POSSIBLE REASONS FOR THE DIFFERENCE BETWEEN HUPX AND EEX DAM PRICES[1]

Why is Hungarian electricity more expensive than German?

ENIKŐ KÁCSOR

A MAGYAR ÉS NÉMET MÁSNAPI ÁRAMÁRAK KÜLÖNBSÉGÉNEK OKAI

Miért drága a magyar árampiac?

Az elemzés célja, hogy feltárja a német és magyar másnapi áramárak közötti különbségek lehetséges okait. A cikk a 2011-2013-as időszak adatai alapján vizsgál három hipotézist: i) az északi (különösen a szlovák) határon nem áll rendelkezésre kellő határkeresztező kapacitás; ii) a kedvezőtlen hidrológiai helyzet a Balkán országaiban megnövekedett áramimport keresletet gerjeszt, ami megemeli a magyar árakat; iii) a hazai nem tervezett erőművi kiesések okozta kínálati sokkok hatására ugranak meg a magyar árak.

Kereszttáblák segítségével mind az osztrák, mind a szlovák határkeresztező kapacitások, a balkáni csapadék mennyiség, és a nem tervezett hazai erőművi kiesések árkülönbségre gyakorolt hatása is igazolható. Lineáris regresszió segítségével utóbbi, vagyis a kínálati sokkok hatása nem igazolható. Mindkét esetben kimutatható volt, hogy az árkülönbség szignifikánsan nagyobb hétvégén, mint hétköznap. A REKK Európai Árampiaci Modelljének (EEMM) segítségével szintén vizsgálható volt a fenti változók hatása. Az eredmények alátámasztják a kereszttáblák és lineáris regresszió által kimutatottakat, ugyanakkor a modellezés alapján a nagyobb árkülönbség a csúcsidőszakban várható.

The aim of this paper is to analyse the price convergence between the German (EEX) and the Hungarian (HUPX) power exchanges, in the case of daily average DAM prices. Many articles have sought to explain the persistent spread between the two markets but there is no accepted consensus among the oft appearing hypotheses.

The paper focuses on the 2011-2013 period, and three hypotheses are established to explain the spread: i) insufficient net transfer capacity (NTC) on the northern borders (especially with Slovakia) for equalization between the markets; ii) unfavourable hy-

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[1] The Author would like to thank Adrienn Selei, András Mezősi, Péter Kaderják, Péter Kotek and Nolan Theisen for valuable comments and discussions.

drological conditions in the Balkan area that lead to increased demand for Hungarian imports and push up prices in Hungary; iii) non-planned domestic power plant outages increase the Hungarian price.

The methodology applies cross-tabs and linear regression. With the cross-tabs, the effect of both the Slovakian and Austrian NTC, the Balkan precipitation and the non-planned outages on the spread are tested. All these have been proved to have a significant effect on the price difference. Linear regression reaches almost the same conclusions, however effect of non-planned power plant outages is not significant. Both cases the higher vulnerability of weekends is demonstrated.

Finally the effect of the above used variables is tested with the 2015 version of REKK's European Electricity Market Model (EEMM). The model confirms the above findings, except that the higher spread appears in peakload periods.

1. INTRODUCTION

Since the beginning of deregulation in Hungary, electricity prices on the Hungarian wholesale market have surpassed the price level of the neighbouring Slovakian and Czech markets and the German wholesale prices that are used for reference. The spread reached 14 EUR/MWh in 2007, and then effectively disappeared in the first few years of the economic downturn, before rising again in the region of 3-10 EUR/MWh. The aim of this paper is to analyse the price difference between the German (EEX) and the Hungarian (HUPX) power exchanges, in the case of daily average day-ahead market (DAM) prices. Many market participants have sought to explain the persistent spread between the two markets but there is no accepted consensus among the recurring hypotheses.

The paper concentrates on the 2011-2013 period, and uses three hypotheses to explain the spread: i) insufficient net transfer capacity (NTC) on the northern borders (especially with Slovakia) obstructing equalization between the markets; ii) unfavourable hydrological conditions in the Balkan area increase demand for Hungarian imports and push up prices in Hungary; iii) non-planned domestic power plant outages increase the Hungarian prices.

The methodology applies cross-tabs and linear regression to test the hypotheses. After that, the effect of the variables used in the first two methods is tested with the 2015 version of REKK's EEMM model. This way it can be tested, that the found relationships and effects in the analysed period (2011-2013) still exist in the later years.

2. PREVIOUS ANALYSES ON ELECTRICITY MARKETS

After the market liberalization in Europe, at the end of the last decade, electricity market has become a salient topic, particularly with respect to prices. More than 10 electricity exchanges in Europe - mostly established around 2000[2] - have provided ample

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[2] OTE, EPEXSPOT, Nordpool, EEX, HUPX, SEMO, GME, OMIP, OMIE, ELEXON, POLPX, OPCOM, etc.

data for in-depth analyses. Transparent and detailed information is provided for traders since historical and on-time data is essential for everyday work. At the same time, regulators can also keep an eye on market participants by analysing market data. In 2012, for example, the Hungarian Energy Office carried out an investigation [MEH, 2012] using Hungarian Power Exchange (HUPX) data to determine whether high prices could be a result of market manipulation. They found no evidence on market power abuse. And, indeed, detailed, continuously verified, quality data provides the opportunity for economic research to be carried out with sophisticated methodology.

Usually the benchmark power price in the region is the German electricity price [Ziel et al., 2015], the price published on the European Energy Exchange (EEX)[3], as it is one of the biggest power exchanges in Europe, with a yearly spot market volume of around 350-400 TWh (EEX, 2015). Many articles deal with the issue of electricity price convergence in Europe or the effect of foreign markets on domestic electricity prices [Ziel et al., 2015, Bollino et al. (2013) and Bosco et al. (2010)]. In this article we focus on the difference between HUPX and EEX prices. In the observed period there is a high correlation between the Hungarian prices and the spread (0.58), meaning that the cause of the huge price difference is often the high Hungarian price, rather than the low German price (however -0.28 correlation exists between the German prices and the spread). The topic appeared many times in the media [Platts, 2011; Reuters, 2011; Argusmedia, 2013], debating the possible reasons for price spikes and prolonged periods of high prices in Hungary.

There is no consensus on whether high electricity prices have a negative effect on the competitiveness of a country: [Berk & Yetkiner (2014)] argues that higher Hungarian energy prices lead to lower economic growth, [Bretschger (2015)] finds that higher prices incentivise innovation, and on a long run lead to higher economic growth. However both cases it is important to know the reasons behind the high electricity price. The following summary contains a selection of articles analysing the Hungarian electricity market, and electricity prices in general.

There are two main approaches in electricity price modelling. One way is to build a fundamental model, trying to find the factors that affect the prices in a given market. These models treat electricity as a special good, thus its price is influenced by different outside factors. This idea is applied by e.g. [Hagfors et al. (2016), Kaderják et al. (2008), Kotek (2011), Ihász-Tóth (2013) and Derekas (2014)]. The other approach is to treat electricity price data as a financial time series data. Most of the times AR or ARMA models are used to estimate or forecast electricity prices. Some cases ACF functions and special distributions (e.g. different types of long-tailed distributions) are also used. Examples of these type of models are [Ziel et al. (2015), de Menezes et al. (2016), Kristiansen (2012) and Marossy (2012)]. Sometimes a combination of fundamental and econometric modelling is applied, [Halužan (2014) and Paraschiv (2015)] use this approach.

[Kaderják et al. (2008)] analysed the relationship between the electricity markets of the Balkan countries and Hungary. This gave a brief overview of the electricity market in Croatia, Serbia, Montenegro, Albania, Bosnia and Herzegovina, Macedonia, Romania and Bulgaria. They find that at least 25% of the electricity production comes from

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[3] prices are also available on the EPEX SPOT exchange

hydro power plants in all of these countries (except Bulgaria), meaning they are highly exposed to weather conditions. Croatia plays a key role in the region, importing a significant amount of energy from Hungary, and exporting to other Balkan countries. The article tries to determine whether the high Hungarian prices could result from the at times limited electricity generation (due to unfavourable weather conditions) available in the Balkans. They find that closing all borders (in order to exclude the effect of the Balkan demand on Hungary) has a small effect on the Hungarian prices and a much greater effect on the Balkan prices.

[Kotek (2011)] analyses the effect of a sudden drop in available transmission capacity at the Hungarian-Slovakian border on the Hungarian prices. He finds that after the drop, Hungarian wholesale spot price is far above the German spot price, while the Czech and Slovakian prices follow it. Kotek concludes that the high spread is a possible result of the lack of available transmission capacity on the Slovakian-Hungarian border, and the insufficient information on the sudden decrease of it.

[Argusmedia (2013)] writes about price spikes in Hungary and finds a connection between low market-coupling capacity on the Slovakian-Hungarian border and high HUPX prices. The article also mentions the high temperature period that increases demand, not only in Hungary but in the Balkan region as well. It states that price spikes are possibly the result of the combined effect of a heat wave and the lack of market-coupling capacity, and that the Hungarian market is still very exposed to the risk of high prices. [Derekas (2014)] also addresses the issue of price spikes on HUPX DAM market. He carries out an analysis of so-called outlier hours – which in the case of electricity markets form an important part of the data and should not be left out, unlike in many other fields of economic analysis. He finds that price spikes in the Hungarian market can be explained with non-planned power plant outages, hot temperatures and the type of day (weekend/weekday).

[Halužan (2014)] builds an ARMAX model to explain HUPX day-ahead prices. In addition to the AR and MA parts, he uses daily average temperature, daily average wind production in Hungary and Romania, and the daily average Drava river stream as explanatory variables. Also dummies for holidays and seasons are included. He finds that the best model contains only temperature, type of day (weekend/weekday) and seasonal dummies and the AR and MA elements. [Ihász-Tóth (2013)] also models Hungarian DAM prices. The model includes export to Croatia, available transmission capacities on the border of Slovakia and Ukraine, non-planned power plant outages in Hungary, a seasonal dummy, EPEX SPOT day-ahead prices, and HUPX prices as AR elements, and fits well. It also shows the correlation between German and Hungarian prices, the effect of previous HUPX prices on current HUPX prices, and that summer is the most expensive season.

In addition, there are lot of articles using unique methodological approaches for solving similar problems. Paraschiv [2015] estimates electricity prices with a quantile linear regression, using AR part, and changing betas in time. Marossy [2012] analyses price spikes with the help of so-called long-tailed distributions, such as Gumbel, Weibull or Fréchet. These distributions are usually used in the field of actuary, modelling situations where the probability of a large loss is high. She finds it is very relevant to differentiate between peak and off-peak periods.

My three hypotheses are in line with the results of the previous analyses. Moreover demand can also have an effect thus it is worth to be included, and also the effect of the previous day spread, however building a fundamental model may lack this latter.

3. INPUT DATA

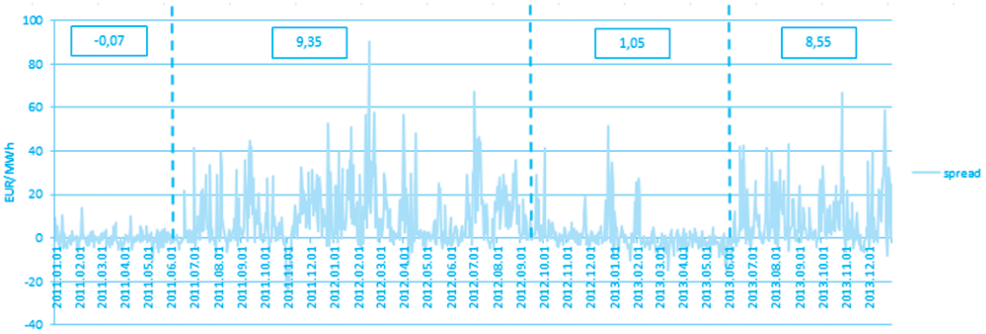
3.1. Prices

The basis of our analysis is HUPX and EEX data. As it is shown on the next figure, there are separate periods with higher and lower spreads. Thus variables were looked for, that are changing the same way over time, so would be capable of explain these changes.

There are several ways to compare the prices of the two power exchanges, beginning with the futures market (PhF) and day-ahead market (DAM), but also different types of products such as peak and off-peak delivery, etc. The futures prices are closely connected to the spot market prices, but at the same time usually respond slower, which makes them less volatile. A short-term event (such as removing a power plant from the system or a bottle-neck on the border) can increase the difference in spot prices significantly, but would not have a large impact on futures prices. At the same time, the day-ahead spread gradually seeps into the futures markets, thus the futures price (next year delivery) difference converges to the average day-ahead spread of the previous year.

In our analysis the daily average spread is used, instead of the hourly spread. The main reason is, that there was no intraday trading in the observed period, and thus gate-closure was on the previous day. This way e.g. NTC values in a given hour were not known by the traders when they traded electricity for a given hour. Also precipitation data is available on a daily basis, not on an hourly. While average daily prices might lack the extreme volatility that hourly prices can provide, still more than 1000 data points are available for analysis.

Figure 1. The price difference between HUPX and EEX daily average baseload prices 2011 January – 2013 December

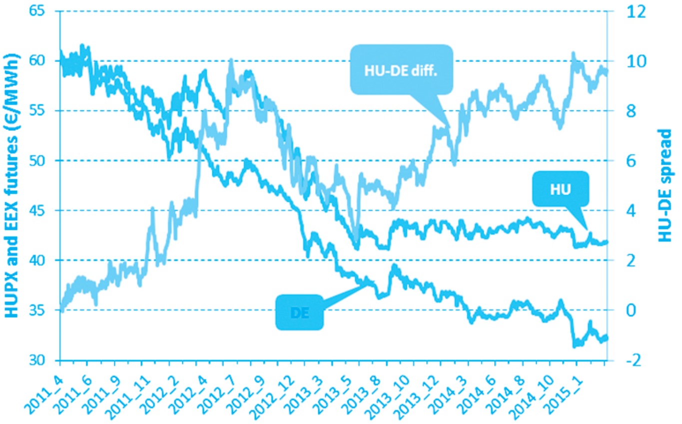


source: HUPX, EEX

As it is visible, Hungarian and German prices moved closely together from January 2011 to July 2011. The average price difference was even negative, but close to zero: only - 0.07 EUR/MWh in this half year period. From then on, until the Czech-Slovak-Hungarian market-coupling in 2012 September, the average spread went up to 9.35 EUR/MWh. The market-coupling was able to moderate the price divergence until the following summer: the average spread fell to 1.05 EUR/MWh again. In the final half year period, prices separated considerably again, with an average price difference of 8.55 EUR/MWh.

The next figure illustrates the above mentioned pattern: a slow reaction in the futures market to events in the spot market is clearly apparent. Although the period of analysis is 2011-2013, the spread between the two markets remained significant in the later years as well, and even increased. Thus the importance of the issue is still valid.

Figure 2. The average daily price difference of the HUPX and the EEX baseload futures deliverable in the next year, 2011-2015



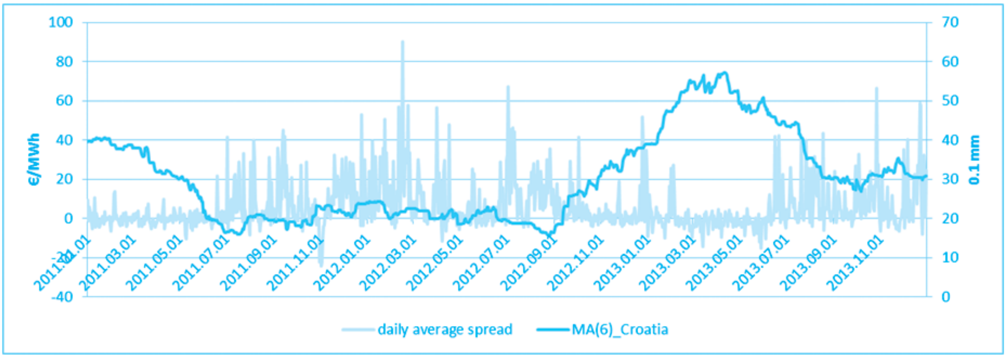
source: PXE, EEX

The most conspicuous event occurred in 2011 July, resulting in a sudden change mostly visible in the spot market. The above mentioned MEH investigation [MEH, 2012] was conducted in response to this price divergence, and believed that the increasing spread could be explained by a regulatory change. The power plants capable of co-generation were removed from the feed-in system, which meant that their electricity production in the summer was no longer profitable. Therefore, the domestic supply suddenly dropped and the plants were only turned on again in the heating season. MEH concluded that the persistence of the spread can be attributed to the drought period in the Balkans.

3.2. Balkan weather

As an indicator for demand for Hungarian import electricity hydro production data seems satisfactory. However in the Balkans only monthly production data is available, there is daily precipitation data on a country level. To find the connection between the Balkans weather and the demand for Hungarian import electricity, hydropower generation was estimated with precipitation values. As only monthly production data was available, the best fitting model was the 6 months moving average of the daily precipitation values. Therefore this is applied in the later analysis. It is shown, that the most significant from all the Balkan countries was Croatia, possibly because from 2007 to 2012 hydropower generation constituted around 50% of its total electricity production. In the following figure the connection between rainy and drought periods and the HUPX-EEX spread is clearly visible.

Figure 3. The six-monthly moving average of the Croatian rainfall, 2011-2013



source: European Climate Assessment & Dataset

3.3. Non-planned domestic power plant outages

Data on non-planned outages were applied of two major players in the Hungarian power plant portfolio: Paks, the nuclear power plant in Hungary, 100% owned by the incumbent player, and Mátra, a lignit power plant, another important market player, jointly owned (at the time of the analysis) by RWE (51%) and the incumbent player (26%). The total installed electricity generation capacity in Hungary is around 9 GW, from which more than 1 GW is on a permanent shutdown, and around 500 MW functions only as reserve. In the case of large power plants, the incumbent player owns 2.8 GW generation capacity, around third of the total domestic installed capacity. A few international companies own a further 3.4 GW capacity (MET: 1 GW, RWE jointly owned with MVM: 1 GW, E.ON: 0.5 GW, Alpiq: 0.5 GW, EDF: 0.4 GW), while another 1 GW is in the hands of a Hungarian investor, IFC group. The rest of the generation capacity comes from small power plants (with an installed capacity less than 50 MW)[4]. Thus both Paks and Mátra plays a significant role on the Hungarian market.

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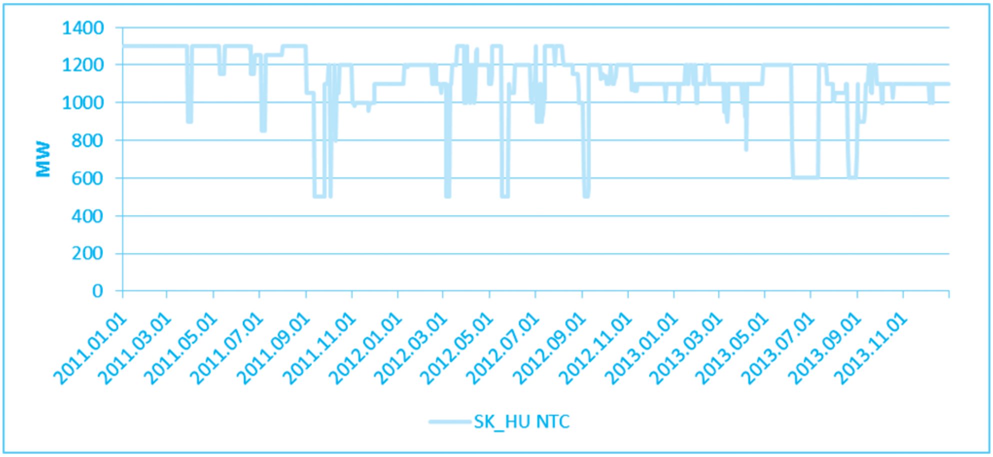
[4] source: MAVIR (Hungarian Transmission System operator) and the websites of the companies

For our analysis a dummy variable was created, containing all the days when non-planned outages of a block of either Mátra or Paks occured. This helped to highlight the effect of a sudden decrease in Hungarian supply.

3.4. Slovakian and Austrian NTC values

In our modelling the net transmission capacity (NTC) of the Slovakian and Austrian border are included.[5] Hungary usually imports from its Northern neighbours (Austria and Slovakia), and exports to its Southern neighbours (Croatia, Serbia), with an average 23% net import rate in the observed period (nowadays this number is even higher). In case of such a high import rate, availability of the transmission capacity can have a huge effect on price convergence with the neighbouring markets. However, an abundance of research has focused on the relationship between sufficient cross border capacity and the spread between the German and Hungarian prices. The change from 2011 July is clearly visible in the case of the SK-HU NTC values – just like in the case of spread. From then on the NTC rarely went beyond 1200 MW, and at the beginning of the summer of 2013 a longer capacity reduction can be observed.

Figure 4. NTC values on the Slovakian border, 2011-2013



source: MAVIR

The long-run reduction of the NTC under 1200 MW is explained by the regional Transmission System Operators (TSOs) [ČEPS, 2013] with the so-called non-planned flows, or loop flows[6]. To ensure system security, the Hungarian TSO "saved" (did not offer on

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[5] I would like to thank the Hungarian Transmission System Operator – MAVIR – for the valuable data provided on NTC values.

[6] Loop flows are non-planned physical flows, caused by e.g. sudden increase in generation in one area. In Germany many times renewable generation goes up quickly in one part of the country, while most of the consump-

auctions) more capacity for the more frequent and sizable non-planned flows, which some say were a possible effect of increasing renewable production in Germany. The Agency for the Cooperation of Energy Regulators (ACER) has estimated [ACER, 2015] that these loop flows cost the Polish and Czech economies 25 million euros/year, as less NTC is available for power trade. This highlights the fact that days with less available transmission capacity are more exposed to the risk of higher prices, thus in our case a higher spread.

4. APPLIED METHODOLOGY AND RESULTS

4.1. Hypotheses

After examining the data, and the oft appearing explanations for the spread, three hypotheses were established:

1) The hydrological pattern in the Balkans has a significant effect on its electricity imports, transmitting through the Hungarian price and ultimately the spread
2) The sudden decrease in the domestic supply also negatively affects the Hungarian market, raising Hungarian prices and increasing the spread
3) Insufficient NTC on the Slovakian and/or Austrian border limits price converge, thus the possibility of a larger spread is higher when NTC values are lower, reflective of a negative relationship between NTC and spread values

The latter is usually discussed in connection with unbundling: if the TSO and the owner of the generation capacities would be the same legal entity (as it was the case before the market liberalization), then it may occur that the amount of offered NTC is defined on a level that maximizes the profit of the generator – for example through closing the borders and keeping out cheap electricity, in order to keep domestic prices high. However after market liberalization a fully independent TSO was established in Hungary, so it is not in the scope of this paper to analyse the possibility of cooperation between the TSO and the incumbent market player.

4.2. Cross-tabs

Connectivity tests were applied with the help of cross-tabs in the case of all above mentioned variables. As demand seemed an important factor not only weekday/weekend dummy ("peak_wd") was included, but the daily average net load in the Hungarian system. As it is shown later, demand itself does not have a significant effect on the spread, rather on the EEX and HUPX prices. The applied test was a two-sided two-sample T^2 test with non-equal variance.

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tion is situated in the other part of the country. While transferring, electricity sometimes „uses" other ways, as it always goes to the direction with the least resistance, thus it can happen that an inland transport in Germany causes non-planned flows in Hungary, Poland, Slovakia, etc. For further information see [Pató et al. (2016)].

Table 1. Average spread values in case of lower than average and higher than average values of the given variables[7]

	Average spread		p-value
	under average	above average	
hupx	1.80	9.95	3.5E-31
eex	8.25	4.06	1.39E-08
sk_hu_NTC	7.97	3.79	4.82E-09
at_hu_NTC	7.50	4.09	1.43E-06
MA_BA	7.60	3.14	1.85E-10
MA_HR	8.13	3.31	7.48E-12
MA_RO	5.12	6.64	0.035431
MA_RS	7.58	4.72	0.000161
MA_av	7.38	4.17	2.49E-05
non_planned_PM*	5.23	7.58	0.004658
peak_wd*	7.86	5.13	0.001276
Demand (net load)	5.43	6.35	0.203087

*in case of dummy variables, under average means ’0’ value, above average means ’1’ value
source: own calculation

In Table 1. it is visible that most of the cases the average spread value is significantly different in days with lower than average and higher than average values of the given variables. This means, that whenever there was less rain in the Balkans (except Romania) or insufficient capacity on the SK-HU or the AT-HU border, or a non-planned power plant outage occurred in Paks or Mátra power plants the spread was higher than the other way – and this difference is significant (in a 5% significance level). The connection between the spread and HUPX and EEX is also visible here. However the connection between demand and the spread is not significant, and also the results in the case of the weekday/weekend dummy (1 on weekdays, 0 on weekends) are not intuitive for first sight. It seems that at weekends, (that are usually off-peak periods compared to weekdays), the average spread is higher, than on weekdays and the difference is significant.

4.3. Linear regression

In order to avoid multicollinearity in our model the following correlation table was calculated. From those variables that are closely correlated only one was included in the regression.

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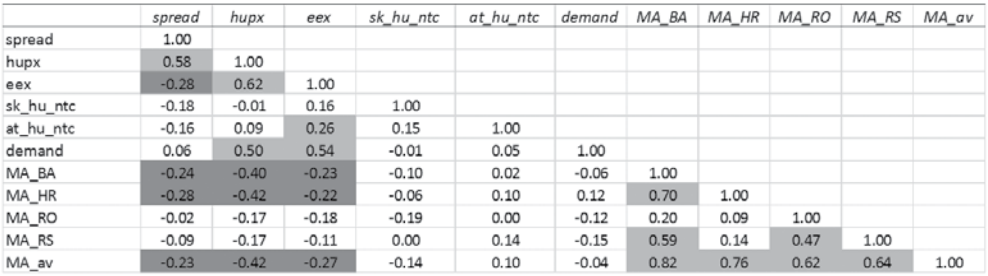
[7] for further information on the distribution of the variables, and their average values, see ANNEX III on the website of Köz-Gazdaság

2. Table: Correlation between the variables



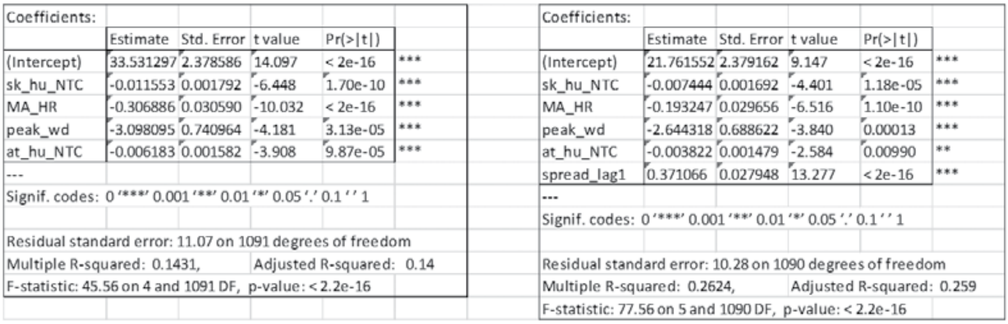
	spread	*hupx*	*eex*	*sk_hu_ntc*	*at_hu_ntc*	*demand*	*MA_BA*	*MA_HR*	*MA_RO*	*MA_RS*	*MA_av*
spread	1.00										
hupx	0.58	1.00									
eex	-0.28	0.62	1.00								
sk_hu_ntc	-0.18	-0.01	0.16	1.00							
at_hu_ntc	-0.16	0.09	0.26	0.15	1.00						
demand	0.06	0.50	0.54	-0.01	0.05	1.00					
MA_BA	-0.24	-0.40	-0.23	-0.10	0.02	-0.06	1.00				
MA_HR	-0.28	-0.42	-0.22	-0.06	0.10	0.12	0.70	1.00			
MA_RO	-0.02	-0.17	-0.18	-0.19	0.00	-0.12	0.20	0.09	1.00		
MA_RS	-0.09	-0.17	-0.11	0.00	0.14	-0.15	0.59	0.14	0.47	1.00	
MA_av	-0.23	-0.42	-0.27	-0.14	0.10	-0.04	0.82	0.76	0.62	0.64	1.00

source: own calculation

Colouring shows variables with less than -0.20 or more than +0.20 correlation. Balkans precipitation moving average are closely correlated with each other, thus only one of them will be used in the regression. Croatia has the highest correlation with the spread, but the average Balkan precipitation can also be a good indicator while building a fundamental model. As it was mentioned above, demand (net load) variable has a strong correlation with both the German and the Hungarian prices, but almost nothing with the spread. Thus it will not be included in the model. Instead the above mentioned peak_wd dummy variable will be included (see Table 1). Effect of NTC values does not seem strong, but is in line with the above findings: less NTC values go with higher spread.

Several different linear regressions were built from the above presented variables, from which the two best fitting ones are presented here (for further results see Annex 1 on the website of Köz-Gazdaság). The models included 1096 data points for each variable (365+365+366 days). One regression was called "better fitted" if more variables were significant, and the R^2 was higher. As it is mentioned above, day(-1) spread is typical to be included in such models, as the market depends heavily on expectations. As it is shown it does increase the explanatory power of the model (only itself explains more than 20% of the variance), however it is not considered a fundamental variable (also this is the reason why not price of NTC is included in the model: that can possibly say more about how much scarcity is in the system on the given day, however it is less fundamental, as the price is an outcome of an auction). Thus a model with and without this variable is presented here.

Table 3. Results of the linear regressions



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Coefficients:
              Estimate   Std. Error  t value  Pr(>|t|)
(Intercept)   33.531297  2.378586    14.097   < 2e-16   ***
sk_hu_NTC     -0.011553  0.001792    -6.448   1.70e-10  ***
MA_HR         -0.306886  0.030590    -10.032  < 2e-16   ***
peak_wd       -3.098095  0.740964    -4.181   3.13e-05  ***
at_hu_NTC     -0.006183  0.001582    -3.908   9.87e-05  ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 11.07 on 1091 degrees of freedom
Multiple R-squared:  0.1431,        Adjusted R-squared:  0.14
F-statistic: 45.56 on 4 and 1091 DF,  p-value: < 2.2e-16
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Coefficients:
              Estimate   Std. Error  t value  Pr(>|t|)
(Intercept)   21.761552  2.379162    9.147    < 2e-16   ***
sk_hu_NTC     -0.007444  0.001692    -4.401   1.18e-05  ***
MA_HR         -0.193247  0.029656    -6.516   1.10e-10  ***
peak_wd       -2.644318  0.688622    -3.840   0.00013   ***
at_hu_NTC     -0.003822  0.001479    -2.584   0.00990   **
spread_lag1   0.371066   0.027948    13.277   < 2e-16   ***
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Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 10.28 on 1090 degrees of freedom
Multiple R-squared:  0.2624,        Adjusted R-squared:  0.259
F-statistic: 77.56 on 5 and 1090 DF,  p-value: < 2.2e-16
```

source: R output, own calculation

All variables are significant on a 0.1% level. The betas are in line with the cross tab results, thus all of them are negative (excluding the spread (day-1)) – meaning less precipitation in Croatia (in the last 6 months) and less NTC in the SK-HU and AT-HU borders lead to higher spread. Also weekends are more vulnerable to the risk of high spread (as the value of the dummy is 1 on weekdays and 0 at weekends). The positive beta of the one day earlier average daily spread means that it is normal to expect that the average daily spread will be close to the average spread on the day before. As it is visible, non-planned power plant outages are not included in the regressions, as they can not be proved to be significant. Neither the multiplication with peak_wd dummy – non-planned outages of Paks or Mátra do not matter significantly, nor only on the more vulnerable weekends.

It should be noted here that both models have relatively low R^2 values, thus the explanatory power of the model is also relatively low. This can indicate the problem of missing variables that can lead to biased betas. This can explain the change of betas when the spread_lag1 variable is included. However all betas are negative in both cases. Possible further improvement of the model can be based on the deeper examination of the error, (e.g. calculation of autocorrelation, etc.). A possible outcome is a development of a GARCH-type model. Also a possible way to improve the model is to test structural break, and build a model with changing bates over time if necessary.

From the above model an estimation of the spread in an "average" day can be given. Assuming (as later in the modelling) 766 MW NTC for SK-HU and 515 MW NTC for AT-HU, 3.27 mm six-month moving average of rainfall in Croatia (which is 32.7 in the calculation as 0.1 mm is the unit of precipitation) the weekend spread is 12.2 EUR/MWh, while the weekday is 9.1 EUR/MWh. As it will be shown, these are close to the baseload spread according to the EEMM model. However the fact average spread in the observed period was only 5.91 EUR/MWh.

To sum up, both NTC values (SK-HU and AT-HU) and hydrological conditions in the Balkans are proved to be important, thus our first and third hypotheses are verified. Although there is no evidence from the linear regression that the sudden decrease in the Hungarian supply has a significant effect on the spread. Weekends once more seem to be more vulnerable to the risk of higher spread.

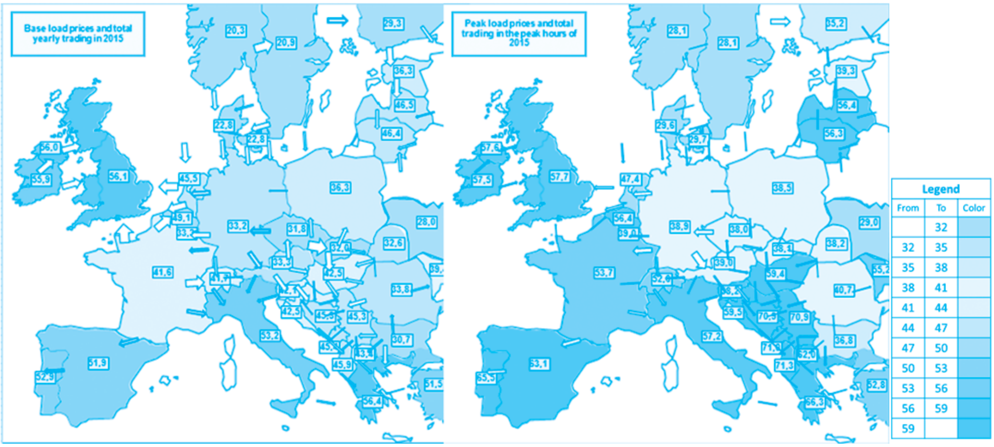
4.4. Applying the European Electricity Market Model

After testing the above mentioned hypothesis for the 2011-2013 data the effect of the variables is also tested with the 2015 version of REKK's EEMM model. This is a bottom-up model that assumes perfect competition and optimises the total welfare in the modelled region. It contains the electricity markets of 36 European countries, with detailed technological representation. Power plants in the given markets are included on a block level, thus 5000 units of 12 different technologies are modelled. Cross-border transmission capacities are modelled on an aggregated manner (one NTC value for every two countries). The prices are determined by the supply-demand balance in every country, allowing cross-border trade using NTC values as constraints. For every year 90 reference hours are simulated, yearly average peakload and baseload prices are calculated from these hourly prices. For more detailed description see Mezősi & Szabo [2016].

In order to validate the regression results, and gain information on the more recent state of the markets, and thus the spread, the 2015 version of the model is applied. This contains all infrastructure elements included in the ENTSO-E Ten Year Network Development Plan [TYNDP, 2012], put in operation not later than 2015. Also the list of power plants is actualised for 2015 – taken into account ongoing investments and planned closures from the last few years. The reference case represents the 2015 price levels in the analysed countries.

In the following part of the paper the effect of changes in three factors are tested: the decrease and increase of the SK-HU NTC, the utilization of the hydro power plants and the outage of one block of Paks and Mátra. SK-HU NTC can be increased in this case, because the reference scenario calculates with a 70% utilization rate of the total NTC, as a result of loop flows. When increasing the NTC it is assumed that loop flow related problems are solved – at least for the observed period.

5. Figure: Reference prices, 2015, Baseload and Peakload



source: EEMM output, own figure

In the reference case, the spread between the two observed markets is 42.5 – 33.2 = 9.3 EUR/MWh in the baseload, and 59.4 – 38.9 = 20.5 EUR/MWh in the peakload period. Colours indicate higher and lower prices, while arrows show cross-border trade: grey arrows indicate congested lines. According to the model peakload hours are much more exposed to high spread than baseload hours. This however does not mean directly that weekdays are more vulnerable than weekends, as here peakload and baseload prices are calculated from the 90 reference hours, thus there are no weekdays and weekends in the model.

In case of hydro utilization rate every country has a normal, a low and a high utilization rate, calculated from the last 7 years utilization data. The reference scenario includes normal utilization, while in the other two cases it is analysed what happens in low and high utilisation rate situations. These utilisation rates are not only changing in the Balkans, but for every country, however hydro based production is the highest in the Balkans, thus the change has the biggest effect on this region. HUPX and EEX prices are summarised in the following table. It shows that both the peakload and baseload prices change significantly, low utilization rates can generate 20.3 and 14.6 EUR/MWh spread respectively, while high utilization rates bring down these numbers to 6.5 and 1.5 EUR/MWh.

4. Table: Average spread in case of changing hydro utilization rates

	HUPX (EUR/MWh)	EEX (EUR/MWh)	spread (EUR/MWh)
Baseload, low	48.6	34.0	14.6
Peakload, low	60.3	40.0	20.3
Baseload, normal	42.5	33.2	9.3
Peakload, normal	59.4	38.9	20.5
Baseload, high	32.8	31.3	1.5
Peakload, high	43.6	37.1	6.5

source: own calculation from EEMM output

The next analysis includes the outage of one block in Paks and in Mátra power plants. The results are summarised in the following table. In both cases the spread went up from 9.3 to 11.8 and 10.6 (in case of Paks and Mátra respectively) and from 20.5 to 21.5 and 20.9 EUR/MWh. Thus the model proves the positive effect on the spread of a supply decrease in the Hungarian market.

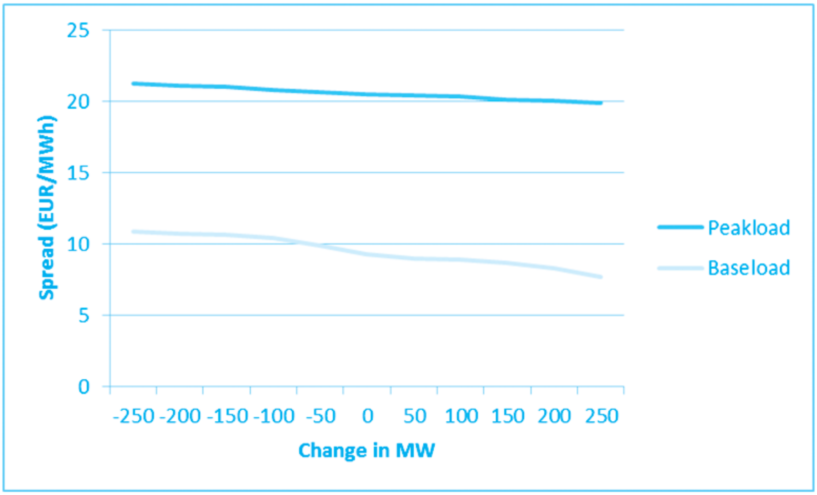
5. Table: Average spread in case of the outage of one block in Paks or Mátra power plants

	HUPX (EUR/MWh)	EEX (EUR/MWh)	spread (EUR/MWh)
Baseload, Paks	45.0	33.2	11.8
Peakload, Paks	60.4	38.9	21.5
Baseload, Mátra	43.8	33.2	10.6
Peakload, Mátra	59.8	38.9	20.9

source: own calculation from EEMM output

Finally the effect of the change in the SK-HU NTC was modelled. From -250 to 250 MW change was introduced, and the results were calculated for every 50 MW change. In the case of peakload the change is almost linear, in the case of baseload, it is only linear at the "edges" (more than 100 MW increase or decrease).

6. Figure: Average spread with different change of SK-HU NTC levels



source: EEMM output, own figure

Most of the results of the linear regression and the cross-tab analysis can be observed in the results of EEMM. As it is mentioned above peakload and baseload hours can not be compared to weekdays and weekends, but the three hypotheses are all supported. However further analysis can be carried out choosing only one reference hour (one peak- and one baseload), and observe the effect of the above mentioned variables in only that one hour, instead of assuming changes for the whole year. These would probably lead to similar results, but the effect on the different reference hours can be observed separately.

5. CONCLUSIONS

The aim of this paper is to find the possible reasons for the high spread between the Hungarian and German day-ahead average daily electricity prices. The reason for the large spread is almost always the high Hungarian price in the observed period. Examining the higher Hungarian price, three hypotheses are applied: unfavourable hydrological conditions in the Balkan raise demand for imported Hungarian electricity and thus Hungarian prices; non-planned domestic power plant outages increase the Hungarian price by decreasing available domestic supply; an insufficient amount of cross-border capacities at the Slovakian-Hungarian and Austrian-Hungarian borders leads to bottlenecks preventing the natural equalization of prices. Using cross-tabs all three hypotheses can be proved, while linear regression only shows significant effect of precipitation in the Balkans and NTC values. Both cases weekends seem more vulnerable to the risk of high spread. Finally results of the EEMM model shows that all three hypotheses can be proved, and a bit contradictory to the previous results, it shows peak hours are more vulnerable than offpeak hours.

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