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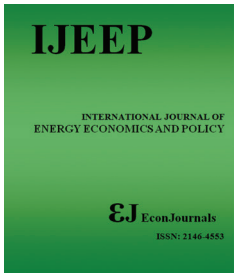

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Market Efficiency and Risk Premium in the Turkish Wholesale Electricity Market

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[#]The ideas expressed in this paper are the author's own and do not connected to, not represent and not be evaluated as those of the Company she works for.

ABSTRACT

Due to the nature of electricity, prices in the wholesale electricity market show great variation according to the hours of the day. Thus, it is important for market participants to forecast hourly prices to give accurate orders. This study covers the analysis of hourly electricity prices by referring to the relationship between spot and forward prices and volume in the Turkish market over two sub-periods of dual pricing: December 2011-May 2016 and June 2016-December 2017. The latter period is characterized by the implementation of a new trading algorithm in the market. The results reveal that forward prices behave as unbiased predictors of spot prices, most of the time. Remarkably, evolution of the difference between spot and forward prices, namely risk premium, depicts that the spot price supports the arbitrage opportunities in the electricity market. The introduction of the new trading algorithm does not depict significant effect on the risk premium.

Keywords: Electricity Market Efficiency, Day-ahead Market, Forward Prices, Risk Premium
JEL Classifications: G10, G13, Q40, Q49

1. INTRODUCTION

Electricity plays a vital role in every aspect of the life and it stimulates growth in the economy. It is different from other financial assets and commodities in the market due to its idiosyncratic features. Non-storability, demand inelasticity, requirement of maintaining constant balance between demand and supply by the system operator are among these features. Also, climate conditions and economic activities affect electricity consumption throughout the day. These features cause some special swings in electricity prices such as seasonality, high volatility, sharp price spikes and mean reverting processes (Hayfavi and Talasli, 2014). Therefore, one needs to put special efforts to analyze the pattern of electricity prices for valuation and risk management.

In line with other markets, electricity market has also been affected from the liberalization process. Until the early 90s, the electricity industry had been vertically integrated, where regulators fixed prices as a function of generation, transmission and distribution costs, and thus there was little uncertainty in prices. In the last two decades, however, electricity markets in many countries have experienced a deregulation process to bring competition in generation and supply activities. One of the main consequences of this reform is that prices are determined on the market by the interaction of supply and demand. Thus, generators compete to sell electricity, while the suppliers purchase electricity from the pool at equilibrium prices set by the intersection of aggregated demand and supply on an hourly basis. Due to aforementioned idiosyncrasies of electricity, these new deregulated prices have been characterized by having extremely high volatility and adverse effect on efficiency in the market.

The Turkish electricity market has also gone through a liberalization process since the beginning of 2001. In 2006, the

market rules were introduced to allow for the purchase and sale of electricity from day-ahead market (DAM) on an hourly basis. Then, the hourly balancing and settlement system was set up in December 2009 to enable market participants to trade electricity in the DAM and spot market. On December 2011, the dual-pricing system for imbalances in the market was introduced. This implementation changed the price dynamics of electricity. The dual pricing is introduced to discourage market participants seeking arbitrage opportunities by making unattractive for them to make false bids or offers, since these could harm the system security. It also enforces market participants to bid their actual forecast using available information (Asan and Tasaltin, 2017). Although this system provides market participants an opportunity to hedge their positions against the real-time price fluctuations, it also raises questions on market efficiency and relationship between DAM and spot prices.

In this study, price convergence of DAM and spot market is analyzed to determine whether persistent price differences exist between these markets over the period of 2011-2017 and the implementation of the new trading algorithm in Energy Exchange (EXIST) since June 2016 has created some influence on risk premium. The question is that while dual-pricing increases short-term system security, it may also create a difference between DAM and spot prices, i.e., risk premium, and may lead to market inefficiency. The efficiency increases as the market becomes more mature and market participants trust the proper functioning of the trading system.

The rest of the article is organized as follows. Section 2 discusses some related literature. Section 3 describes the Turkish electricity market. Section 4 presents the data set and methodology. Section 5 discusses the empirical findings. Finally, section 6 concludes.

2. LITERATURE REVIEW

According to the Efficient Market Hypothesis, there is no opportunity to make profit above average in the market by exploiting price differences since the prices reflect all information and everyone could easily access to it. In terms of information diffusion between the forward and spot contracts, both markets jointly contribute to price discovery. However, the predominant source of information spillovers appears to be the direction of price change (i.e., return spillover), rather than the magnitude of price change (volatility spillover) (Milunovich and Joyeux, 2007).

Regarding electricity market liberalization and efficiency, although some argue that liberalization is a failed concept pointing out California crisis and market breakdown in 2001, widespread blackouts in North America, Italy and Scandinavia in 2003 and Enron bankruptcy, there are various studies on economic benefits of the electricity market liberalization (Serena, 2014; Erdoğdu, 2010; Madlener, 2002; Pollitt, 1997). While liberalization introduces competition and brings efficient use of market assets, it still requires on-going government commitment and support, but in different roles. Governments, regulators and independent system operators must collaborate to establish rules and market design that will create a competitive marketplace (OECD, 2005). Many countries have resorted to the market liberalization for higher efficiency and expect the price could guide the efficiency through the competition among the generators, but the market does not get mature quickly in a short time, especially in developing countries (Yang et al., 2014).

While the literature on electricity market efficiency is limited compared to financial markets, most of the studies are either on derivatives market or on derivatives and spot market price relationship. Bessembinder and Lemmon (2002) presented an equilibrium model implying that the forward price is a downward biased predictor of the future spot price if expected power demand is low and demand risk is moderate and detected that the equilibrium forward premium increases when either expected demand or demand variance is high, because of positive skewness in the spot power price distribution. Arciniegas et al. (2003) compared the degree of efficiency across markets (forward vs. real time) and across time in California and suggested that differences in price behavior between these two markets did not arise from differences in efficiency. They also stated that as these markets become more mature over time, their efficiency level goes up.

Longstaff and Wang (2004) conducted an analysis of forward prices in the Pennsylvania–New Jersey–Maryland (PJM) electricity market using a high-frequency data set of hourly spot and day-ahead forward prices and found that there are significant risk premia in electricity forward prices and they vary systematically throughout the day and are directly related to economic risk factors, such as the volatility of unexpected changes in demand, spot prices, and total revenues. Boogerta and Dupont (2005) analyzed the effect of dual-pricing implemented by Dutch regulator to prevent trading across DAM and real-time markets in the Netherlands by studying the ex-post profitability of trading strategies and showed that implementing a profitable trading strategy between the day-ahead and imbalance markets is not possible under dual-pricing.

Feng et al. (2007) conducted a study on Nordic electricity market and found that the futures price is an unbiased estimate of spot price and there is unidirectional causality from the futures price to the spot price. Thus, in the long term the influence of futures price is greater than that of spot price on the market, and the futures market plays an important role in the price discovery. Pietz (2009) conducted an analysis of the German electricity wholesale spot market covering three market segments, namely the intraday market, the block contract market and the DAM from August 2002 to May 2009 and found significant positive risk premia, both in the block contract market and in the DAM, the risk premia in DAM varying in magnitude and in sign throughout the day. Furthermore, he detected a term structure of risk premia during the sub-period in which all three market segments were simultaneously existent.

Umutlu et al. (2011) conducted an analysis on the relationship between spot and futures electricity market of APX-ENDEX in 2008 and found that the market is in normal backwardation and they rejected the efficiency hypothesis indicating that the futures prices are not unbiased predictors of the future spot prices. Haugom and

Ullrich (2012) examined the time-varying relationship between spot and short-term forward prices in the PJM wholesale electricity market and found that forward prices have converged towards unbiased predictors of the subsequent spot prices and the risk premia decreased over time. Jha and Wolak (2013) evaluated the market efficiency of California's wholesale electricity market after the implementation of virtual bidding by estimating the cost of trading in the market through using the day-ahead forward and real-time spot marginal prices and concluded that financial forward market trading can improve the operating efficiency of short-term commodity markets.

Ballester et al. (2016) analyzed the relationships between prices from three different markets within the Spanish zone of the Iberian Electricity Market (MIBEL), namely futures, spot and OTC forward markets, and found that future and spot markets generally satisfy weak-form efficiency and futures market price is a valuable reference. Valitov (2016) analyzed risk premia in the German/Austrian DAM from 2005 to 2015 and found that the risk premia are still paid in the German/Austrian DAM, but their magnitude decreased remarkably over time.

Asan and Tasaltin (2017) analyzed the price dynamics of day-ahead and real-time electricity prices following the implementation of dual-pricing legislation in Turkey and found that as market participants have more experience regarding the dynamics of the market, the difference between real-time and day-ahead forward prices converges to zero.

3. TURKISH ELECTRICITY MARKET

Turkey has passed through three stages in the privatization of utilities: Shifting ownership from public to private sector, restructuring the companies and changing the way the sector operates by introducing competitive policies. Electricity market is no exception. It was dominated by the state-owned vertically integrated company Turkey Electricity Institution until the early 1990s. It was then split into two companies: TEAS (carrying out generation, transmission and wholesale) and TEDAS (distribution) in 1993. With the enactment of the Electricity Market Law in 2001, TEAS was further unbundled into EUAS (generation), TETAS (wholesale) and TEIAS (transmission), each of them being a separate legal entity. Operating rights of some distribution companies have been privatized. The privatization process in the electricity distribution was initiated in 2009 and completed in 12 regions by early 2013. As of 2017, there are 21 regions in the market.

The dual-pricing system for imbalances was introduced on December 1, 2011 and with this mechanism, the difference between the actual consumption or generation and that which was purchased/sold through the DAM (simply imbalances) is charged based on the price that is least favorable to the market participant. In other words, buyers have to pay greater of DAM or real-time prices, while sellers receive the lesser.

DAM, launched on December 1st, 2012, started operating as the organized wholesale electricity market. It was established to enable for the purchase and sale of electricity on hourly basis, and operated by TEIAS as the market operator. Market participants submit their bids and offers on hourly basis and the hourly market clearing price (MCP) is determined by the Market Financial Settlement Centre. Moreover, the DAM enabled financial settlement on a daily basis performing daily clearing of payables/receivables next day after the transaction date. This allows market participants to receive income generated by the sale of electricity on a daily basis rather than monthly, which provides them liquidity. Hence, DAM has the following four main objectives:

1. To allow balancing of day-ahead portfolios,
2. To ease production optimization in the country,
3. To ensure that the spot price reflects the supply-demand balance and to reduce real-time balancing market by reducing the load of system operation and
4. To increase system security.

According to the Electricity Market Law No. 6446 dated back to 14/03/2013;

1. Balancing power market (BPM) and ancillary services market is operated by TEIAS,
2. The DAM and the intra-day market (IM) are operated by EXIST,
3. Derivatives market on power contracts is operated by Borsa Istanbul,
4. The central settlement and clearing is operated by Takasbank, the Central Settlement Bank.

With the new regulatory and operational framework, the collateral mechanism has been put into practice and market participants are required to deposit margins for DAM operations at Takasbank.

In the DAM, participants can submit hourly buy and sell offers. Offers can be made in Turkish Lira (TL), US Dollar, and Euro and the prices submitted other than TL are assessed by converting them into TL. Offer quantities are submitted in Lot and 1 Lot is equivalent to 0.1 MWh. Depending on the sign of the offer quantity, the offer is marked either as a buy (100 lot) or sell (−100 lot) offer. Minimum and maximum price limits are determined by the Energy exchange as 0 TL and 2000 TL respectively. Minimum and maximum offer quantities are determined by market operator as 0 Lot and 100,000 Lot respectively.

Another important step in the Turkish wholesale electricity market took place on September 2015 by the establishment of Energy Exchange (EXIST) to create an efficient and transparent market in order to ensure reliable reference price formation. EXIST operates two electricity spot markets, day-ahead and intra-day. A daily double-sided blind auction is held in the DAM under the principle of uniform pricing. On the other hand, intra-day market (IM) is operated under continuous trading mechanism. The IM was launched on July 1, 2015 and aims to reduce the imbalances between the DAM and the BPM. The IM is on operation until a few hours in advance from delivery and offers the opportunity for market participants to balance their portfolio in a short period of time.

BPM is designed to maintain the physical supply and demand equilibrium through a transparent market. It is established to deal with the inability of market participants to comply with their

accepted bids/offers in the DAM. Offers and bids submitted by the market participants on BPM are ranked by system operator according to their prices. In case there is energy deficit in the system, maximum accepted hourly offer price applied to up-regulated balancing entities to correct this deficit is accepted as the system marginal price (SMP). On the other hand, if there is energy surplus in the system, the minimum accepted bid price applied to down-regulated balancing entities to correct the energy surplus is accepted as the SMP. Price calculated in the BPM is higher than price calculated in the DAM. BPM price is used for settlement of imbalances and this relationship incentives market participants for trading into a balance on the DAM.

Derivatives contracts on electricity were launched on September 26, 2011 in Turkey and they have been traded in Borsa Istanbul Futures and Options Market. Compared to spot market, the trading volume and depth are not at expected levels, but with increasing transparency in the energy market, the performance of derivatives market will improve in the future. Table 1 shows the milestones in the Turkish electricity market liberalization process.

In 2017, with 1058 market participants, about 30% of the electricity trading was executed in EXIST markets. As of 2017 year-end, the distribution of electricity market trading volume is as follows:

- OTC bilateral agreements 67.7%
- EXIST DAM 27.5% (TRY 41.47 billion/USD 10.99 billion [123TWh])
- EXIST BPM 4.5%
- EXIST intraday market 0.4% (576.7 million TL/USD 152.89 million [1.7 TWh]).

Payments of renewable energy resources support mechanism is also executed via EXIST. Total renewable energy trading volume was TRY15.34 billion (USD 4.07 billion) in 2017.

When we refer to the Turkish electricity DAM market settlement price (MSP) and BMP SMP from 2011 to 2017, we observe that the average forward prices follow an "upward" trend from 2011 to 2015 and then decreased from 163.97 to 138.01 in 2015. When we evaluate the price decrease from 2014 to 2015, it stems mostly because of the extra supply by the launch of the larger-scale power generation premises and renewable energy investments (EXIST Yearly Report, 2016). Nevertheless, we observe a similar upward trend from 2015 to 2017 due to fluctuations in the FX/TRY rates, which increased cost of input (e.g., import price of natural gas or coal) for electricity generation, as well as increase in demand that could not be met by newly added generators (Figure 1).

4. DATA AND METHODOLOGY

Since supply and demand must be balanced instantly on the electricity market, hourly contracts are traded on 7/24 basis. Therefore, in conducting the analysis, we use electricity market data on hourly basis. We get the data from the EXIST transparency platform for;

- Forward electricity prices in the DAM,
- Spot electricity market prices in the BPM and
- Trading volume in the DAM.

All prices are in TL per megawatt hour. They are the average market prices for each of the 24 h. The data set consist of 1643 observations for the period of 2011/12-2016/05 and 578 observations for the period of 2016/06-2017/12, where the new trading algorithm is in place (Figure 2).

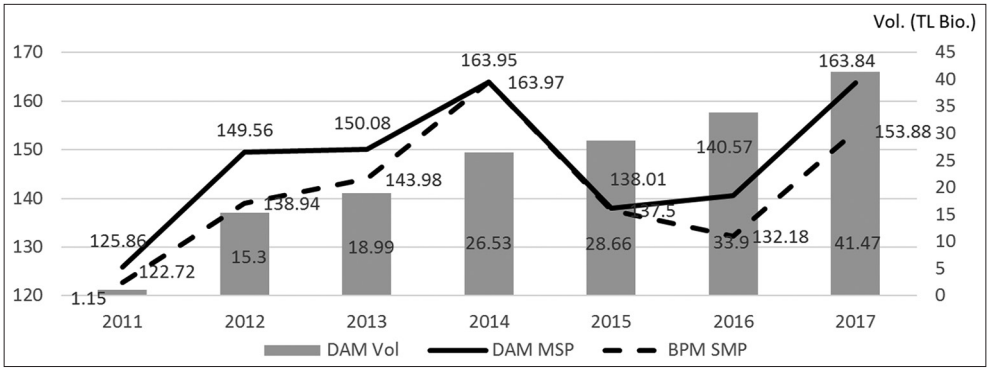
In the study, rather than working directly with the price and volume data, we convert both the price and volume series into log-prices and log-volumes (log (t/t-1)) to investigate the relation of spot prices and forward prices as well as trading volume. This method is generally followed in order to eliminate stationarity in time series.

Table 1: Milestones of the liberalization process in the Turkish electricity market

2001 Enactment of the 4628 Electricity Market Law was published	2004 Temporary balancing and settlement regulation was published	2006 1st phase of BPM was introduced	2009 Introduction of the day ahead planning mechanism	2011 DAM was inaugurated
2013 Establishment of EXIST regulation by 6446 Electricity Market Law	March 18, 2015 EXIST was established	July 1, 2015 EXIST intraday market was launched	June 1, 2016 new algorithm for the EXIST DAM was introduced	

Source: EXIST 2017 yearly report

Figure 1: Turkish electricity market volume and yearly average DAM MSP and BPM SMP



Source: EXIST transparency platform data

The analysis on the Turkish organized electricity market covers two periods:

- Previous trading algorithm period: December 2, 2011-May 31, 2016 period, where TEIAS and EXIST actively operates the organized market by using the E-terra market system.
- New trading algorithm period: June 1, 2016-Dec. 31, 2017 period, where new trading algorithm is applied in EXIST market management system.

The former market management system E-terra which was developed by a French company, Areva, was replaced by the new trading algorithm software developed in-house by EXIST. In the new trading algorithm, the optimization engine takes market data consisting of bids from market participants into account, calculates hourly settlement prices (MSPs) and accordingly matches prices and quantities for each bid. The engine includes several problem solving algorithms to reach the optimum solution. Since the problem has to be solved in a restricted time, the engine guarantees to find a feasible solution first, and then tries to find the optimal solution to the problem (EXIST, 2016).

Data in the analysis consists of hourly values for MSP and trading volume in the DAM and SMP in the BPM. The difference between MSP and SMP is expected to converge to zero since the market enforces participants to forecast accurately by punishing the forecast error (Asan and Taşaltın, 2017).

- Electricity reference price is determined in the DAM. The market operations are performed on a daily basis through hourly contracts. Each day starts at 00:00 and ends at 00:00 the following day. Market participants in the DAM should notify EXIST via proposals for the next day through the system until 12:30 every day. Each reported DAM offer is verified by the EXIST between 12:30 and 13:00. Confirmed bids are evaluated from 13:00 until 13:30 with the optimization tool, and the MSPs and quantities for each hourly interval are determined. Transaction approvals at 13:30 each day are notified to the relevant market participant. At 14:00, the price and matched quantity for the next 24 h are announced. From 00:00 to 17:00 each day, market participants sign bilateral agreements in the DAM system.
- The BPM is a market that allows the system transmission operator to provide a reserve capacity that can be appointed within 15 min for real-time balancing. Independently, in 15 min, balancing units capable of carrying a load of at least 10 MW or carrying a load within it shall participate in BPM.

In the electricity market, the average prices and volume vary throughout the day. Graphic III shows the average price and volume on hourly basis for each period under study. Peak prices in the market take place from 8:00 am to 8:00 pm, where the demand is considerably high. The standard deviations are also high for this time span. Forward and real time market prices and forward volume are low in the off-peak hours compared to peak hours (08:00 am-08:00 pm) (Figure 3).

5. EMPIRICAL ANALYSIS

5.1. Descriptive Statistics

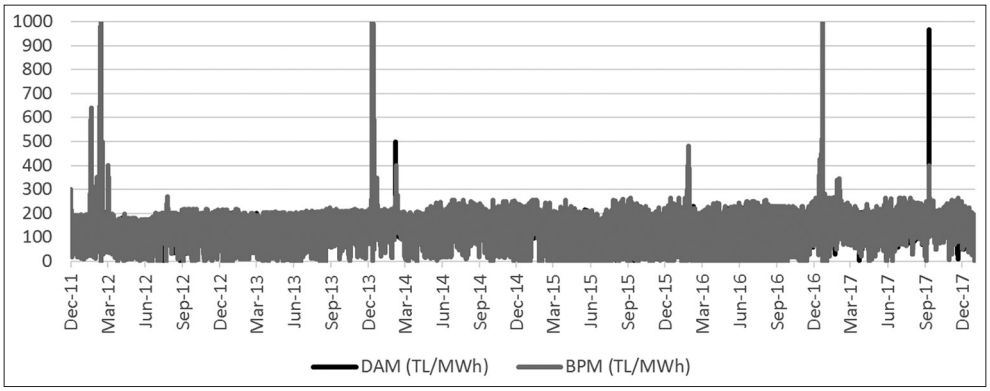
One of the implications of not allowing market participants to explore arbitrage opportunities under dual pricing could be seen as an increase on skewness, making the system more vulnerable to price spikes. We observe this case in the Turkish wholesale electricity market as well. The summary statistics for DAM clearing prices, trading volumes and BPM spot prices are given in Appendix 1.

The results show a highly right-skewed distribution of electricity spot prices. While the skewness is positive for the peak hours due to wide price spread in between 0 and 2000, there is not much remarkable difference before and after the implementation of the new algorithm.

Regarding to the trading volume, while the skewness before the implementation of the new algorithm changes in between 1 and 2 for all hours, indicating that there were insignificant volume spikes, it increases significantly in 2016-2017 period because of the fluctuations in the price due to increase in FX/TRY rates as well as supply uncertainties due to the increase in cost of electricity production.

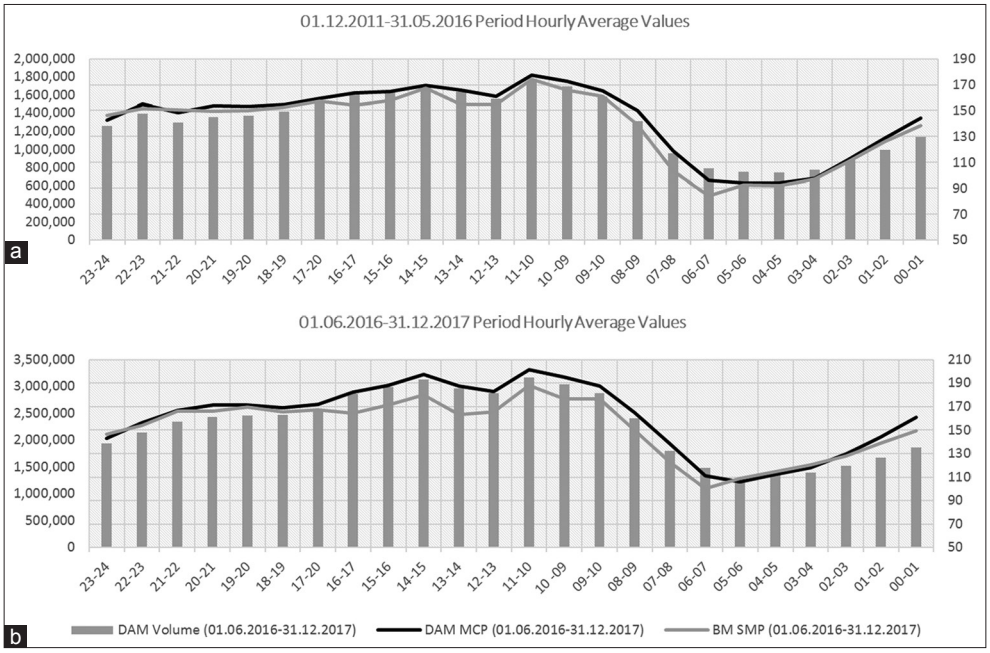
The statistics results of the DAM forward prices are similar to spot prices. The average price is lower for night hours compared to peak hours. Following the implementation of the new algorithm, the skewness is positive for the peak hours, whereas it is around 1-2 for the rest of the day. The standard deviation of the forward

Figure 2: Electricity market hourly prices for December 2011-2017 Period for day-ahead market and balancing power market



Source: EXIST transparency platform

Figure 3: Electricity market hourly average prices and trading volume



Source: EXIST disclosure platform. *DAM: Day-ahead market; MCP: Market clearing price; BM: Balancing market; SMP: System marginal price

prices are lower than the spot prices for all hours and this is in line with the expectation that forward prices tend to be less volatile than spot prices.

5.2. Regression Analysis

To evaluate market efficiency, we conduct two analyses via regression. First, we run regression analysis to describe the relationship between the dependent variable, DAM MSP, and independent variables, namely BMP SMP and DAM trading volume. Secondly, we run regression on the difference of DAM MSP and BMP SMP. The details are given below:

5.2.1. The relation of spot price and forward trading volume and forward price

According to the efficient market hypothesis, ignoring the transaction costs, expected return in the DAM and the BPM should be equal. The major factor that affects forward price is spot price of that underlying as well as trading volume since a forward contract is an agreement between two parties who agree to buy and sell a particular asset of specific quantity at a predetermined price, at a specified date in future. This relation can be stated as follows:

$$F_{t-1} = \alpha+\beta_1 S_t+\beta_2 V_{t-1}+e_t \quad (1)$$

Where;

F_{t-1}	DAM forward price at t−1 for t delivery
S_t	Spot price for t delivery at t−1
V_{t-1}	Trading volume at the DAM at t−1 for t delivery
α	Constant
β	Coefficient of the relevant independent variable

The results of the regression are given in Table 2. There are 1643 observations for the period of December 1, 2011 – May 31, 2016 and R^2 for each time interval is in between 0.5062 and 0.8747. For this period, out of 24 time intervals, 16 of them have significant results. There are 578 observations for the period of May 31, 2016-December 31, 2017 and R^2 for each time interval is in between 0.5420 and 0.9497. The model shows better results for this period, namely out of 24 time intervals, 21 of them have shown significant results. In general "volume" betas have higher values than "SMF" betas therefore, a 1% increase in "volume" affects the change in the MSP price more than a 1% increase in SMP. Thus, we can draw the conclusion that volume has more influence on MSP than SMP does have.

For the period of 2011-2016, among the eight time intervals ("03-04," "04-05," "12-13," "13-14," "14-15," "16-17," "17-18," "18-19") having insignificant results for either volume or SMP, two of them are at off-peak hours, where prices and volumes are comparatively low. The volume coefficients do not explain the variation in forward price for the intervals of "03-04" and "04-05." For the other six time intervals, the SMP does not explain the relation of the variation in forward price. For the period of 2016-2017, in three time intervals ("02-03," "17-18," "20-21") BPM SMP does not explain the variation in forward price. Two of these intervals are off-peak hours, where the volume and price levels are low compared to peak-hours. For 21 time intervals, the model explains the relation of spot price and forward volume and prices.

5.2.2. Risk premium

For the risk premium analysis, we take the difference of SMP and MSP series (t-(t-1)). We first check for the stationary in the difference of SMP and MSP series by performing augmented Dickey-Fuller test statistic using a generalized least squares rationale (DF-GLS) where the null hypothesis is that the series are non-stationary. Elliott et al. (1996) have shown that this test has significantly greater power than the previous versions of the

Table 2: Test Statistics of the regression model regression

(01.12.2011-31.05.2016)							(01.06.2016-31.12.2017)						
SMF				Volume			SMF				Volume		
Interval	Coefficient	Standard error	t-stat	Coefficient	Standard error	t-stat.	Interval	Coefficient	Standard error	t-stat.	Coefficient	Standard error	t-stat
23-24	0.2999483	0.0111018	27.02*	1.360285	0.038140	35.66*	23-24	0.072855	0.012103	6.02*	1.273195	0.038022	33.49*
22-23	0.0263621	0.005686	4.64*	0.909408	0.016053	56.65*	22-23	0.045136	0.009501	4.75*	0.877487	0.031276	28.06*
21-22	0.0118379	0.0037371	3.17*	0.718396	0.012142	59.16*	21-22	0.032226	0.008975	3.59*	0.742886	0.028488	26.08*
20-21	0.0126723	0.0032621	3.88*	0.666371	0.010749	61.99*	20-21	0.007496	0.005291	1.42	0.822318	0. 0.027560	29.84*
19-20	0.0150328	0.0049774	3.02*	0.744933	0.011909	62.55*	19-20	0.025969	0.006637	3.91*	0.910350	0.026685	34.11*
18-19	−0.0021777	0.0053602	−0.41	0.882177	0.015929	55.38*	18-19	0.067629	0.008578	7.88*	0.964730	0.033730	28.60*
17-18	−0.0046864	0.0050373	−0.93	0.823690	0.012616	65.29*	17-18	0.007123	0.004670	1.53	0.875223	0.016064	54.48*
16-17	−0.0080029	0.0056883	−1.41	0.756444	0.015525	48.72*	16-17	0.016183	0.003825	4.23*	0.726482	0.014713	49.37*
15-16	−0.0112	0.0067989	−1.65***	0.750815	0.014125	53.15*	15-16	0.017536	0.003600	4.87*	0.690059	0.014406	47.90*
14-15	−0.0104979	0.0075276	−1.39	0.778377	0.013892	56.03*	14-15	0.016728	0.003778	4.43*	0.696764	0.014084	49.47*
13-14	0.0046694	0.0063507	0.74	0.733035	0.011963	61.28*	13-14	0.026226	0.004121	6.36*	0.611915	0.018331	33.38*
12-13	0.000754	0.0084866	0.09	0.782957	0.016128	48.54*	12-13	0.019146	0.003885	4.93*	0.665099	0.016477	40.37*
11-12	0.0287743	0.0065426	4.40*	0.722743	0.008937	80.87*	11-12	0.022176	0.003355	6.61*	0.619013	0.012889	48.03*
10-11	0.143754	0.0132598	10.84*	0.956450	0.020456	46.76*	10-11	-0.005820	0.003461	−1.68***	0.076137	0.011650	65.35*
09-10	0.2104475	0.0115084	18.29*	0.896208	0.024746	36.22*	09-10*	-0.024102	0.010088	−2.39*	1.158663	0.023916	48.45*
08-09	0.033156	0.0078879	4.20*	1.261518	0.026151	50.16*	08-09*	0.152755	0.020618	7.41*	1.751492	0.065184	26.87*
07-08	0.2388588	0.0111253	21.47*	0.808546	0.291054	27.78*	07-08*	0.115099	0.016091	7.15*	1.834483	0.055007	33.35*
06-07	0.344486	0.131419	26.01*	0.655953	0.036525	17.96*	06-07*	0.288083	0.02191	13.15*	1.814822	0.088263	20.56*
05-06	0.2955952	0.11507	25.69*	0.638578	0.029504	21.64*	05-06*	0.075411	0.018782	4.01*	1.787521	0.062825	28.45*
04-05	0.46084	0.0131413	35.07*	−0.008339	0.017150	−0.49*	04-05*	0.134279	0.018773	7.15*	1.855305	0.065426	28.36*
03-04	0.507351	0.139928	3.63*	−0.038073	0.382726	−0.99	03-04*	0.055027	0.015135	3.64*	2.127671	0.051376	41.41*
02-03	0.1654006	0.0100183	16.51*	1.202684	0.031980	37.61	02-03	0.000164	0.009117	0.02	1.495825	0.277717	53.86*
01-02	0.0827736	0.0077521	10.68*	1.361551	0.238512	57.09*	01-02*	0.036444	0.006826	5.34*	1.027221	0.011535	89.05*
00-01	0.0803634	0.0068532	11.72*	1.207506	0.014525	83.13*	00-01*	0.035589	0.007188	4.95*	0.884699	0.018085	48.92*

*Level of significance is 1% for *; 5% for **; 10% for ***

augmented Dickey–Fuller test. The results are presented in Table 3. The series are stationary since test statistics are smaller than the critical values (1% critical value: −3.43, 5% critical value -2.86; 10% critical value: −2.57).

Table 3: Unit root test results of forward and real-time spot price difference series

Hours	01.12.2011-31.05.2016	01.06.2016-31.12.2017	01.12.2011-31.12.2017
23-24	−32.138	−18.134	−36.781
22-23	−31.632	−18.912	−36.586
21-22	−30.829	−17.996	−35.529
20-21	−27.639	−17.707	−32.426
19-20	−27.911	−17.292	−32.393
18-19	−27.054	−17.068	−31.572
17-20	−26.399	−16.572	−30.859
16-17	−26.961	−16.269	−31.256
15-16	−28.704	−16.796	−33.016
14-15	−28.390	−18.384	−33.467
13-14	−28.458	−17.319	−32.877
12-13	−29.026	−17.859	−33.617
11-12	−30.016	−18.100	−34.656
10-11	−30.484	−17.843	−34.977
09-10	−30.205	−17.776	−34.753
08-09	−35.594	−29.617	−40.029
07-08	−35.435	−18.373	−39.977
06-07	−31.659	−16.910	−35.945
05-06	−34.793	−17.951	−39.296
04-05	−36.832	−17.678	−41.156
03-04	−38.034	−18.531	−42.557
02-03	−35.692	−19.128	−40.477
01-02	−35.058	−19.055	−39.759
00-01	−34.384	−21.906	−39.939

For the risk premium analysis, we run the second regression for the difference of DAM prices and spot prices by using the following equation for each hour:

$$F_{t-1}-S_t = \theta+e_t \quad (2)$$

If the constant θ is equal to 0, in other words if there is no difference between the spot and forward price, the market may be described efficient. The results are shown in Table 4. It is obvious that significant risk premium exists for each hour. The risk premium is statistically significant for 20 over 24 h for the period of 2011-2017; 22 over 24 h for the period of 2011-2016 and 19 over 24 h for the period of 2016-2017. For the peak hours, the significance level is very high, most of the time being at 1%.

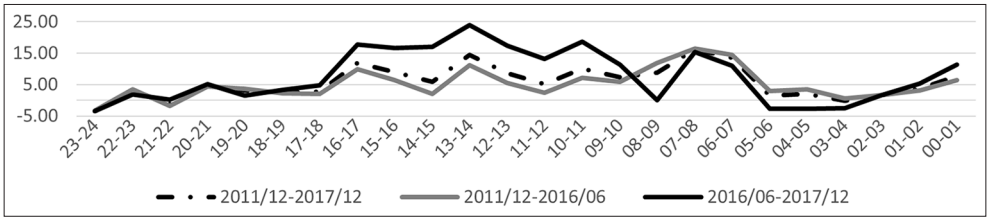
Regarding the risk premium analysis, the summary statistics in Appendix 2 show that mean values of the forward and spot price differences are positive for both terms for peak hours while it depicts left skewed pattern for December 2011-May 2016 period and right skewed pattern for the June 2016-December 2017. The standard deviation of the forward and spot price difference is lower in the December 2011-May 2016 period compared to the June 2016- December 2017. When we evaluate risk premium regression analysis for the period of 2011-2017, 3 out of 24 h have negative sign, while 21 out of 24 h have positive risk premium. This result coincides with the general market expectation that bearing risk should be compensated by a reward in adverse market conditions. Negative ones are at the off-peak hours (23-24, 21-22 and 03-04). For the period of December 1, 2011-May 31, 2016, only 2 out of 24 h have negative risk premium and they are also

Table 4: Presence of risk premium

Interval	(01.12.2011-31.05.2016)			(01.06.2016-31.12.2017)			(01.12.2011-31.12.2017)		
	Constant coefficient	Standard errors	t-stat.	Constant coefficient	Standard errors	t-stat.	Constant coefficient	Standard errors	t-stat.
23-24	−3.339808	1.028004	−3.25*	−3.53133	1.522748	−2.32**	−3.383176	0.8666299	−3.90*
22-23	3.218443	1.064167	3.02*	1.910466	1.620744	1.18	2.922268	0.9012242	3.24*
21-22	−1.939343	1.068382	−1.82***	0.2665458	1.762857	0.15	−1.439848	0.9178349	−1.57
20-21	4.011001	1.130902	3.55*	5.072228	1.794954	2.83*	4.251302	0.9645117	4.41*
19-20	3.077887	1.155921	2.66*	1.477979	1.729085	0.85	2.715608	0.9779007	2.78*
18-19	2.028879	1.216394	1.67***	3.382159	1.813262	1.87***	2.335389	1.026539	2.28**
17-18	2.152412	1.25785	1.71***	4.860173	1.92557	2.52**	2.765549	1.066318	2.59*
16-17	9.477912	1.233101	7.69*	17.76449	2.088856	8.50*	11.3543	1.066731	10.64*
15-16	7.089171	1.231515	5.76*	16.59028	2.053034	8.08*	9.240575	1.062761	8.69*
14-15	2.092594	1.152583	1.82***	17.1056	2.224201	7.69*	5.49255	1.031318	5.33*
13-14	10.86996	1.208721	8.99*	23.9885	1.984501	12.09*	13.84049	1.042889	13.27*
12-13	6.398225	1.22141	5.24*	17.37126	1.952864	8.90*	8.882929	1.04697	8.48*
11-12	3.208357	1.19935	2.68*	13.11737	1.885362	6.96*	5.452127	1.024405	5.32*
10-11	6.573504	1.156676	5.68*	18.59126	1.981097	9.38*	9.294771	1.00567	9.24*
09-10	4.293079	1.106642	3.88*	11.31154	1.706568	6.63*	5.882319	0.9408795	6.25*
08-09	11.00705	0.9962349	11.05*	0.0054577	0.0199573	0.27	8.515882	0.7759824	10.97*
07-08	15.53935	1.029684	15.09*	15.44119	1.562758	9.88*	15.51712	0.8714556	17.81*
06-07	12.54552	1.141239	10.99*	11.03021	1.474595	7.48*	12.20239	0.9438124	12.93*
05-06	1.493706	1.070521	1.40	−2.769879	1.321836	−2.10**	0.5282714	0.8811419	0.60
04-05	2.366577	1.00378	2.36**	−2.642055	1.352015	−1.95***	1.232436	0.8355728	1.47
03-04	0.5313751	0.9793733	0.54	−2.494663	1.41664	−1.76***	− 0.1538326	0.8229776	−0.19
02-03	1.763175	0.9730308	1.81***	1.60829	1.428696	1.13	1.728103	0.8191541	2.11**
01-02	2.438726	0.931446	2.62*	5.322815	1.408135	3.78*	3.091791	0.7881682	3.92*
00-01	5.986577	0.8877825	6.74*	11.33772	1.286037	8.82*	7.198275	0.7471475	9.63*

*Level of significance; 10%: ***, 5%: **, 1%*

Figure 4: Mean values of the hourly price difference of the day-ahead market and balancing power market (2011/12-2017/12)



at the off-peak hours. For the period of June 1, 2016-December 31, 2017, 4 out of 24 h have negative risk premium at the off-peak hours.

When we compare the sub-set of pre- and post- algorithm periods' mean value of prices, volatility and price level is higher during the peak hours in the new algorithm period (2016/06-2017/12) compared to the peak hours during the old algorithm period (2011/12-2016/05) as can be observed in Figure 4. Significant risk premia might also directly related to economic risk factors, such as the volatility of unexpected changes in demand and/or supply, spot prices as stated by Longstaff and Wang (2004).

5. CONCLUSION

Electricity markets support open access and non-discrimination among market participants to allow competition, which follows the incentives induced by market prices. To achieve the intended outcomes of reliability and economic efficiency, it is important to have proper prices that are consistent with the objectives and operation of the underlying system. On this respect, the challenge to create efficient MCPs in DAM stands to be a vital issue because when it is ignored, marginal prices may result in economic losses to market participants seeking welfare maximizing solution (O'Neill, Hytowitz and Eldridge, 2017). In this study, we analyze the efficiency of the Turkish wholesale electricity market by referring to the impact of dual pricing, which has been implemented since December 2011. Specifically, we elaborate how market spot prices and DAM forward price and trading volume interact under this regime by looking at two different time intervals, namely December 2011-May 2016 and June 2016-December 2017, where the latter period is characterized by the application of a new trading algorithm in the Energy Exchange (EXIST).

The results reveal that DAM forward prices show similar pattern to spot prices. The average price is lower for night hours compared to peak hours. The skewness is positive for the day and peak hours and follows a significantly right skewed pattern. The standard deviation of the forward prices are lower than the spot prices for all hours and this is in line with the expectation that forward prices tend to be less volatile than spot prices. However, the skewness of forward prices is higher than spot prices. The study also evaluates the relation between spot price and forward price and volume. The findings show that a 1% increase in "volume" affects the change in the MSP price more than a 1% increase in SMP. Thus, the volume has more influence on MSP than SMP does have. For 21 time intervals, the model explains the relation of spot price and forward volume and prices. It is obvious that significant risk premium exists for each hour. The risk premium is statistically significant for 20 over 24 h for the period of 2011-2017; 22 over 24 h for the period of 2011-2016 and 19 over 24 h for the period of 2016-2017. For the peak hours, the significance level is very high. To conclude, the efficiency and risk premium show gradual progress since the initiation of dual pricing in the Turkish wholesale electricity market, while this progress seems to improve over time and is expected to be better in the long-run. The introduction of the new trading algorithm in EXIST does not have significant effect on the risk premium. On the other hand, connecting market inefficiency and risk premium is not straightforward and the ability of forward prices to predict subsequent spot prices may be influenced by other macroeconomic factors. Therefore, forthcoming studies should also search for other factors that may influence the market micro and macro structure.

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APPENDICES

Appendix 1: Summary statistics

a. Day ahead market trading volume

Hours	(01.12.2011-31.05.2016)						(01.06.2016-31.12.2017)					
	Mean±SD	Min	Max	Median	Skew.	Vol-TL Mio.	Mean±SD	Min	Max	Median	Skew	Vol-TL Mio.
23-24	1,258,963±462,754	118,865	3,180,486	1,192,956	0.89	2,070	1,940,638±546,013	646,786	4,998,247	1,861,166	1.52	1,123,63
22-23	1,396,454±486,494	103,053	3,474,399	1,311,937	0.96	2,296	2,139,440±539,163	1,189,846	4,914,269	1,992,045	1.48	1,238,74
21-22	1,295,017±501,910	382,152	3,353,020	1,204,708	0.86	2,129	2,344,277±568,362	1,313,333	5,874,229	2,234,209	1.37	1,357,34
20-21	1,353,495±527,810	384,512	4,098,379	1,246,413	0.95	2,225	2,434,364±644,364	809,660	8,321,567	2,312,363	2.75	1,409,50
19-20	1,368,239±547,076	277,300	4,923,303	1,266,555	1.02	2,249	2,455,772±712,181	179,431	8,638,807	2,349,571	2.57	1,421,89
18-19	1,418,827±606,119	119,120	6,897,839	1,319,888	1.30	2,333	2,474,490±886,935	56,069	13,348,547	2,332,951	3.92	1,432,73
17-20	1,531,744±705,670	122,639	7,870,905	1,386,784	1.56	2,518	2,580,016±1,149,234	370,948	19,474,487	2,481,460	7.29	1,493,83
16-17	1,624,251±743,510	174,569	8,011,302	1,474,778	1.48	2,670	2,868,603±936,185	630,620	13,701,909	2,798,351	3.06	1,660,92
15-16	1,632,250±726,992	63,535	7,573,422	1,502,979	1.22	2,683	2,985,069±1,199,319	581,701	24,041,914	2,943,029	9.53	1,728,36
14-15	1,679,652±781,448	21,320	13,435,913	1,546,908	2.82	2,761	3,122,868±1,441,872	973,265	30,102,362	3,051,521	12.04	1,808,14
13-14	1,631,702±732,788	65,099	11,189,878	1,520,325	2.15	2,683	2,962,913±899,733	972,052	14,072,642	2,873,399	3.80	1,715,53
12-13	1,563,704±681,451	64,341	8,439,335	1,448,360	1.41	2,571	2,881,081±956,186	944,430	17,284,812	2,797,969	6.10	1,668,15
11-12	1,757,190±809,801	13,491	11,664,739	1,616,491	1.99	2,889	3,169,375±1,050,085	941,450	19,686,174	3,157,885	7.11	1,835,07
10-11	1,693,360±790,799	1,513	12,468,151	1,587,029	2.33	2,784	3,042,451±982,308	89,417	17,080,422	3,062,753	5.22	1,761,58
09-10	1,584,854±698,734	1,513	5,807,728	1,484,456	0.63	2,606	2,872,213±911,856	12,391	12,449,490	2,955,322	1.89	1,663,01
08-09	1,313,976±571,665	1,513	3,698,821	1,253,912	0.43	2,160	2,411,463±822,872	11,143	5,548,164	2,469,517	−0.46	1,396,24
07-08	955,191±445,755	0	2,983,594	937,830	0.35	1,570	1,803,980±687,583	8,793	4,328,037	1,857,731	−0.24	1,044,50
06-07	794,837±415,898	0	2,753,090	753,281	0.49	1,307	1,488,912±708,215	7,448	3,777,768	1,567,167	−0.12	862,08
05-06	754,630±380,537	0	2,586,556	728,085	0.47	1,241	1,291,849±503,046	8,793	3,375,171	1,294,518	0.19	747,98
04-05	749,012±385,568	0	2,550,754	732,396	0.34	1,231	1,339,815±487,263	8,793	3,389,304	1,368,958	0.17	775,75
03-04	777,583±396,037	0	2,555,310	763,156	0.37	1,278	1,392,729±469,151	8,793	3,410,405	1,404,299	0.31	806,39
02-03	880,582±408,100	1,040	2,593,443	873,675	0.29	1,448	1,514,965±446,665	9,804	3,572,766	1,517,740	0.53	877,16
01-02	997,181±404,153	1,513	2,682,848	995,001	0.30	1,639	1,667,951±446,849	31,429	3,825,432	1,653,446	0.84	965,74
00-01	1,142,144±418,773	1,743	2,862,025	1,123,561	0.44	1,878	1,861,920±463,112	363,606	4,095,276	1,821,120	1.16	1,078,05

SD: Standard deviation

b. Day ahead market forward clearing price

Hours	(01.12.2011-31.05.2016)					(01.06.2016-31.12.2017)				
	Mean±SD	Min.	Max.	Median	Skewness	Mean±SD	Min.	Max.	Median	Skewness
23-24	142.85±35.20	0.00	232.13	145.00	−0.62	142.87±33.01	11.31	238.00	142.34	0.06
22-23	155.02±31.59	4.46	250.01	155.99	−0.46	156.05±29.57	50.87	238.00	149.99	0.57
21-22	148.35±29.89	30.01	250.01	149.95	0.01	166.65±29.06	97.00	297.00	160.87	0.65
20-21	153.57±29.39	40.00	450.05	150.00	0.51	171.09±34.32	65.00	460.06	166.03	1.95
19-20	153.13±34.56	11.44	599.17	151.64	1.35	171.21±38.71	10.39	500.00	166.91	1.26
18-19	154.54±42.72	0.82	952.13	155.00	4.02	169.01±49.31	0.86	777.00	169.18	3.46
17-20	159.67±47.11	5.04	925.87	164.01	3.15	172.03±63.90	29.91	1,169.55	169.98	8.12
16-17	163.45±43.40	1.02	999.00	168.71	4.18	182.13±47.01	44.97	800.00	181.83	4.21
15-16	164.78±41.83	1.07	999.01	169.96	4.37	188.13±65.99	48.92	1,500.05	190.00	13.73
14-15	169.24±55.35	1.08	2,000.00	173.81	18.54	197.16±84.93	65.00	1,899.99	200.72	15.35
13-14	165.84±48.70	5.10	1,600.04	170.00	13.10	187.33±42.97	50.23	799.99	189.99	5.57
12-13	161.31±42.83	0.94	1,162.77	164.99	6.47	183.08±48.22	64.99	999.98	181.97	8.45
11-12	177.29±57.54	0.95	2,000.00	179.84	18.03	201.16±51.93	65.00	1,159.18	203.85	11.38
10-11	172.51±55.08	0.00	2,000.00	175.00	18.99	194.91±47.69	6.26	999.99	202.03	8.48
09-10	165.44±38.98	0.00	756.10	170.98	1.10	187.68±44.08	0.10	699.18	201.01	2.08
08-09	149.98±39.89	0.00	233.98	154.74	−0.94	165.16±48.18	0.00	236.08	172.94	−1.42
07-08	118.90±43.09	0.00	231.06	126.54	−0.82	138.14±47.21	0.00	229.79	143.20	−0.99
06-07	96.41±45.31	0.00	230.42	104.01	−0.37	111.13±55.39	0.00	223.76	124.62	−0.64
05-06	94.09±42.14	0.00	230.06	100.07	−0.40	106.03±40.94	0.00	219.33	110.00	−0.31
04-05	94.16±44.31	0.00	228.95	100.59	−0.43	112.24±38.42	0.00	220.10	115.77	−0.38
03-04	97.80±44.50	0.00	228.97	108.36	−0.43	117.97±36.31	0.00	221.06	120.00	−0.26
02-03	113.19±41.51	0.00	230.10	120.00	−0.66	129.81±32.42	0.09	223.16	133.76	−0.21
01-02	128.91±37.02	0.00	230.67	132.00	−0.82	144.36±28.34	2.00	226.24	144.88	−0.07
00-01	144.31±32.81	0.00	231.80	144.99	−0.60	160.70±27.05	40.06	232.74	157.99	0.20

SD: Standard deviation

c. Balancing market system marginal price

Hours	(01.12.2011-31.05.2016)					(01.06.2016-31.12.2017)				
	Mean±SD	Min.	Max.	Median	Skewness	Mean±SD	Min.	Max.	Median	Skewness
23-24	146.19±51.27	0.00	580.00	150.00	−0.17	146.41±42.85	0.10	280.00	149.99	0.01
22-23	151.80±50.63	0.00	820.00	160.00	1.12	154.14±44.86	1.00	450.00	155.00	0.55
21-22	150.29±51.64	0.00	820.00	154.78	1.18	166.39±47.93	1.33	600.00	165.00	1.20
20-21	149.56±53.67	0.00	820.00	150.00	1.57	166.02±52.40	0.00	600.00	166.53	1.01
19-20	150.05±59.06	1.00	820.00	156.12	1.72	169.74±55.72	0.00	712.00	170.00	1.79
18-19	152.51±68.47	0.00	960.00	165.00	2.64	165.62±64.89	0.00	777.00	165.00	2.56
17-20	157.52±74.37	0.00	1,100.00	170.00	3.32	167.17±76.20	0.00	1,169.55	165.00	5.09
16-17	153.97±69.56	0.00	999.00	165.00	3.16	164.36±68.93	0.00	800.00	160.00	2.57
15-16	157.69±66.42	0.00	999.01	170.00	3.03	171.54±83.73	0.00	1,500.05	168.99	7.40
14-15	167.14±75.00	0.00	2,000.00	178.01	8.84	180.05±95.85	0.00	1,899.99	179.00	10.48
13-14	154.97±71.70	0.01	1,600.04	165.00	5.85	163.34±68.29	0.00	799.99	158.48	2.65
12-13	154.92±66.52	0.01	1,162.77	165.00	3.37	165.71±69.23	0.00	999.98	162.19	3.67
11-12	174.08±78.34	0.01	2,000.20	180.01	8.99	188.04±73.91	0.00	1,159.18	200.00	4.65
10-11	165.94±76.08	0.00	2,000.20	175.00	8.98	176.31±71.36	0.00	999.99	180.00	3.40
09-10	161.15±61.63	0.00	959.00	170.96	2.44	176.37±63.08	0.00	699.18	188.98	0.85
08-09	138.98±58.35	0.00	580.00	150.00	−0.41	149.74±59.60	0.00	296.16	159.00	−0.58
07-08	103.36±60.31	0.00	256.60	109.99	−0.13	122.70±53.93	0.00	266.01	130.00	−0.54
06-07	83.86±61.71	0.00	250.00	84.61	0.29	100.10±56.04	0.00	265.04	106.95	−0.25
05-06	92.60±60.73	0.00	259.98	96.00	0.13	108.80±48.20	0.00	265.00	115.16	−0.45
04-05	91.79±61.15	0.00	232.49	97.48	0.13	114.89±45.71	0.00	265.00	119.18	−0.45
03-04	97.27±61.00	0.00	250.00	100.00	0.04	120.46±43.08	0.00	263.00	125.00	−0.40
02-03	111.43±58.59	0.00	265.01	116.00	−0.20	128.20±43.28	0.00	265.00	135.25	−0.44
01-02	126.47±53.44	0.00	265.00	129.99	−0.43	139.04±42.03	1.00	265.60	145.00	−0.40
00-01	138.32±48.03	0.00	265.50	140.00	−0.56	149.36±40.08	3.05	266.03	155.00	−0.20

SD: Standard deviation

Appendix 2: Statistics for the forward-spot price (MSP – SMP) difference

Hours	(01.06.2016-31.12.2017)					(01.06.2016-31.12.2017)					(01.12.2011-31.12.2017)				
	Mean±SD	Min	Max	Median	Skewness	Mean±SD	Min	Max	Median	Skewness	Mean±SD	Min	Max	Median	Skewness
23-24	−3.34±45.72	−380.01	183.85	0.00	−0.05	−3.53±36.64	−125.01	174.22	−5.61	0.54	−3.35±43.46	−380.01	174.22	0.00	−0.15
22-23	3.22±47.33	−620.00	189.11	0.00	−1.08	1.91±39.00	−214.99	196.96	−4.80	0.61	3.05±45.66	−620.00	196.96	0.00	−1.21
21-22	−1.94±47.52	−620.00	176.00	0.00	−1.09	0.27±42.42	−320.01	193.35	−3.47	−0.03	−1.32±46.76	−620.00	193.35	0.00	−1.21
20-21	4.01±50.30	−620.00	185.02	0.00	−1.26	5.07±43.19	−139.94	157.61	0.00	0.60	4.62±49.00	−620.00	157.61	0.00	−1.30
19-20	3.08±51.41	−620.00	189.11	0.00	−1.60	1.48±42.09	−212.00	142.91	0.00	0.15	3.11±49.98	−620.00	164.92	0.00	−1.67
18-19	2.03±54.10	−740.00	181.99	0.00	−2.35	3.38±43.63	−212.95	142.62	−1.25	0.28	2.49±52.62	−740.00	181.99	0.00	−2.36
17-20	2.15±55.94	−750.01	191.30	0.00	−2.59	4.86±46.33	−214.99	148.85	0.00	0.17	2.76±53.95	−750.01	184.00	0.00	−2.57
16-17	9.48±54.84	−649.00	196.53	0.00	−1.44	17.76±50.26	−249.99	148.96	0.00	−0.14	11.92±53.95	−649.00	156.64	0.00	−1.51
15-16	7.09±54.77	−693.99	441.00	0.00	−1.42	16.59±49.40	−212.00	143.32	0.00	0.08	9.05±53.40	−693.99	160.00	0.00	−1.75
14-15	2.09±51.26	−714.00	181.41	−0.01	−1.95	17.11±53.52	−280.00	567.15	0.00	1.79	5.92±52.75	−714.00	567.15	0.00	−1.26
13-14	10.87±53.76	−770.00	192.82	0.00	−2.00	23.99±47.75	−250.22	142.79	0.01	−0.14	14.47±53.02	−770.00	164.48	0.00	−2.07
12-13	6.40±54.32	−693.94	192.83	0.00	−2.27	17.37±46.99	−276.99	167.96	0.00	−0.11	8.55±53.21	−693.94	167.96	0.00	−2.32
11-12	3.21±53.34	−759.99	377.03	−0.01	−2.44	13.12±45.37	−248.99	168.89	0.00	0.17	5.17±52.06	−759.99	377.03	0.00	−2.61
10-11	6.57±51.44	−658.00	187.75	0.00	−2.24	18.59±47.67	−249.99	143.98	0.00	−0.10	10.08±51.45	−658.00	187.75	0.00	−2.21
09-10	4.29±49.22	−729.93	168.00	0.00	−3.43	11.31±41.06	−149.33	134.10	0.00	0.48	7.33±48.41	−729.93	163.92	0.00	−3.26
08-09	11.01±44.31	−380.01	174.72	0.00	0.06	0.01±0.48	−4.82	4.81	0.00	0.76	8.81±37.76	−380.01	139.96	0.00	0.12
07-08	15.54±45.79	−172.32	150.00	0.04	0.17	15.44±37.60	−110.37	222.82	0.00	0.83	16.28±42.73	−172.32	222.82	0.01	0.37
06-07	12.55±50.76	−170.78	144.74	0.99	−0.21	11.03±35.48	-129.05	188.09	0.00	0.47	13.54±47.26	−170.78	188.09	0.64	−0.09
05-06	1.49±47.61	−179.90	126.99	0.00	−0.28	−2.77±31.81	−92.74	142.67	0.00	0.76	1.46±43.52	−179.90	142.67	0.00	−0.10
04-05	2.37±44.64	−159.18	145.09	0.00	−0.16	−2.64±32.53	−116.56	181.91	0.00	0.98	1.97±41.39	−159.18	181.91	0.00	0.09
03-04	0.53±43.56	−150.01	140.00	0.00	−0.18	−2.49±34.09	−140.00	178.92	0.00	0.78	−0.19±41.11	−150.01	178.92	0.00	0.00
02-03	1.76±43.28	−184.93	154.99	0.00	0.16	1.61±34.38	−78.00	161.44	0.00	1.40	1.59±40.50	−184.93	161.44	0.00	0.42
01-02	2.44±41.43	−204.09	181.51	0.00	0.41	5.32±33.88	−105.90	195.88	0.00	1.46	3.66±39.15	−204.09	195.88	0.00	0.62
00-01	5.99±39.48	−133.96	195.85	0.00	0.73	11.34±30.95	−79.26	203.06	0.00	1.36	7.65±36.22	−133.96	203.06	0.00	0.75

SD: Standard deviation, MSP: Market settlement price, SMP: System marginal price