Possible reasons for the difference between HUPX and EEX DAM prices*

Why Hungarian electricity is more expensive than German?

Enikő Kácsor[1] (Regional Centre for Energy Policy Research - REKK)
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Abstract

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 hourly 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 hydrological conditions in the Balkan area that leads to increased demand for Hungarian imports and pushes 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 the Slovakian NTC, the Balkan precipitation and the non-planned outages on the spread are tested. All have been proved to have a significant effect on the price difference while emphasizing increased vulnerability during peak hours. Linear regression reaches the same conclusions.

Beginning with the premise that non-planned power plant outages have a significant effect on the spread, the construction of profit function of the incumbent market player in Hungary can test whether this is a result of intended capacity withholding. As a new approach, the above mentioned linear regression is used to estimate the effect of capacity withholding on Hungarian prices.

The profits at optimal production level with and without capacity withholding are compared, and the difference marks the additional profit realized by capacity withholding. The results are compared to the actual non-planned outages data.

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[1] Research associate, Regional Centre for Energy Policy Research – REKK, Corvinus University of Budapest; PhD student, Corvinus University of Budapest; e-mail: eniko.kacsor@uni-corvinus.hu

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 period of price difference between the German (EEX) and the Hungarian (HUPX) power exchanges, in the case of hourly day-ahead market (DAM) prices. Many articles 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) unplanned domestic power plant layoffs increase the Hungarian price. In the case of the latter, we investigate the possibility of capacity withholding by the domestic incumbent player.

The methodology applies cross-tabs and linear regression to test the hypotheses. In a new approach, the latter is used to create the profit function of the incumbent player and test whether intended capacity withholding would increase its profit. This compares the profit at the optimal production level with and without capacity withholding, with the difference representing additional profit realized by capacity withholding. The results are then compared to the actual unplanned power plant layoff data.

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 price. More than 10 electricity exchanges in Europe - mostly established around 2000[2] - have provided ample 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

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

determine whether high prices could be a result of market manipulation. 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, 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). Thus in the 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, meaning that the cause of the huge price difference is often the high Hungarian price, rather than the low German price. 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. Therefore the following summary contains a selection of articles analysing the Hungarian electricity market, or electricity prices in general, while touching upon the issue of market power abuse.

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 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 prices are far above the German spot price, while the Czech and Slovakian prices follow them. 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.

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

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 unplanned power plant layoffs, 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, unplanned power plant layoffs 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.

A very popular topic of electricity market analysis is the abuse of market power. In most countries of Central and Southeast Europe (CSEE) the incumbent has a legacy of high market share. Hungary is not an exception, with around half of domestic production coming from power plants owned by the incumbent player (MVM, 2014). Thus the issue of capacity withholding inspired many authors since the liberalization of the electricity market in Hungary. Paizs and Mészáros (2002) applies a Cournot oligopolistic model to the Hungarian electricity market, with an additional group of competitive players who cannot influence market price by capacity withholding. They find that with sufficient cross-border capacity, this type of abuse could be eliminated. Gerse (2004) argues that the incumbent player does not have sufficient capacities to manipulate price as alleged. He also points out that additional cross-border capacities are needed. Gordos (2005) further analyses Paizs and Mészáros's model. He finds that, unlike in their model, the nuclear power plant in Hungary can have the power to influence market prices, and a simple Cournot model cannot take into account the bilateral trade that is present on the Hungarian market. Kiss (2008) analyses the effect of regional market opening on domestic market power in Hungary. In his article he also uses a Cournot oligopolistic approach, but applied to the region, instead of just Hungary. He finds that there is no significant difference in the results if Hungarian companies are excluded as participants of the oligopoly, meaning that none of them have the power to manipulate prices at the regional level. Csercsik (2015) deals with the optimization problem of the lying generators, applying a DC load flow model to represent the power transmission network. He sets up the profit function of the generators, and calculates the different profits with and without capacity withholding. He finds significant profit can be earned by reporting less available capacity than the true values.

Electricity markets and capacity withholding have been modelled together many times in connection with the Californian power market and the events of the summer of 2000. That year, wholesale electricity prices peaked around 5 times higher than the same period the previous year, for close to a two week period. The case was observed by Joskow and Kahn (2002), who also applied a profit maximizing approach. They restricted their analysis to the high price hours and found that high prices cannot be explained only by market fundamentals, concluding that competitive behaviour was also one of the reasons for the extremely high prices. Hewicker et al. sought evidence of market power in the Dutch (Hewicker et al., 2002) and the German markets (Hewicker et al., 2003). In Denmark they found the market quite vulnerable for import capacity reduction in cases where insufficient domestic production capacity is available. Similar conclusions were drawn in the case of Germany, where the timing of power plant outages and the availability of import capacities can influence prices and.

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. Huppmann and Siddiqui (2015) applies a binary optimization model for power plants where the decision variable is to turn on or not to turn on the power plant. They optimize the profit in both cases and then compare the results. We use a quite similar optimization method for the profit function optimization of the incumbent player in our article.

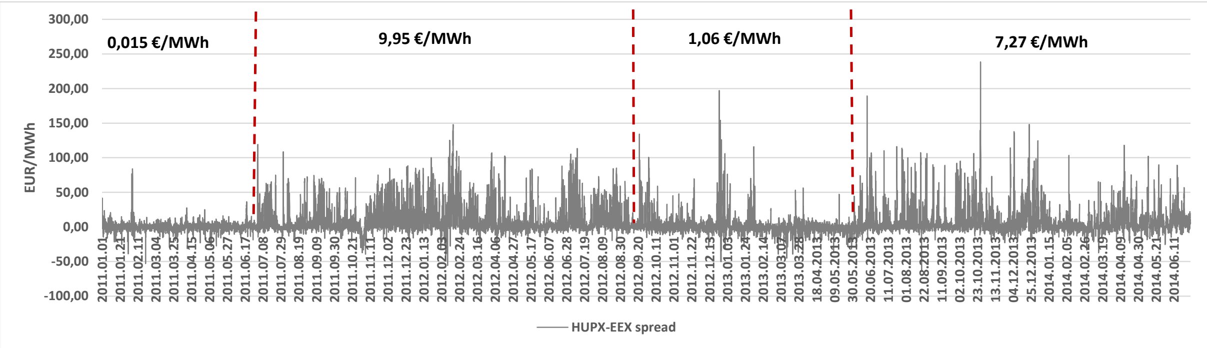
INPUT DATA

Prices

The basis of our analysis was HUPX and EEX data. As it is shown on the next figure, only looking at the prices gives us the intention, that there are separate periods with higher and lower spreads. Thus we looked for variables, acting somehow the same way, that 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.

Figure 1. The price difference between HUPX and EEX hourly baseload prices 2011 January – 2014 June

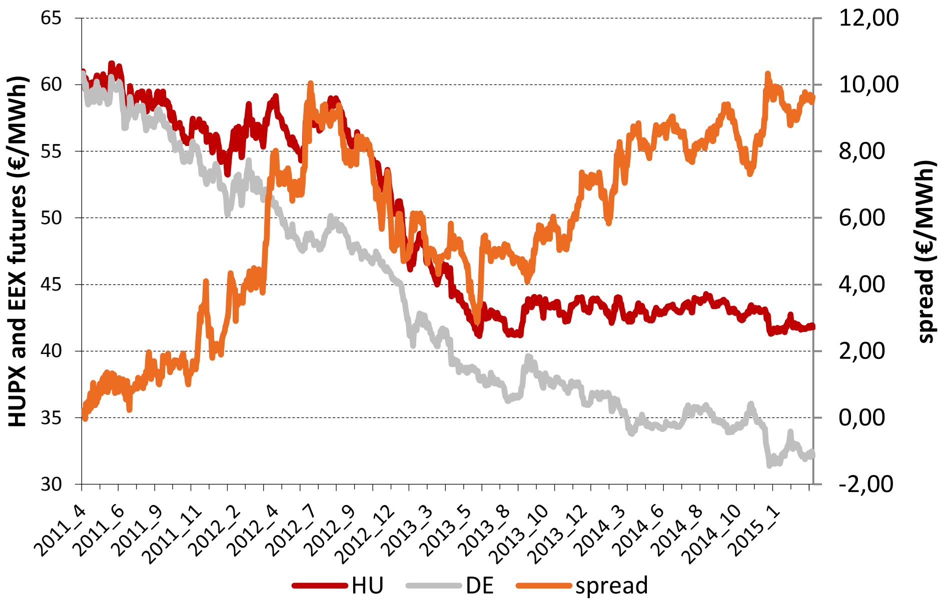


source: HUPX, EEX

As we can see, Hungarian and German prices moved closely together from January 2011 to July 2011. The average price difference was only 0.015 EUR/MWh in this half year period, which is practically negligible. From then on, until the Czech-Slovak-Hungarian market-coupling in 2012 September, the average spread went up to 9.95 EUR/MWh, which is quite significant. The market-coupling was able to moderate the price divergence until the following summer, when the average spread fell to 1.06 EUR/MWh again. In the final one year period, prices separated considerably again, with an average price difference of 7.27. 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 remains significant.

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



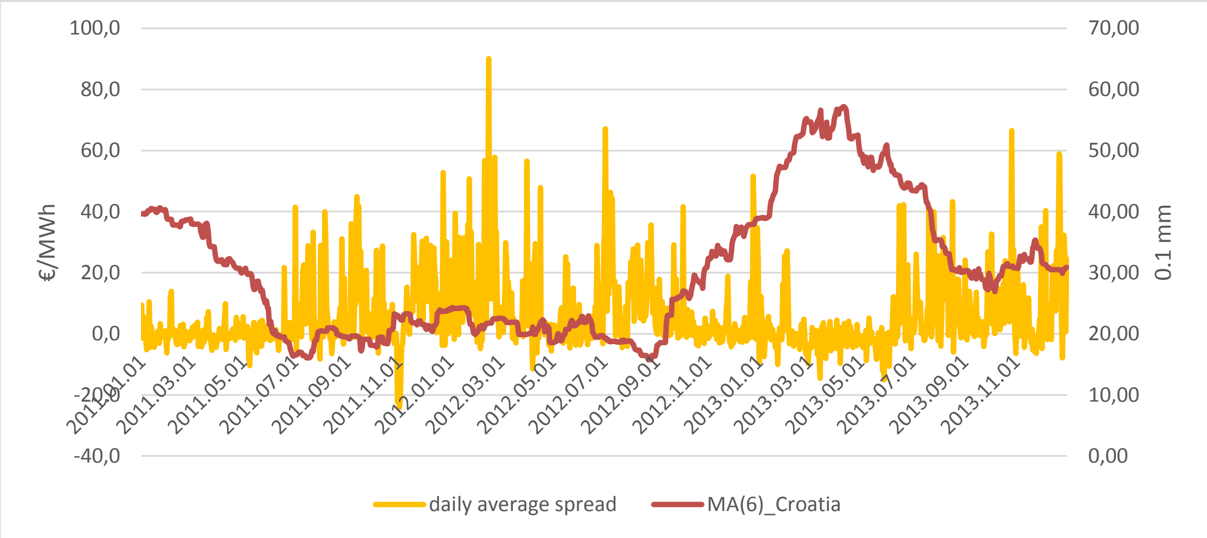
source: PXE, EEX

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.

Balkan weather

To find the connection between the Balkans weather and the demand for Hungarian import electricity, we estimated hydro power generation 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 was applied in the later analysis. Since hourly spread data was used, the daily data was converted to hourly by simply using every value 24 times. This way the variable – as shown later – was proved to be significant. The most significant from all the Balkan countries was Croatia, possibly because from 2007 to 2012 hydropower generation constituted around 50% of total 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

Unplanned domestic power plant layoffs

The data was also applied to the unplanned layoff 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 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.

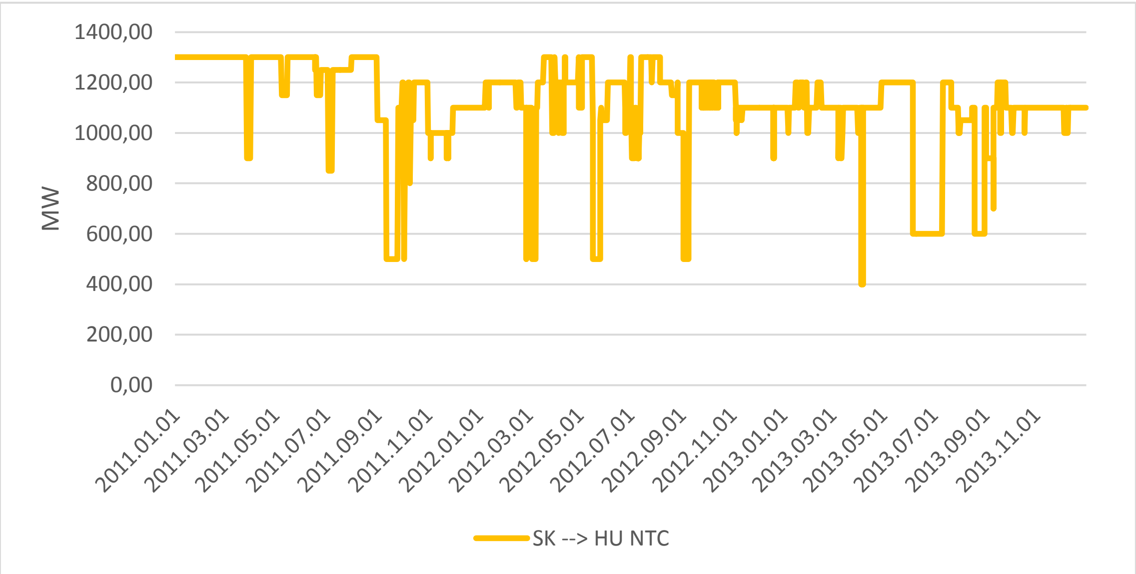
The rest of the generation capacity comes from small power plants (with an installed capacity less than 50 MW)[4]. Thus both Paks and Mátra plays a significant role on the Hungarian market.

For our analysis two dummy variables were created: one containing all the unplanned layoffs of both Mátra and Paks power plants and the other only the unplanned layoffs of Paks. The former helped to highlight the effect of a decrease in Hungarian supply. The latter was used in the linear regression, and later also in the profit function of the incumbent player in the linear regression, under the assumption that the incumbent player can only influence the production of Paks and not the production of Mátra. Therefore, only the effect of capacity withholding could be observed with that variable.

Slovakian NTC values

In our modelling we also include the net transmission capacity (NTC) of the Slovakian and Hungarian border[5]. Again, an abundance of research has focused on the relationship between sufficient cross border capacity and the spread between the German and Hungarian prices. Although not all periods that could be separated in connection with the spread are visible here, the change in 2011 July is. 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



[4] source: MAVIR and the websites of the companies

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

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 unplanned flows. To ensure system security, the Hungarian TSO "saved" (did not offer on auctions) more capacity for the more frequent and sizable unplanned flows, which some say were a possible effect of increasing renewable production in Germany. This however does not change the fact that the hours with less available transmission capacity are more exposed to the risk of higher prices, thus higher spread.

APPLIED METHODOLOGY AND RESULTS

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 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.

As the later sub-chapters demonstrate, all the three hypotheses can be proved with the application of cross tabs and linear regression.

Cross-tabs

Two types of connectivity tests were applied with the help of cross-tabs in the case of all three hypotheses. In the first case, the data was split into two parts: the hours with a spread of more than 50 EUR/MWh and the hours below this threshold. These high-spread hours were compared with the whole of the data, revealing significant discrepancies. The results are summarized in the following table.

Table 1. Average values of variables in the high spread hours and in the whole data

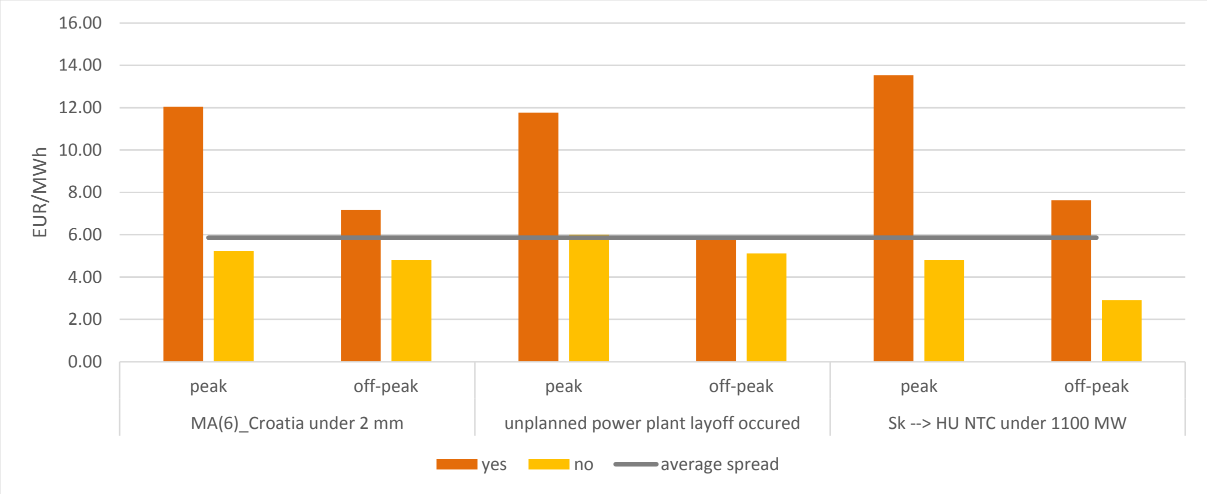
	average		
	every hour	hours with a spread of more than 50 EUR/MWh	p value
MA(6)_Croatia (mm)	3.03 mm	2.54 mm	3,87E-69
proportion of hours with unplanned power plant layoffs	18%	26%	3,73E-08
proportion of peak hours with unplanned power plant layoffs	7%	16%	8,68E-13
SK --> HU NTC (MW)	1114 MW	1056 MW	2,11E-17

source: own calculation

Table 1. shows that the difference of the average values of all the observed variables between the high-spread hours and the whole data is significant (at the 5% level, tested with two-sample T^2 test). Thus when the high spread occurred, there tended to be suboptimal hydrological conditions in Croatia, the rate of hours with unplanned power plant layoffs was higher (especially in the case of peak hours), and there was less capacity on averagely at the Slovakian border to import electricity.

Next, the effect of the variables was measured “the other way”: we set them at a given level, and calculated the average spread in the hours with higher and lower values than the given value. The data was split between peak and off-peak hours, to determine if there was a difference in exposure. The results are summarized on the following figure.

Figure 5. Average spread values in different situations



source: own calculation

The effect of all three variables is evident; whenever there was a drought period, unplanned power plant layoffs, or insufficient capacity on the SK-HU border, the spread was at least as high as the average spread over the whole period and mostly much higher. The vulnerability of peak hours is also apparent: The peak hours prove to be particularly vulnerable in these scenarios, with a spread nearly double the average of the whole period. After testing the significance of these differences with the two-sample T^2, it can be concluded that, at a 5% level, the effect of the above mentioned variables on the spread is significant.

Linear regression

The above data was then used to construct a linear regression to explain the spread. The analysis included precipitation in four Balkan countries (6 months moving average, Bosnia and Herzegovina, Croatia, Romania and Serbia), dummy variables for unplanned power plant layoffs - for all the hours and peak hours separately -, a variable for the size of the unplanned layoff (in MW), a dummy variable for peak hours, NTC values for both the Slovakian-Hungarian and the Austrian-Hungarian borders and an AR(1) variable. This latter is quite typical with respect to financial data analysis – the fundamental explanation is that the market depends heavily on expectations, thus the price of the previous hour has a significant effect on the immediate market price. As mentioned before, the unplanned power plant layoffs are to this point restricted to Paks since subsequent analysis requires a variable that can be influenced by the incumbent player. The best model included the following variables:

Table 2. Results of the linear regression

	Coefficients:	Estimate Std. Error	t value	Pr(>|t|)	
(Intercept)	4.9746782	0.4066182	12.234	< 2e-16	***
MA_BA	-0.0564810	0.0171420	-3.295	0.000986	***
MA_HR	-0.0420888	0.0078673	-5.350	8.88e-08	***
sk_hu_NTC	-0.0009891	0.0001258	-7.862	3.92e-15	***
peak_layoff_dummy	1.9269824	0.2359141	8.168	3.27e-16	***
spread_lag_1	0.8184329	0.0035301	231.846	< 2e-16	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Multiple R-squared: 0.6928, Adjusted R-squared: 0.6927

source: R output

Above, all variables are significant on a 0.1% level. The first two variables are the precipitation moving average of Bosnia and Herzegovina and Croatia. The coefficients are negative, meaning that they agree with the results of the cross-tabs: worse hydrological conditions (less precipitation) in the Balkan region lift up the spread. The same is true for the Slovakian-Hungarian border, where less NTC capacity increases the spread because the prices cannot equalize naturally. The variable "peak_layoff_dummy" refers to the dummy variable that has a value of '1' when an unplanned layoff of Paks occurred in a peak hour, and '0' for all other hours. The regression shows that this event can increase the spread, ceteris paribus, with 1,93 EUR/MWh. The last variable of the model is the AR(1), representing the value of the spread in the previous hour. It also has a positive coefficient, close to 1, that indicates there is a strong correlation between the spread in hour (t) and (t-1).

THE PROFIT OF THE INCUMBENT PLAYER – POSSIBILITIES THROUGH CAPACITY WITHHOLDING

The model

Since there is evidence that unplanned power plant layoffs has a significant effect on the spread, the next step is to determine whether the incumbent player can ultimately earn higher profit by increasing prices through reporting technical failures. If prices are driven high enough, total profit can exceed the original profit level even with lower production. Thus a profit function was established for the incumbent player. In order to analyse the situation, simplifications were introduced. Only the two largest power plants from the portfolio were included: Paks nuclear power plant and Vértes power plant in Oroszlány that uses biomass and coal. Since the production cost is much lower in Paks, its 2000 MW will be used first, while anything more (maximum 240 MW) will be taken from Vértes. An unplanned power plant layoff can only be reported by Paks, with the maximum capacity being withdrawn – to remain credible - equalling the size of one unit, 250 MW. Import is also included in the profit function, but not as a decision variable. For every hour, the total imported electricity was divided between the incumbent player and the rest of the market by the same ratio as the total yearly production split between them for 2011, 2012 and 2013 respectively. This is a rather strong restriction, but using import as a decision variable makes the model unnecessarily complicated and beyond the scope of this paper.

To measure the impact of capacity withholding we included the linear regression in the profit function whereby unplanned power plant layoffs form part of the regression as a dummy variable of 1 in peak hours with unplanned layoff and 0 otherwise. For all the other variables actual data was used, the decision variable was production level. The profit function is the following (since we calculate with Forint, exchange rates are applied when necessary):

$$\pi(q_t) = (q_t + q_{imp}) * exch * (spread + eex) - eex * exch * q_{imp} - p_{NTC} * q_{imp} - \overline{MC}(q_t) * q_t$$

where:

q_t – production level (MW)

q_{imp} – import by the incumbent player in the given hour (MW)

exch – exchange rate in the given hour (daily data was used for all the hours of the given day)

spread – we include the above regression with the data of the given hour, a dummy variable of 1 or 0 according to the decision of the incumbent player, and peak or non-peak (EUR/MWh)

eex – German price in the given hour (EUR/MWh)

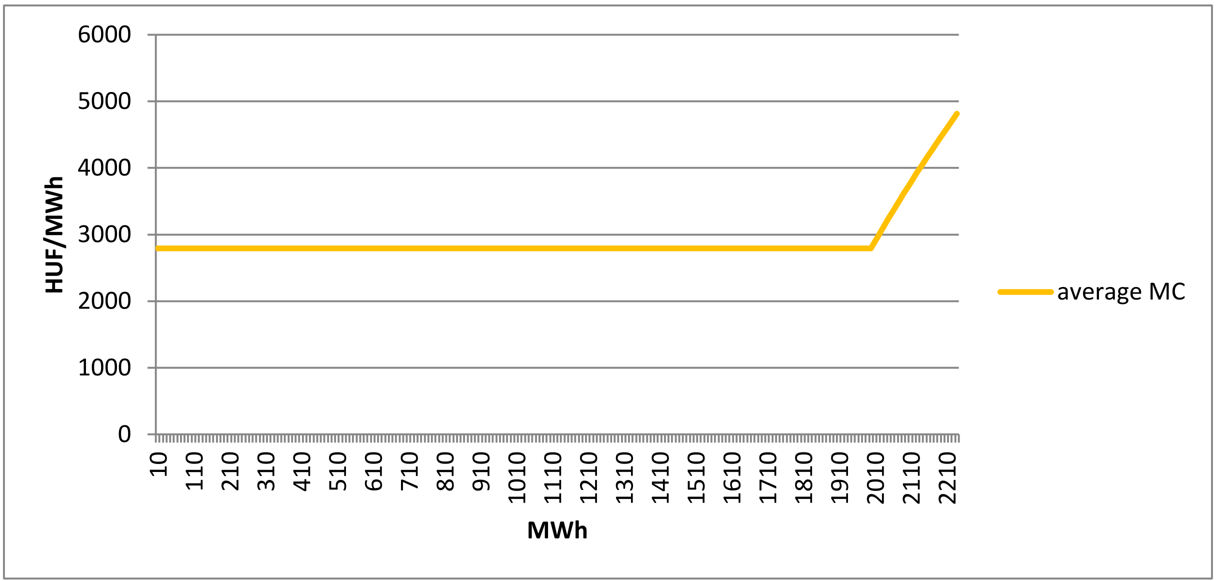
p_{NTC} – price of the cross-border capacity usage in the given hour (we used the (-1)*HU-->SK p_{NTC} if q_{imp} was negative, to keep it as a cost element) (HUF/MWh)

MC(qt) – the "average marginal cost" of production (will be explained later in more detail) (HUF/MWh)

The income side includes "(production + import) * HUPX price", where this latter is calculated as "EEX price + spread" so that the effect of capacity withholding on Hungarian prices is included in the model. If the import was negative, the non-domestic income is "EEX price*import;" if it was positive, "EEX price*import" is the cost of purchasing electricity abroad. The cost of electricity transportation is "cross-border capacity usage price*import". The last cost element is the cost of production.

Some assumptions were necessary in order to calculate the production costs. It is assumed that both Paks and Vértes sell electricity on constant marginal costs, which are calculated from data provided in yearly reports (total production cost/total produced quantity). This way the "average marginal cost," or the marginal cost for one MWh of electricity production is the marginal cost for Paks until 2000 MWh (or 1750 MWh with an unplanned layoff), with each additional MWh being produced from Vértes able to reflect its higher cost. The structure of the average cost of producing 1 MWh electricity is shown in the following figure.

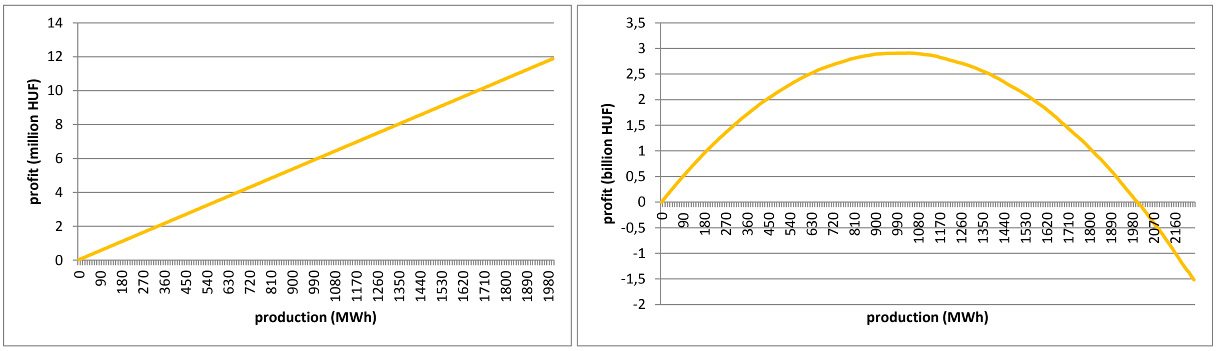
Figure 6. (Average) cost of production of 1 MWh electricity



source: own calculation with the help of data from MVM annual reports, and (REKK, 2013)

This way, the profit function also includes a breakpoint at 2000 or 1750 MWh depending on the decision regarding capacity withholding. The precise level of profit is highly dependent on the actual values of the variables included, but there are two basic shapes of the function a) only using Paks and b) using Paks and Vértes at the same time.

Figure 7. Typical shape of the profit function (a) is relevant from 0-2000 MW, b) is relevant from 2000 to 2240 MW)



a) b)

source: own calculation

There are some hours where it is not worth switching on the plants, for example when profit function a) has a negative slope the optimal production level is 0. The maximum of function b) is between 992 and 1010 MWh without an unplanned layoff and 868 and 886 MWh with an unplanned layoff, meaning from 2000 to 2240 MWh the function is decreasing. With production at or above 2001 MWh or 1751 MWh the profit value in function b) is always smaller than the profit value of function a) at 2000 MWh or 1750 MWh respectively. Thus profit maximization is always found at this breakpoint of 2000 MWh or 1750 MWh, or it is 0. By this standard, it is never worth switching on Vértes power plant. In reality the plant does generate electricity, but this does not mean it is worth to do so. Further development of the model could include additional constraints for the Vértes power plant.

Optimization and results

The profit function is optimized for every hour separately with the given variables using a binary optimization method. Paks operates at 2000 MW capacity since there is no capacity withholding (the dummy variable is set to 0), and the maximum profit level is calculated for every hour. Next, capacity withholding is assumed to calculate maximum profit using a dummy variable of 1 in peak hours with the maximum capacity of Paks limited to 1750 MW. Lastly, the two profit levels for every hour are compared.

Over the course of the 3 years period, 396 hours were found to be more profitable when reporting technical problems. But the additional profit is rather negligible, totalling only 158 million HUF, around one-fifth of the average daily profit according to our model. In reality the incumbent player has several ranges of activities, and many are likely cross-financed through what is expected to be a profitable operation of Paks. Therefore it is not unimaginable that such high profits can be realized from this activity. But because the model contains many simplifications, its purpose is mainly to compare the relative outcomes of different decisions rather than arrive at the exact profit level of the company.

Finally we also compared the data with the original data of unplanned power plant layoffs to determine whether there were actual unplanned layoffs over the profitable hours of the optimization results. Of the 396 hours there were only 14 actual unplanned layoff at Paks, meaning even if the possibility existed for the incumbent player to gain higher profits by withholding capacity the model indicates it did not take this opportunity.

CONCLUSIONS

In this paper, the goal was to find the possible reasons for the high spread between the Hungarian and German day-ahead hourly electricity prices. At the core, the reason for the large spread was almost always the high Hungarian price. In examining the higher Hungarian price, three hypotheses were applied: unfavourable hydrological conditions in the Balkan are raising demand for imported Hungarian electricity and thus Hungarian prices; an insufficient amount of cross-border capacities at the Slovakian-Hungarian border leads to bottlenecks preventing the natural equalization of prices; unplanned domestic power plant layoffs that increase the Hungarian price by decreasing available domestic supply. Ultimately, all hypotheses were proved correct using cross-tabs and linear regression. It was also proved that peak hours are more exposed to the risk of high spread.

Finally a profit function of the incumbent player was created to calculate whether unplanned power plant layoffs could be a result of intended capacity withholding. As a new approach, the linear regression for the spread in the profit function was included to measure the effect of unplanned power plant layoffs on the spread, and implicitly on the Hungarian prices. There was no evidence of intended capacity withholding, as the cumulative profit from the less than 400 hours during which the profit could be raised by capacity withholding was negligible. Furthermore, from the 400 hours in the observed period there were only 14 where actual unplanned layoffs at Paks power plant occurred.

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