't have the same dynamics as in previous case. This can be partly explained by an increase in transfer capacity as in case of RO-HU, or by improper functioning of settlement mechanism as the peripheral electricity prices tend to be higher that core ones. Therefore, a relatively homogenous demand and supply, harmonized regulatory framework and increment in electricity trade are adequate prerequisites for occurrence of a price convergence in the electricity market in the context of deepening the integration level between the countries.

Table 2.3. Efficiency of cross border transmission capacity, %



Source: made by author based on OTE database

2.3. Hypothesis

If electricity markets integrate their capacities and allocate their resources efficiently then according to Bower (2002), the difference between 2 bidding regions should be the cost of transportation. This approach implies the lack of market frictions that can influence an arbitrage opportunity. If price differentials are on average higher than transmission costs then the price convergence is not achieved and markets are not fully integrated. In order to test this hypothesis we need to determine several elements: the proxy zone to which other regional zones should converge, the interest group of converging markets and the price differential (transmission cost).Our interest group is 4M day ahead markets. As a proxy for the analysis of price convergence of 4M market, we use the Germany and specifically the EPEX SPOT day ahead prices. There are several reasons for such an assumption. Firstly, EPEX SPOT is power exchange that is trading in Western and Central Europe (DE, FR, BE, UK, NL, AU, CH, LU) and covers markets that count for 85% of European electricity consumption. Secondly, EPEX SPOT offers price coupling services for 4M power exchanges. Furthermore academic literature like Bollino,Ciferri, Polinori(2013) found German market act as a reference for the wholesale markets in Europe. This is due to the fact that Germany is the largest regional market and its market structure contains elements of both conventional (the effect of combine cycle technology) and nonconventional sources of electricity generation. As a result, EPEX SPOT represents a good proxy for the European electricity market in our analysis. With respect to price differentials, EU (2017) considered the threshold of €2/MWh or less to be a confirmation of integration of 4M in the single European electricity market:

"A well-functioning internal market should lead to competitive electricity prices for all Europeans. Member States should therefore aim at minimising differences in their wholesale market prices. Additional interconnections should be prioritised if the price differential exceeds an indicative threshold of €2/MWh between Member States, regions or bidding zones to ensure all consumers benefit from the internal market in a comparable manner. The higher the price differential, the greater the need for urgent action."

However, we consider the abovementioned threshold to be too ungrounded taking into consideration the current constrains in electricity transmission. According to ENTSOE (2018), the average European unit transmission tariff is €11.53/MWh. Out of this aggregate, €8.64/MWh represents the expenses related to infrastructure, maintenance losses and system services, whether the rest €2.89/MWh accounts for regulatory levies, stranded costs, etc. The experience of other regions confirms the same findings. In U.S. the transmission cost of 1 MWh in 2017 was $13.2

(EIA (2018)) with a forecasted increment till \$16.4 by 2050. Therefore, €11.5/MWh is a reasonable charge for electricity transmission that conforms to current market functioning. Therefore the primary hypothesis will analyze whether the price differentials that are related to zone convergence are in line EU targets and current market environment.

The second hypothesis is related to the interconnectivity level of the 4M markets. As mentioned in chapter 2.2, the existence of fundamental factors for convergence should lead to a better allocation of resources and as a result to price harmonization in the region. The analysis of this market is unique due to their geographical location. 4M countries grid represents a chain, thus the price propagations exhibit a domino effect. This feature implies that any influence from the European core markets to European peripheral markets and vice versa impacts each national market. Therefore, if cross border interconnections are functioning properly and there are no serious market frictions then the cross border price differential should be less than stated threshold of €2/MWh. Otherwise, it can be an indication of a missing chain link and a cause why regional markets cannot converge.

In both cases we analyze the existence of an integration process in the 4M markets starting with its emergence as a regional block in 2014. We expect the Czech and Slovakian markets to be fully integrated whether Hungarian market to exhibit signs of integration starting with 2013(1 year later the inclusion of Hungary in trilateral market coupling). Romanian market should also exhibit signs of integration after 2014.Consequently, our hypothesis are:

Hypothesis 1:

1.a)Starting with 2014, there is an integration of the 4M market in the European market if the price differentials between 4M countries and EPEX SPOT is less than €2/MWh.

1.b) Starting with 2014, there is an integration of the 4M market in the European market if the price differentials between 4M countries and EPEX SPOT is less than €11.5/MWh.

Hypothesis 2:

Starting with 2014, there is an integration of the 4M markets in a single regional market if the price differentials for Czech-Slovakian, Slovakian-Hungarian and Hungarian-Romanian price pairs is less than €2/MWh.

METHODOLOGY, DATA AND RESULTS

3.1 Methodology

The current research question as well as derived hypotheses can be perceived as challenging. The main concept behind the TEM and the integration of 4M in European market represents the uncongested flow of electricity from different bidding zones. As a result, markets will be considered integrated when they are able to provide a frictionless movement of electricity in both directions under the current regulatory framework. Therefore, an integrated market will be only in case when price differentials between core European market and 4M markets are mostly included in range [-2; 2] (blue range in graph 1 appendix C) for hypothesis 1. The same setup is valid for hypothesis 2 except different bidding zones. However, a mean smaller than 2 doesn't imply that we can validate our hypotheses. Such an inference is determined by one of the mean drawbacks: sensitivity to outliers (in our case more relevant are negative outliers in red portion of the graph that can induce a false positive result).

Table 3.1. Descriptive statistics of price differential in base scenario for Czech Republic

Statistic	*2013*	*2014*	*2015*	*2016*	*2017*
Mean	1,2	-0,3	-0,9	-2,7	-2,7
Median	0,7	-0,2	-0,4	-0,9	-0,8
Minimum	-49,1	-36,6	-54,3	-61,8	-70,9
Maximum	63,5	22,9	33,1	21,3	38,5
JB**	0	0	0	0	0

Note: JB-Jacque Berra test on normality of distribution, **- 5% significance level

An issue related to mean usage is how distribution influences the mean. In a normal distribution the mean and the median are the same. When distribution is skewed then mean can become negatively influenced by outlier and thus unrepresentative for the sample. Consequently, we can have a price differential smaller than 2 and still encounter a problem if distributions of price differentials are positively skewed. Such cases are not optimal even if mean is smaller than -2. For example, in table 3.1 are presented the descriptive statistics for price differentials of Czech Republic in base scenario. Firstly, we observe that in case of Czech Republic during 2014-17 the mean values are negative, thus we have confirmation of our hypothesis of convergence as the means of price differentials are less than €2/MWh. But such an inference would be wrong as mean values are smaller than 2 in absolute terms for period 2014-2015, but larger for in absolute terms for 2016-2017. During the same time the median values for this period remained both negative and smaller than €2/MWh. This case exhibits why parametric tests are so vulnerable to outliers and distribution (in our case all distributions fail the Jacque Berra normality test) and how easy we can be misleaded. The same findings are valid for Slovakia and are more severe in cases of Hungary and Romania, where the impact of outlier and distribution is way more pronounced (Appendix D). Therefore, in order to avoid such a methodological error we should find the distribution of the absolute price differentials (express by formulas 1-4) and perform further investigations.

$$|PRICE_{EPEX\ SPOT} - PRICE_{4M\ MARKET}\ | = \Delta_{Price} \leq 2 \tag{1}$$

$$|PRICE_{CZECH} - PRICE_{SLOVAKIA}\ | = \Delta_{Price} \leq 2 \tag{2}$$

$$|PRICE_{SLOVAKIA} - PRICE_{HUNGARY}\ | = \Delta_{Price} \leq 2 \tag{3}$$

$$|PRICE_{HUNGARY} - PRICE_{ROMANIA}\ | = \Delta_{Price} \leq 2 \tag{4}$$

After application of abovementioned transformation we generate a new distribution of price differentials. Following the same line of ideas, the level of integration will determine the skewness of the absolute price differential distribution. The more integrated are the markets the more right skewed will be the distribution and vice versa. Excessive skewness represents an issue parametric test even though they assume the central limit theorem to be functional for moderately skewed distribution[1].If the normality assumptions is violated the t statistics doesn't preserve robustness and the risk of error increases. In such cases Moore et al. (2011) suggest to use nonparametric tests as in strongly skewed distributions the median is preferred to mean. The only nonparametric test that has a distribution free assumption in this case is the *sign test*. The sign test is used to compare whether the sizes of 2 groups are equal. Because the sign test relies on the concept of median, as the value that divides the sample in 2 equal size, the null hypothesis is that the median of a normal distribution is 0 or the sample is equally distributed on both sides of the median[2]. One of the main advantage of the median in comparison to mean is that it is not affected by outliers. Therefore our testing hypothesis are:

$$H_0\ : The\ median\ of\ the\ distribution \leq 2$$

$$H_{al} : The\ median\ of\ the\ distribution >\ 2$$

[1] Our absolute distribution was extremely right skewed and we used the logarithmic data transformation. However, even after this step, the distribution didn't normalize (failed both Jacque Berra and Shapiro-Wilk test on normality).

[2] For example a 200 observations sample with a median 0 will imply that each side has 100 observations.

3.2 Data selection

In order to examine the price convergence we require electricity price differentials for 4M and EPEX SPOT markets. Based on both methodological and conceptual framework we consider the use of aggregate data to be inappropriate (for example the use of daily/monthly prices for calculus of price differential) as it distorts the economic meaning behind our hypotheses. Therefore, in order to preserve accuracy and economic reasoning, we are restrained to usage of data from the lowest timeframe available. Hopefully, both 4M and EPEX SPOT have standardized timeframes, thus we can use in our analysis the day ahead hourly price data of the examined markets. As Czech Republic and Slovakia are the founders of the 4M project, their national power exchanges should have possess the historical database of 4M performance. Therefore, we asked Czech OTE and Slovakian OKTE to provide us their databases and received an affirmative feedback. We obtained the OTE databases that covers all 4M countries starting with the moments of their integration in 4M project. Even though 4M database represents the core of this paper, several limitations should be mentioned. One of the disadvantages of this database is that it didn't contain hourly price information prior 2013. We searched for an extension of the investigated period via considering other sources of information, however our results were negative. Therefore, based on information constrain, this paper covers only the period 2013-2017. Another limitation is the lack of information regarding Romanian market prior to 2015. However, using Datastream we were able to recover the missing period 2013-2014. Nevertheless, we were not able to perform our analysis adequately. Our research goal is the analysis of the market convergence of 4M and how seasonal patterns like working and weekend periods can influence this convergence. From this perspective, our databases proved to be partly incompatible as 4M includes both working and weekend periods, whether Datastream includes only working days period. Due to this incompatibility our study is limited to working days period only, even though at the beginning of our research we considered the study of both periods. With regards to German day ahead market (EPEX SPOT), it also covered only working days period. We obtained the EPEX SPOT database via Datastream. In our paper we consider the analysis of the main case: base load sample (hourly data for all 24 hours), as well as analysis that will involve peak and off-peak sample periods. Due to the relatively general description of the concept of peak hours, we align with Huisman,Kiliç(2013) and Bunn, Gianfreda(2010) determination of peak hours as of a period between 8 :00 and 20:00. Moreover, our view is also supported by the providers of databases, the power exchanges which classify peak hours as prices from the abovementioned range. The 4M database proved to be useful not only for price differential analysis but also for examination of contained cross border flows between the 4M countries for period 2013-2017. We display our findings in table 2.3. We also considered other sources of information for our research. The data related to electricity generation by source for 4M countries during the period 2013-2016, presented in Appendix A, was collected from *"Electricity in Europe"* yearly reports published by ENTSOE. The information related to electricity consumption mix for 4M countries during the period 2013-2016, displayed in Appendix B, was extracted from Eurostat database in division: *Supply, transformation and consumption of electricity - annual data.* As data was presented in absolute values we made some transformations in order to obtain relative shares of electricity consumption per source.

3.3 Results

The results of this paper have a significant academic and practical importance. They not only allow to assess the current situation in the electricity market of the Eastern Europe, but also can provide insights for targeted future policies in order to solve existing problems of the region. In table 3.2 as well as the following ones, we will present our findings regarding the discussed topic. However, before this we describe the notations involved for a better understanding. As mentioned earlier, we investigated the existence of a price convergence based on a one sided test. Therefore, in following tables, we present the statistical decision (Yes/No – we reject/do not reject the null hypothesis of market integration) and below the p-values based on which we based our decision. The results are statistically significant at 2.5% significance level. Firstly we tested the null hypothesis based on our base case scenario (table3.2). We conclude that except some singular values the integration process between European core market and peripheral markets (4M) is missing if the current European threshold is applied. Furthermore, we investigated if the results are consistent for both on peak and off-peak timeframes. Based on tables D1.1 and D1.2, we find out that the integration is missing for all 4M countries in the peak scenario during the period 2013-2017. However, analyzing the off-peak scenario we can attest integrative process on behalf of Czech Republic and Slovakia starting with 2014. This is an indicative finding. It is difficult to infer about the impact of policy measures on these countries or 4M emergence as both countries don't exhibit the same price convergence before 2014, even though from regulatory perspective they are integrated since 2009. It might be concluded that the results can be supported by geographical proximity of both countries to German market, however as mentioned earlier no convergence is present in 2013.We consider that further investigations should be performed, especially with respect to market convergence prior to 2013 as well what other factors could have played a role in establishment of price convergence in these countries in off-peak timeframe. Regarding Hungary and Romania, no signs price convergence with European market were observed during analyzed period. Therefore, we conclude that the mentioned €2/MWh doesn't represent an elusive threshold and can be applied as a benchmark for market integration, even though its applicability is restricted to analyzed timeframe.

Table 3.2. The results of integration process if price differential between EPEX SPOT and 4M markets if price differential is less than €2/MWh (base load case)

	2013	***2014***	***2015***	***2016***	***2017***
CZ	Yes 0,00	No 0,99	Yes 0,00	No 0,98	Yes 0,00
SK	Yes 0,00	No 0,18	Yes 0,00	Yes 0,048	Yes 0,00
HU	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00
RO	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00

Lower numbers represent the p-values at a 2.5% significance level

If we assume the other threshold, €11.5/MWh then, based on the base case scenario (table 3.3) we infer that all countries are in fully integrated in European market during the period 2013-2017. However, some signs of disruption appear to take place in Romania and Hungary during the 2017 year. A further investigation of tables D1.3, D1.4 reveal that mentioned divergence has a peak origin rather than an off-peak one. Therefore, it is possible that we encountered an idiosyncratic element present in both markets that require future investigation. The presence of price convergence at this threshold can imply that current electricity market has a developed infrastructure that is in line with European target of creation the common super grid. Moreover, it also allows to conclude that current state of affairs in 4M market meets average European requirement on electricity exchange so further investments should be allocated to expansion of the market coupling in adjacent areas. However, in order to investigate such a proposal we should search for potential bottlenecks in the region. These congestion areas impact negatively the existing and future functioning of the region.

Table 3.3. The results of integration process if price differential between EPEX SPOT and 4M markets if price differential is less than €11.5/MWh (base case scenario)

	2013	***2014***	***2015***	***2016***	***2017***
CZ	No 1,00	No 1,00	No 1,00	No 1,00	No 1,00
SK	No 1,00	No 1,00	No 1,00	No 1,00	No 1,00
HU	No 1,00	No 1,00	No 1,00	No 1,00	No 0,21
RO	No 1,00	No 1,00	No 1,00	No 1,00	Yes 0,00

Lower numbers represent the p-values at a 2.5% significance level

Based on the unique geographical position of the 4M countries and price propagation mechanism, we can determine the exact area of congestion by determining the lack of price convergence on the cross border level. Consequently, table 3.4 allows us to conclude that in the base scenario there existed bottlenecks at the Hungarian-Romanian cross border. This information might be explained by different level of cross border capacities that both countries possessed at that moment as well as different level of experience related to cross border activities. However, after 2015 cross border flow was normalized and we observe a price convergence of Hungarian and Romanian markets. Regarding the Czech and Slovakian markets we fulfill our expectations as both markets were fully integrated starting with 2012. Important to mention that mostly the same pattern of convergence is present in a peak and off-peak timeframes (tables D1.5 and D1.6). This finding supports our hypothesis that EU effort for harmonization of the electricity market and measures required for market stabilization led to emergence of a highly interconnected regional elect city market that has an efficient allocation of ATC and functional network. We can assume that current 4M market coupling can be an effective basement for further integration of other East European and Balkan countries. Therefore, in context of single European market, 4M achieves the efficiency and social welfare expectations.

Table 3.4. The interregional integration process of 4M markets if price differential is less than €2/MWh (base case scenario)

	2013	**2014**	**2015**	**2016**	**2017**
CZ=>SK	No 1,00	No 1,00	No 1,00	No 1,00	No 1,00
SK=>HU	No 1,00	No 1,00	No 1,00	No 1,00	No 0,11
HU=>RO	Yes 0,00	Yes 0,00	No 1,00	No 1,00	No 1,00

Lower numbers represent the p-values at a 2.5% significance level

CONCLUSION

Integration of the electricity markets is not only perceived as a step further of the liberalization policy but also represents a method of social welfare maximization. Throughout the history integration processes led to emergence of powerful entities with lasting effects. European electricity market is not an exception. Integrative processes in European market and especially the eastern market represented by 4M play a vital role in emergence of the single European market and electricity grid. This is an important step towards achievement of the EU climate targets. Our paper analyzed to what extent the 4M is integrated in the single EU market and what are the future implications of this integration. Therefore, we found out that from regional perspective 4M has high level of integration which is translated in price convergence and can act as a platform for further expansion of European market in the east and Balkan regions. From the perspective of integration with core European market, 4M is not fully meeting the EU requirements, however with relaxation of conditions it exhibits sign of full integration with EU market. Consequently, we found out that despite no past research on eastern markets, 4M evolves as an integral part of EU. It was able to implement European regulatory requirements harmonize its electricity market. This research has a double importance as it contributes to academic literature regarding the markets' integrative processes and their results as well as can serve a guideline for expansion of the European electricity network in the East of the continent.

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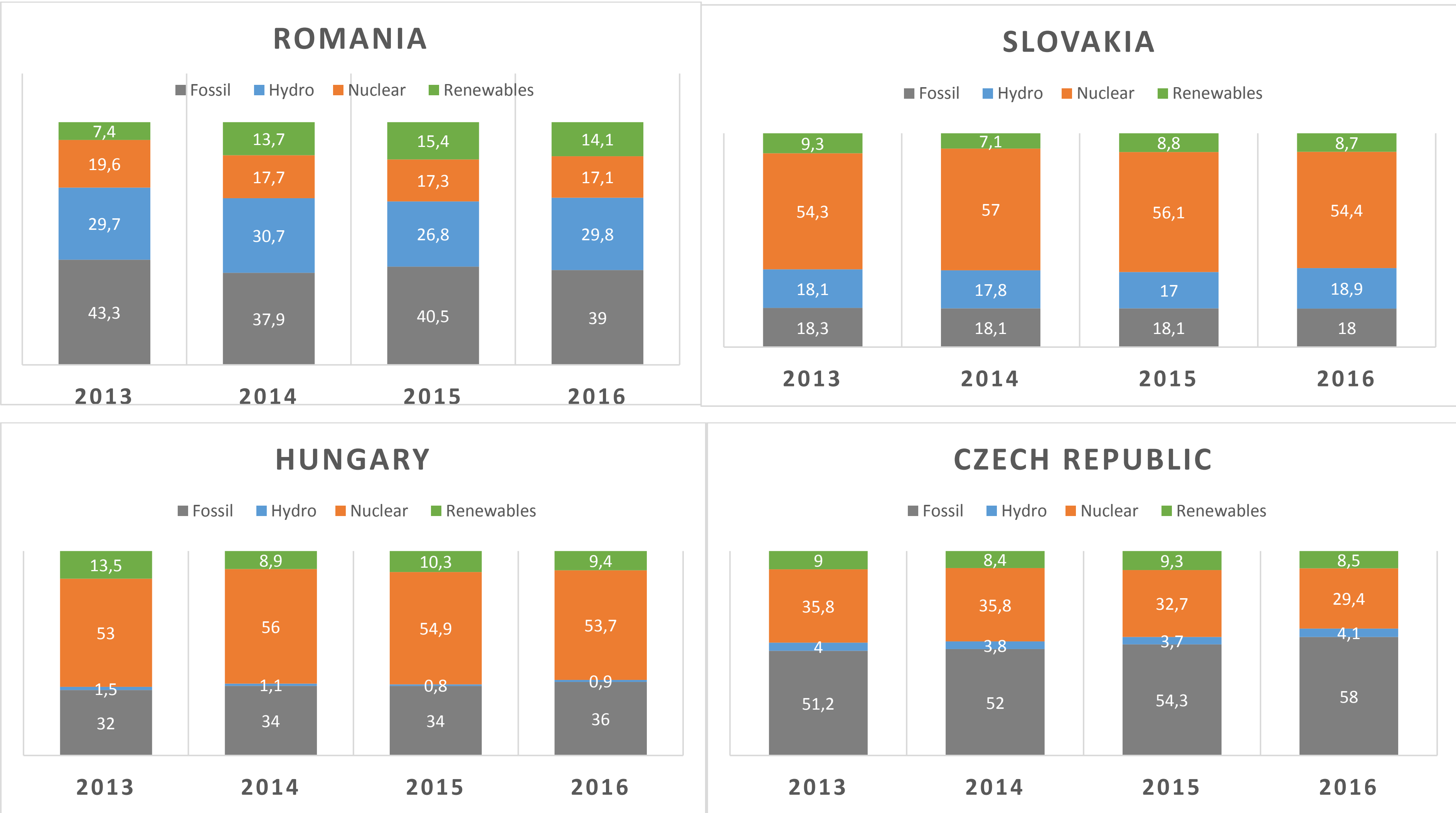
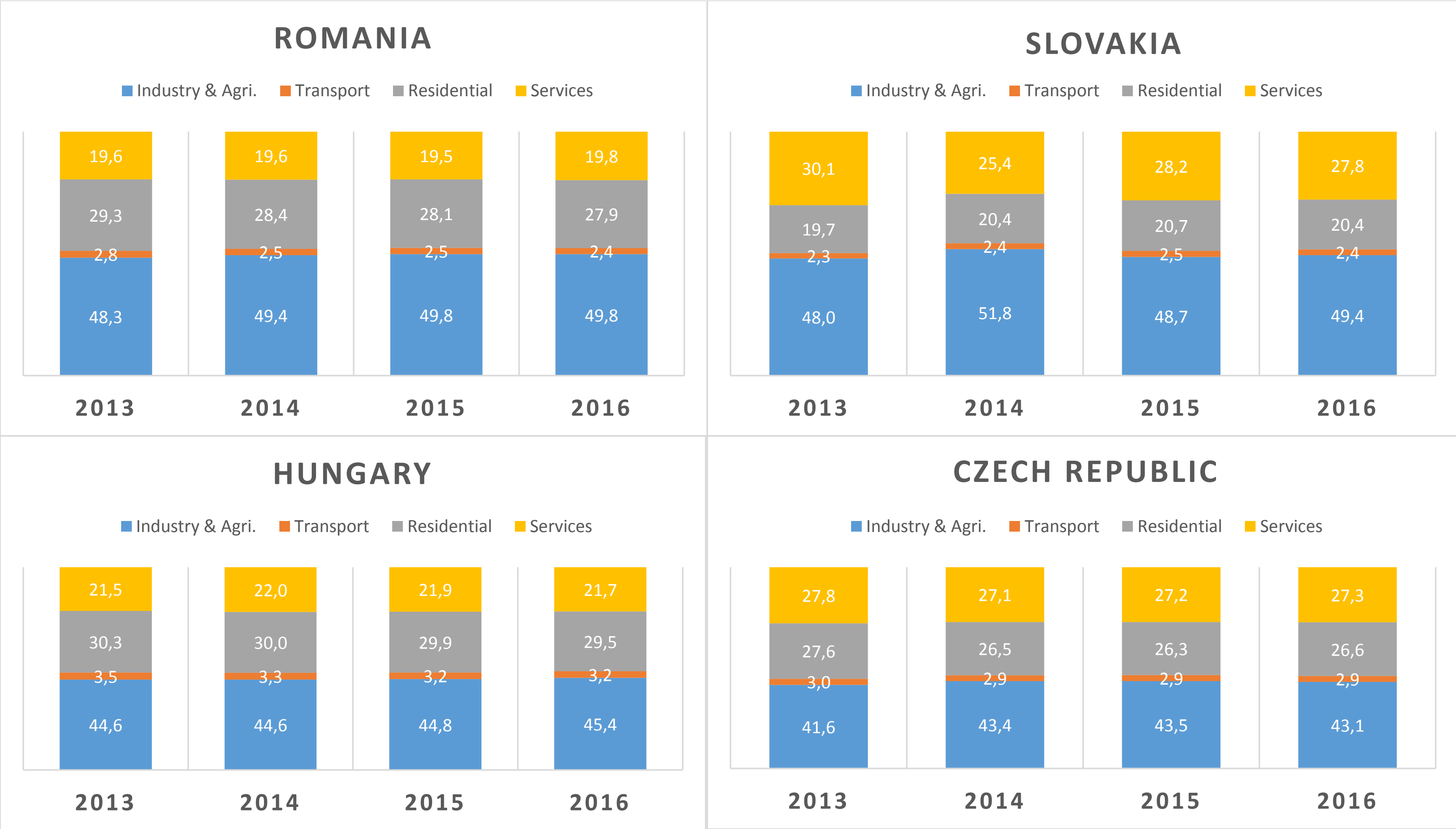
APPENDIX

APPENDIX A. Electricity generation by source for period 2013-2016 for 4M countries, %



Source: ENTSOE

APPENDIX B. Electricity consumption by source for period 2013-2016 for 4M countries, %



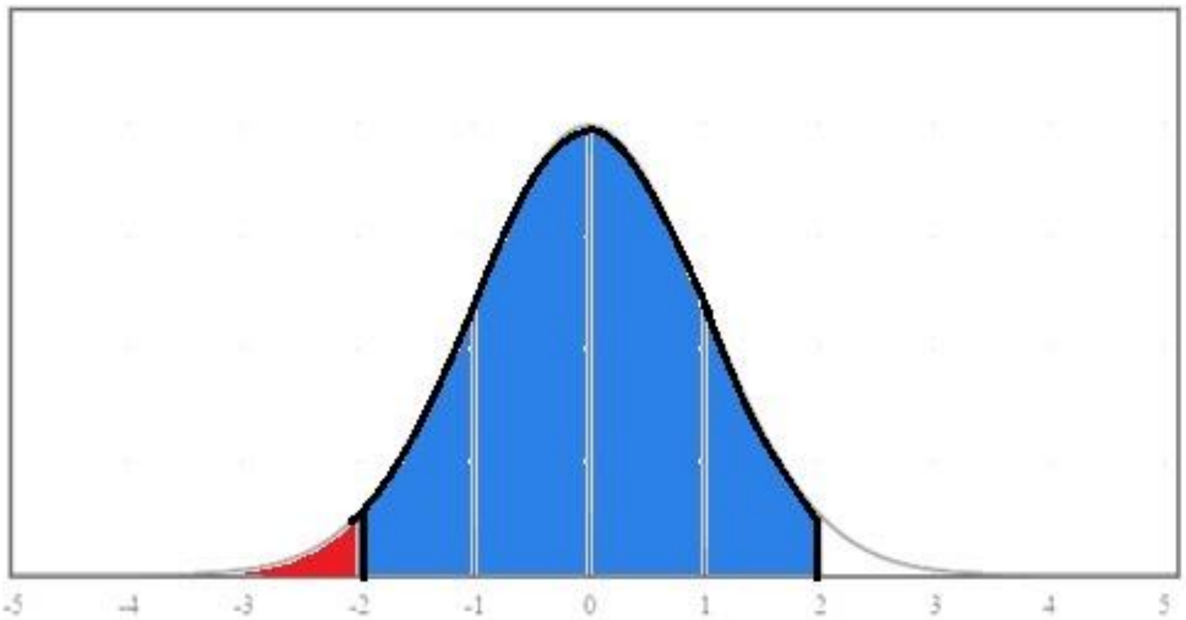
Source: Eurostat

APPENDIX C. Other important data

Table 1.1. 4M Institutional framework

	Czech Republic	Slovakia	Hungary	Romania
National Regulary Agency	ERU	URSO	MEKH	ANRE
Transmission System Operator	CEPS	SEPS	MAVIR	Transelectrica
Electricity Power Exchange	OTE	OKTE	HUPX	OPCOM

Source: made by author



Graph 1. The distribution problem
Source: made by author

APPENDIX D. Descriptive statistics of price differentials in base scenario

Statistic	*2013*	*2014*	*2015*	*2016*	*2017*
Czech Republic					
Mean	1,2	-0,3	-0,9	-2,7	-2,7
Median	0,7	-0,2	-0,4	-0,9	-0,8
Minimum	-49,1	-36,6	-54,3	-61,8	-70,9
Maximum	63,5	22,9	33,1	21,3	38,5
SD	6,3	3,7	5,1	7	9
Kurtosis	8,5	5,8	13,8	14,7	11,3
Skewness	1	-0,5	-2,2	-3	-2,7
JB**	0	0	0	0	0
Count	6264	6264	6264	6264	6240
Slovakia					
Mean	0,6	-1,1	-2,5	-3,2	-8,4
Median	0,6	-0,3	-0,8	-1	-2
Minimum	-79,8	-70,1	-93,6	-61,8	-90,4
Maximum	63,5	22,9	33,1	21,3	27,2
SD	7,8	5,9	7,9	7,5	15,5
Kurtosis	18,8	19,2	20,7	10,9	3,8
Skewness	-1,7	-3,2	-3,4	-2,6	-1,9
JB**	0	0	0	0	0
Count	6264	6264	6264	6264	6240
Hungary					
Mean	-2,9	-7,5	-8,7	-6,2	-16,4
Median	-0,2	-3	-4,9	-3,3	-11,6
Minimum	-148,3	-124,6	-98,5	-102,6	-261,6
Maximum	63,3	22,9	33,1	21,3	22,7
SD	14	12,4	12,2	9,4	19,4
Kurtosis	15,6	7,2	7,7	12,1	16,8
Skewness	-3,1	-2,1	-2,1	-2,5	-2,7
JB**	0	0	0	0	0
Count	6264	6264	6264	6264	6240
Romania					
Mean	4,6	-0,9	-3,9	-3,8	-14,1
Median	5,7	-0,1	-2,9	-2,3	-10,6
Minimum	-73,8	-45,5	-55,3	-102,6	-112,5
Maximum	78,7	53,9	57,7	50,1	81,1
SD	14,2	12,1	12,4	10,9	19,6
Kurtosis	2,2	0,8	1	8,2	3
Skewness	-0,5	-0,1	0,1	-0,7	-0,9
JB**	0	0	0	0	0
Count	6264	6264	6264	6264	6240

Note: JB-Jacque Berra test on normality of distribution, **- 5% significance level
Mean, Median, Minimum, Maximum are displayed in € /MWh

APPENDIX F. Results of the integrative process in the peak and off-peak scenarios under the hypothesis 1 and 2

Table 1.1. The results of integration process if price differential between EPEX SPOT and 4M markets if price differential is less than €2/MWh (peak load case)

	2013	*2014*	*2015*	*2016*	*2017*
CZ	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00
SK	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00
HU	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00
RO	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00

Lower numbers represent the p-values at a 2.5% significance level

Table 1.2. The results of integration process if price differential between EPEX SPOT and 4M markets if price differential is less than €2/MWh (off-peak load case)

	2013	*2014*	*2015*	*2016*	*2017*
CZ	Yes 0,00	No 1,00	No 1,00	No 1,00	No 1,00
SK	Yes 0,00	No 1,00	No 1,00	No 1,00	No 0,18
HU	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00
RO	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00	Yes 0,00

Lower numbers represent the p-values at a 2.5% significance level

Table 1.3. The results of integration process if price differential between EPEX SPOT and 4M markets if price differential is less than €11.5/MWh (peak case)

	2013	*2014*	*2015*	*2016*	*2017*
CZ	No 1,00	No 1,00	No 1,00	No 1,00	No 1,00
SK	No 1,00	No 1,00	No 1,00	No 1,00	No 1,00
HU	No 1,00	No 1,00	No 1,00	No 1,00	Yes 0,00
RO	No 1,00	No 1,00	No 1,00	No 1,00	Yes 0,00

Lower numbers represent the p-values at a 2.5% significance level

Table 1.4. The results of integration process if price differential between EPEX SPOT and 4M markets if price differential is less than €11.5/MWh (off-peak case)

	2013	*2014*	*2015*	*2016*	*2017*
CZ	No 1,00	No 1,00	No 1,00	No 1,00	No 1,00
SK	No 1,00	No 1,00	No 1,00	No 1,00	No 1,00
HU	No 1,00	No 1,00	No 1,00	No 1,00	No 1,00
RO	No 1,00	No 1,00	No 1,00	No 1,00	No 1,00

Lower numbers represent the p-values at a 2.5% significance level

Table1.5. The interregional integration process of 4M markets if price differential is less than €2/MWh (peak case)

	2013	*2014*	*2015*	*2016*	*2017*
CZ=>SK	No 1,00	No 1,00	No 1,00	No 1,00	No 1,00
SK=>HU	No 1,00	No 1,00	No 0,42	No 1,00	No 0,273
HU=>RO	Yes 0,00	No 1,00	No 1,00	No 1,00	No 1,00

Lower numbers represent the p-values at a 2.5% significance level

Table 1.6. The interregional integration process of 4M markets if price differential is less than €2/MWh(off-peak case)

	2013	*2014*	*2015*	*2016*	*2017*
CZ=>SK	No 1,00	No 1,00	No 1,00	No 1,00	No 1,00
SK=>HU	No 1,00	No 1,00	No 1,00	No 1,00	No 1,00
HU=>RO	Yes 0,00	Yes 0,00	No 1,00	No 1,00	No 1,00

Lower numbers represent the p-values at a 2.5% significance level