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BAHCESEHIR UNIVERSITY

GRADUATE SCHOOL

BUSINESS ADMINISTRATION HEAD OF THE DEPARTMENT

ARBITRAGE OPPORTUNITIES IN TURKISH ELECTRICITY SPOT MARKET WITHIN THE FRAMEWORK OF WIND FORECAST ERRORS

MASTER'S THESIS

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ABSTRACT

ARBITRAGE OPPORTUNITIES IN TURKISH ELECTRICITY SPOT MARKET WITHIN THE FRAMEWORK OF WIND FORECAST ERRORS

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Business Administration Masters Program

Thesis Advisor: Dr. Sonat Bayram

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Just as the use of electricity in our lives is very diverse, many different markets have been developed for the professional trade of electricity. Although the purpose of establishing these markets is to decrease energy imbalances and increase system security, market participants find an additional trading opportunity in these various markets. The aim of this study is to investigate a possible arbitrage opportunity between spot markets (Day Ahead Market and Intraday Market) in this trading environment. In order to determine arbitrage opportunities in the Intraday Market, the categorization prepared according to how many minutes in advance the Intraday Market transactions in the spot markets took place by analyzing historical Turkish electricity market data, a certain routine or pattern is obtained. If there is such an opportunity, the conditions under which this arbitrage should take place will also be resolved in the perspective of wind forecast errors. The univariate regression model created with wind forecast errors and price differences in different markets will measure how the change in wind forecasts in the routine arbitrage hours affects the price. An arbitrage strategy was determined for the unidirectional change of wind in 8 of the 11 tranches determined.

Keywords: Electricity Market, Intraday Market, Arbitrage, Day Ahead Market, Wind Forecast Error

To my wife,

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Introduction

From the very genesis of modern human civilization, there has perhaps not been a groundbreaking invention or phenomenon as electricity. Its awe-inspiring power has accelerated the progress of societies by illuminating the path to future. Today, we marvel at the extraordinary role that electricity plays in our lives, intertwining with every aspect of our being. As we travel through time, we witness how this abstract power shapes the life, habits and cultures of humanity.

There has never been a time in our lives when electricity, which shaped history and steered civilization, was so intense. We host it in our homes, workplaces, factories and cars more than ever before; it, too, comes to our location instantly after traveling many kilometers to serve us. Its speed and practicality makes it tempting to consider every new technology or invention with itself. In the current era, electrically powered/charged versions of every item in our lives appear as a new technology, a new "life saver". Leonhart (2001, p. 1) who stated that electricity is the best solution for energy to be produced from many different places and sources and to have a suitable consumption form, while explaining the situation "… because electricity can be generated from primary energy in relatively efficient central generating stations, transported with low losses over long distances, distributed simply with acceptable cost and converted into any final form at the point of destination." emphasized many comparative advantages of electricity use.

With these technologies and new areas of use, the demand for electricity in the world is constantly and regularly increasing. This increase is associated with both the fact that energy needs are met mostly from electrical energy and economic growth. In addition to being a phenomenon that can be predicted to be significantly correlated with economic growth, many studies have been conducted on the relationship between these two parameters. In these studies (Ogundipe, 2013; Kasperowicz, 2014; Sekantsiand and Motlokoa, 2016) a bi-directional casual relationship was observed between economic growth and electricity consumption. As can be seen in Figure 1, electricity consumption in the world was significantly affected during the 2001, 2009 economic crises and the pandemic period. Electricity consumption per capita in the world is increasing despite the increase in population and reached 3.5 MWh per year

at the end of 2021 with an annual average increase of 2.12% between the period 2000-2021.

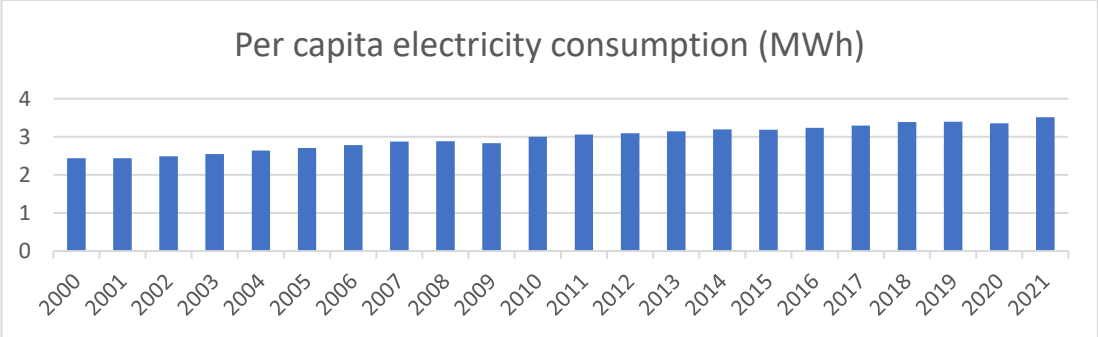

Figure 1. Per capita electricity consumption in worldwide (BP Statistical Review of World Energy, 2023; Ember Yearly Electricity Data, 2023; Ember European Electricity Review, 2022).

While it cannot be denied that recent technologies make our lives easier and more comfortable, our weakness and dependence on electricity increases day by day. With the increase in electrification, which is the indicator of how much of the world's total energy needs are met by electricity, electricity entering all areas makes modern people more dependent on itself. This dependency significantly increases the importance of the safe, consummate and continuous supply of electricity. Aki (2017), which deals with the importance of electricity use in the great earthquake in Japan in March 2011, explains how a natural disaster affects the electricity supply and therefore electricity cannot be transported to homes, hospitals and business centers for weeks. For this reason, if we accept this “dependency”, it is essential to bring the planning and infrastructure required by this into our lives. Although this example is an extreme case, in order to manage this electricity use, to meet the increasing electricity demand, to receive healthy electricity service and to ensure competition, both new power plants were established and new market dynamics and distribution systems were developed for the last 30 years.

1.1 An Eccentric Commodity

Electricity is a product that we forget in its existence but understand its importance in its absence, that we use even though we cannot see it concretely in daily life, and that we can also trade. The most unique feature of electricity, which complicates its use and trade and makes it necessary for human systems to be compatible with its own dynamics, is that it cannot be stored. Although new battery systems are becoming popular these days, electricity cannot be stored in large

quantities, both in terms of cost and feasibility (Epexspot). This unique feature of electricity has created many sub-sectors and working areas, from generation to consumption. In addition to not being able to be stored, the fact that electricity is fluid and that it has to extract its energy after the transmission process is over has forced societies and countries to develop many systems and regulations related to the use of electricity. By following the regulations and regulations in developed countries, Turkey has made significant progress towards becoming one of the fully liberalized electricity markets.

1.2 Theoretical Framework

In this chapter, the historical development of the Turkish Electricity Sector will be explained and the groundwork for the market will be prepared. Sectoral developments will be detailed on the scale of the Turkish electricity market and an introduction to the electricity markets, which is the main subject of the study, will be made.

1.2.1 Development of Turkish electricity sector. The development of the electricity market in Turkey consists of roughly three development stages. Although the Early Stage (1920s – 1960s), Structuring Stage (1960s – 2000s) and Growth Stage (2000s – Present) eras have separate periodic targets and characteristic structures, all these stages have contributed to the liberalization, more competitive structure, transparency and credibility of the sector. (PWC, 7)

Although municipalities and mostly private companies are active in the generation and distribution of the Early Stage, the stage is characterized by the absence of long term planning and the need for more active participation of state or regulatory authorities. Although emphasis was placed on the construction and expansion of the country's electricity grid, state involvement was minimal due to financial constraints.

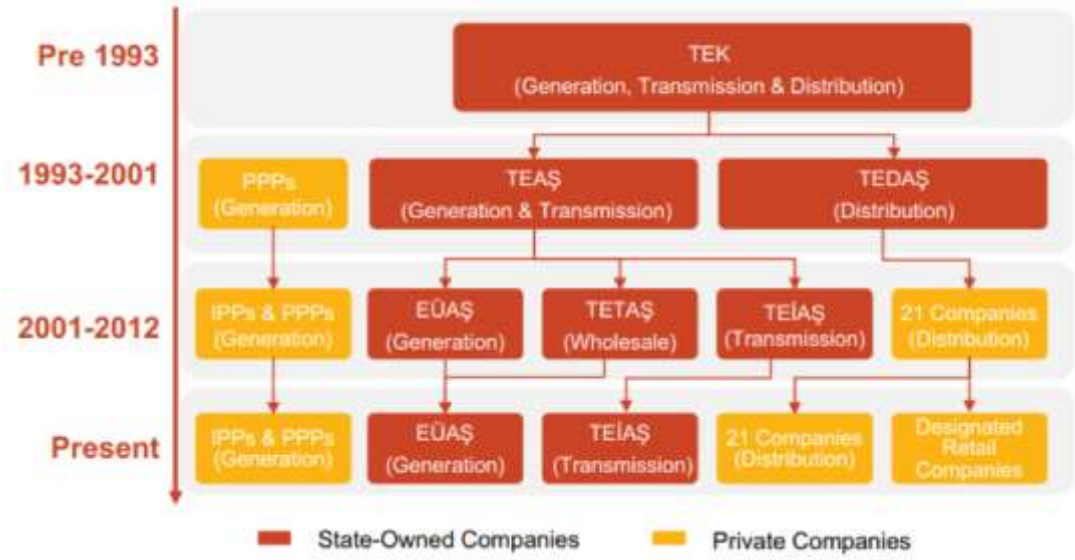

Figure 2. Structural Development of Turkish Electricity Sector

Regulatory government institutions emerged for the first time in the Structuring Stage, as the increasing population, production and consumption amounts required a more institutional structure. A more regulated structure has been established in the sector by partially providing integrity. In addition, the most important characteristic of this stage is the paving the way for investments and liberalization with the concepts of Build – Operate – Transfer, Build – Operate – Own and Transfer – Operating – Rights.

In the Growth Stage of the sector, all processes from the generation of electricity to the consumer are structured with the comprehensive laws and regulations, especially the privatizations in the generation and distribution sides. In this framework, the Electricity Market Law, which came into force in 2001, is seen as the most important milestone of the sector in Turkey. With the awareness that electricity supply is a public service, the implementation of new regulatory institutions and regulations does not fail the steps taken by the sector towards liberalization. Emphasizing that the regulation of the sector in the relevant law is aimed at accelerating the steps towards liberalization, Doğan (2019: 34) explained this development as follows.

> With the Electricity Market Law, it is aimed to create a financially strong, stable and transparent electricity energy market and to provide an independent regulation and supervision in this market that can operate in accordance with the provisions of private law in a competitive environment in order to provide

sufficient, quality, continuous, low-cost and environmentally compatible electricity to consumers.

In this period, in which capacity increases were also supported by additional investments, significant increases were observed especially in renewable capacity.

1.2.2 Structure of Turkish electricity exchange. With legal and regulatory arrangements, privatizations and division of labor setups in the sector, it is aimed to supply electricity to the consumer in a healthy and uninterrupted manner. In addition to security of supply, electricity markets have been developed for the trade of electricity generated or obtained, serving different purposes since the Electricity Market Law that came into force in 2001. In this way, a more transparent, competitive and predictable electricity trading system has been implemented.

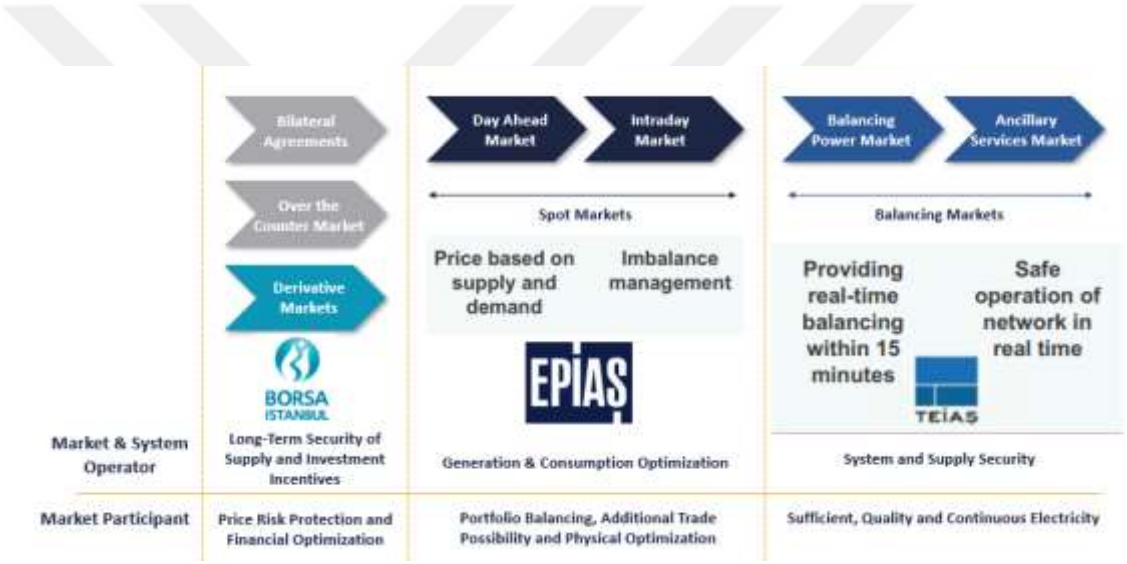

Figure 3. Turkish Electricity Trade Alternatives and Markets

As can be seen in Figure 3, long-term risk planning and financial optimizations can be made with Bilateral Agreements (BA), OTC Market and Derivative Markets alternatives, apart from the spot market.

Due to the topic, the study, which will proceed with more spot market analysis and evaluations, will focus on the analyzes in the Intraday Market and evaluate the arbitrage opportunities in the Intraday Market, which is the subject of research, after the purposes of both the spot market and the balancing market are mentioned and their functions are introduced.

1.2.3 Spot markets and balancing markets. It is the founding mission of Energy Exchange Istanbul (EXIST), which was established in 2015 and is the market operator, that spot markets do not deviate from current dynamics, are transparent and predictable. Two separate spot markets, Day Ahead Market (DAM) and Intraday Market (IDM), which EXIST operates in electricity markets, are markets that serve different purposes and have different principles, bringing together the producer and the consumer, the buyer and the seller, or in the broadest sense, the supply and the demand. The common purpose of the spot markets is to provide a balanced forecast in terms of generation and consumption as much as possible to the system operator, Turkish Electricity Transmission Company (TETC). Due to the nature of electricity, supply and consumption must be equal at all times. If at any time the supply is lower than the demand, there will be areas that will experience a power outage. In the opposite case, the security of supply will be affected again, as the transmission lines will be heavily loaded.

Although TETC has a slightly more balanced generation plan compared to the plan in DAM after IDM is included in the spot market, there will always be a need for balancing the system as it gets closer to real time (when consumption starts). In order to meet this need, the generation capacities previously held by the power plants in two separate markets are activated or deactivated under the control of TETC. In the Balancing Power Market (BPM), the relevant generation capacity of the plant should be kept ready for a maximum of 15 minutes beforehand, while in the Ancillary Services Market (ASM), instant frequency controls of the system are made and the plant is aimed to be activated immediately. TETC needs to keep the system frequency at 50 Hz and must be practical enough to take immediate action. As a current example, the actions taken by TETC in the February 6 Kahramanmaraş Earthquake in Turkey show the importance of balancing markets. In Figure 4, the Load Shedding Instructions given by TETC in the earthquake on February 6 in Turkey are shown together with the 1 week before and after.

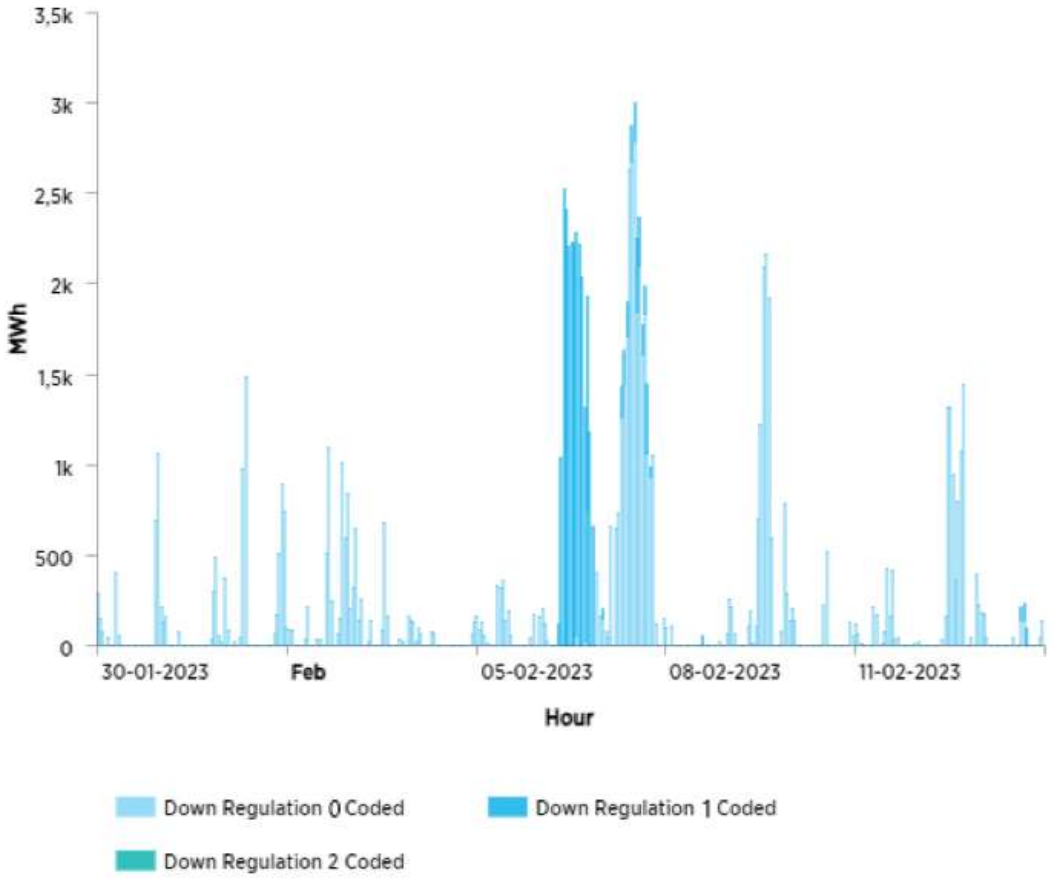

Figure 4. Down Regulation Instructions in the Earthquake Period

The system was able to remain in balance thanks to the intense instructions given to balance the instantaneous severely reduced consumption. Although this success of TETC is not on the agenda due to the severity of the post-earthquake situation in Turkey, Aksan (2023) describes it as a success that there was no power outage anywhere except the earthquake zone after the instantaneous demand drop of up to 12% during and after the earthquake. He finds it positive that the importance of TETC at this point is in practice as well as in theory.

1.2.3.1 Day Ahead Market (DAM). DAM is an organized market operated by EXIST, the Market Operator, used for electricity trading and balancing activities, one day before the delivery date of electricity. This market, which operates completely according to the balance of supply and demand, has three main objectives that we can specify.

Within the framework of system supply and security; to provide TETC with the opportunity to perform constraint management day in advance by creating bidding zones for large-scale and continuous constraints, and to provide TETC with a partially balanced system the day before.

In the commercial framework; market participants are provided with the opportunity to balance themselves by providing the opportunity to buy and sell energy for the next day in addition to their bilateral agreements.

In the framework of market foresight; a single hourly electricity price is determined and this price serves as a reference to the market. The predictability of this market, in which standard supply and demand dynamics are observed, is both an intended feature and a feature needed by market participants.

This price, called the Market Clearing Price (MCP), should not lose its feature of being a reference to the market. Market participants, who forecast prices and make forward-looking trade agreements according to their own expectations, need this price to come out in a liberal and transparent environment. The high transaction volume density of public power plants (PPP) or public institutions that can be traded in the market and the fact that they take action in the market to suppress the price despite high input costs, may damage the transparency and rationality of the market.

In addition to hourly offer, different offering alternatives such as block or flexible offering are available for participants who want to follow a different operational strategy. Market participants must enter their offers in the buy or sell direction for each 24 hours of the next day into EXIST's system until 12.30. Supply and demand at all price levels in each hour are processed in EXIST's optimization system, and the price at the intersection of supply and demand is announced as MCP. The important detail here is that MCP is the common result of all participants' offers and is a single price.

1.2.3.2 Intraday Market (IDM). It is an organized wholesale market, operated by EXIST, like DAM, where transactions are made with the continuous trade method. In IDM, which is chronologically between DAM and BPM, offers are made on an hourly basis and match instantly. Offer can be entered for the relevant hour up to 60 minutes before the physical delivery. Considering that this period was 90 minutes before 1 October 2018 and it was discussed in the sector to reduce it to less than 60 minutes, these practises and applications may change over time according to the expectations and needs of the sector.

We can list the benefits of IDM, which was put into practice in 2016, under 3 headings; increasing the system supply security, increasing the trading volume in the

market and providing additional trading and balancing opportunities to the participants.

Within the framework of system security; as a result of being between DAM and BPM, it reduces the imbalance between the generation and the consumption a little more, thus reducing the amount of regulation instructions in the Real-Time Market, thereby easing the burden on TETC.

In terms of sector and market; the existence of an additional market such as IDM and the provision of continuous trading and instant matches, contribute significantly to the liquidity of the market. This factor, which facilitates trading in the market, also benefits the attractiveness of the market.

In the framework of the market participant; this market, which provides an additional trading opportunity, provides arbitrage opportunities to the participants. The arbitrage opportunity in IDM, which is the research subject of this study, provides a commercial gain to the buyer or seller, depending on which one has better market foresight. Besides the arbitrage, there is also the benefit of reducing the imbalance of the market participant. IDM offers the opportunity to eliminate the imbalance caused by unforeseen reasons in a market closer to real time. With the opportunity to trade much closer to real time than DAM, it is mostly used for this purpose, especially in renewable power plants, which cannot clearly predict the amount of generation.

In IDM, both sellers and buyers enter their sell and buy offers simultaneously and can be thought of as a standard exchange. Each matching offer is assigned a unique contract number and the matching price is only between the relevant buyer and seller. As seen in Figure 5, MCP which the reference price in DAM and the unique prices in IDM, which diverge at this point, provide an arbitrage opportunity.

Figure 5. Difference between IDM and DAM

Although there are 2 different types of offers in this market; hourly and block which consist of combination of several hours, hourly offers will be researched in this study. Offers for the next day start to be given at 18.00 and offers can be entered at any time up to 60 minutes before the real time. The next day's MCP is announced

at 14:00 at the same time every 24 hours. Therefore, there will be sufficient time for market participants to adjust their IDM offers.

Figure 6. Chronological Transaction Order in the Spot Markets

1.3 Statement of the Problem

The context of the study is the evaluation of possible arbitrage opportunities in IDM trading with the perspective of wind forecast errors. An arbitrage strategy is tried to be developed according to the course of wind forecasts by examining the effects of wind forecasts deviations as the timeline approaches from DAM to IDM, on the prices at the same hour in the spot markets. In the study, a statistical approach will be displayed by making use of historical data while regression model is discussed in order to examine the relationship between wind forecasts and prices in the spot market.

1.4 Purpose of Study

The purpose of the study, within the scope of "additional trade" in the Turkish electricity spot market, is to investigate under which market conditions deviations in wind forecasts can provide arbitrage opportunities and to develop a trading strategy for market participants.

1.5 Research Question

The subject of the study is to what extent arbitrage opportunities in Turkey's spot electricity markets change with errors in wind forecasts and the study seeks answers to the following research question. Depending on the change in wind

forecasts, is it possible to come up with a trading strategy that can make a profit in a certain routine by buying/selling the same electricity at different times?

1.6 Significance of Study

The IDM literature remains weaker than other stakeholders in electricity markets, and the literature addressing arbitrage opportunities in IDM in a practical and strategic way is much more limited, perhaps almost non-existent. Since the IDM literature mainly works on estimating the weighted average of the IDM price and which parameters affect this price and to what extent, a study evaluating arbitrage opportunities will make a big difference to the literature. Additionally, this study will help a market participant develop a real arbitrage strategy by grouping IDM transactions according to how long ago they occurred. At this point, considering the hourly grouping created in this study, which is thought to bring significant differences and perspectives to the literature, together with the deviations in wind forecasts, gives a different approach to the literature in terms of detailing arbitrage strategies.

Chapter 2

Literature Review

When we look at the electricity market literature as a whole, we can say that most studies have been researched for DAM and BPM. The reasons why IDM remains sterile in this regard can be stated as it is still seen as an alternative to other markets and there is no consensus as a result of the fact that IDM is not available in every country or that we encounter it in different regulations. After stating the importance of IDM for system security, Hagemann (2013) states that "The literature so far has neglected the analysis of intraday market prices, even though the intraday market is becoming increasingly important in the presence of high shares of electricity generation from intermittent renewable energy sources." Although it is studied less frequently than other markets, we can divide the IDM literature into various topics. After emphasizing that the feature of IDM as an intermediate market in the renewable world is essential for supply security, the pros and cons of arbitrage in electricity markets, how much the price in IDM is affected by which parameters and which methods are used for price forecast will be discussed under three subheadings.

With the increasing integration of renewable energy sources such as wind and solar energy into the electricity and grid system, the importance and use of IDM has increased. The increasing participation and integration of renewable power plants, such as hydro, wind and solar, which cannot operate at base load, into the electricity grid system may endanger the system supply security and make it difficult for the balancing units to work properly unless adequate base load capacity is deployed. Peter and Wagner (2021), which tries to determine the coverage rate of renewable capacity, infers that renewable resources should be in equilibrium with baseload resources. The study, modeled for the European electricity market, concluded that "The additional yearly costs for firm capacity provision when applying exogenous fixed wind power capacity values of 5 % compared to endogenous capacity values amount to 1.5 and 3.8 bn EUR in 2030 and 2050, respectively, which represents additional costs of 3 % and 7 %." These high costs consist of the investment and operational costs of the power plants that need to be added in order to balance the power plants that are not part of the balancing unit. In addition, since these costs are calculated in the scenario where IDM is in our lives, these costs will be calculated much more in a parallel universe where this market does not exist. As a matter of fact, when we take into account how effective IDM is in the European electricity market -IDM/DAM ratio is almost 5 times that of Turkey for 2021- (Epexspot, 2021 & EPİAŞ, 2021), it is inevitable that these costs will increase much more in different countries and different scenarios.

We have stated that the most important contribution of IDM, in addition to its feature that increases trade and liquidity, is that it reduces the imbalance amounts and therefore reduces the regulation costs resulting from imbalances. In this regard, in a study conducted for the Nordic market with wind forecasts, which is the most difficult source to predict (Holttinen, 2006), it has shown that activity in IDM is inversely proportional to imbalance costs. In the study, which shows that weather-dependent power plant production forecasts increase as they approach real time, forecast performances increase significantly as the forecast horizon shortens, thus the need for balancing decreases significantly. By updating the wind forecasts for DAM (13-37 hour forecast horizon) with the forecasts for IDM (2 hour forecast horizon), the mean absolute percentage error (MAPE) decreased from 20% to 9%.

Table 1

Income and Costs for Wind Power Producer in Western Denmark, with and without Forecasts, Calculated from 2001 Data

2.1.-16.8, 25.8.-31.12.2001	**13-37 hour forecasts**	**7-13 hour forecasts**	**2 hour persistence**
Prediction error up/down as % of total 3.35 TWh	20 % / 19 %	15 % / 15 %	9 % / 9 %
Income Nordpool elspot, average Eur/MWh	22.9	22.9	22.8
Income Nordpool elspot, predicted and realised production* average Eur/MWh	22.4	22.4	22.5
Regulation: up/down % of time % of energy average Eur/MWh	40 % / 29 % 15 % / 16 % 30.1 / 13.8	37 % / 27 % 10 % / 11 % 30.6 / 13.3	28 % / 25 % 5 % / 5 % 29.4 / 13.4
Regulation costs Eur/MWh regulated Eur/MWh produced	 5.9 2.3	 5.2 1.5	 3.8 0.7
Net income Nordpool average Eur/MWh	20.1	20.9	21.8

This update also contributed to the system operator's security of supply by reducing the up and down regulation instruction amounts from 15% to 5% and the total regulation cost from 8.2 Eur/MWh to 4.5 Eur/MWh. Also Dobschinski et al. (2010) makes a similar inference on this topic and says for system security, "The large-scale integration of wind power into electricity supply systems leads to rising challenges to balance the energy demand and the power generation." The mentioned essential role of IDM comes into play at this point and minimizes high uncertainties in the production plan. Allowing buyers and sellers to trade in near real-time is beneficial for themselves as well as for the electricity system as it reduces volume and price in BPM (Dobschinski et al. 2010).

As a result, the importance of the existence of IDM in a renewable world is a fact that all industry stakeholders, as well as the literature, agree on. Ultimately, not being able to update any forecasts until the real time of the electricity traded in DAM with a prediction made the day before will bring a great burden and risk to the grid system. However, the absence of IDM or its low effectiveness will be a major obstacle to future renewable investments. Despite all their financial difficulties, the situation of countries that want to produce electricity from their own natural resources and minimize carbon emissions while doing so does not seem that easy in

this respect (Peter and Wagner, 2021). With IDM, we can at least put these goals on our agenda and find them probable. At the end of the day, electricity needs to be balanced and flow through the grid in a healthy way, and our leniency of all kinds of regulatory collocations and developments to ensure this will be for the benefit of humanity in the long run.

Before looking at the literature on determinants in IDM price and electricity price forecasting in the spot market or balancing power market, it is useful to understand the effects, advantages and disadvantages of arbitrage in an electricity and energy market as a general concept.

2.1 Speculation or Efficiency

Arbitrage may sound like a manipulative operation of sorts or the working style of an organization trying to raise prices in the market in their favor and we believe that this thought is not unfounded, both through the media and our individual perceptions. As a matter of fact, although the relevant "speculators" are blamed for high prices that occurred by trying to disembody the market from its fundamentals by politicians and the media as a result of assessment related to commodity markets, it is very difficult to find a judicial statement with this accuracy in the literature.

The definition of market speculation is “the purchase (or sale) of an asset or a commodity with the expectation that the price of the asset will rise (or fall) to create the opportunity for a capital gain.” Knittel and Pindyck (2016) clearly state that the existence and definition of speculation are more innocent than we perceive. At the end of the day, a speculator may take a long position in futures contracts because he believes the price is more likely to rise rather than fall and hopes to "beat the market," and this transaction is legal as well as morale. If the spot price of the commodity resulting from these future contracts changes suddenly, this situation should be investigated. Even when research is limited to this scope, it will not be that easy to find evidence that speculative trade significantly affects spot prices (Knittel and Pindyck, 2016). Kilian and Murphy (2014), stating the importance of including the fluctuations in inventories as a result of speculative transactions involving future contracts in the model in order to reach any conclusion, also emphasize that the price elasticity of demand should also be taken into consideration. “It has been suggested that it is possible for speculative trading to occur even without any change in

inventories, if the short-run price elasticity of demand is zero." Looking at the literature investigating the serious price fluctuations in crude oil in the period between 2003 and 2008, price elasticity of oil demand is not close to zero and much higher than traditional estimates from dynamic models that do not account for price endogeneity (Kilian and Murphy, 2014).

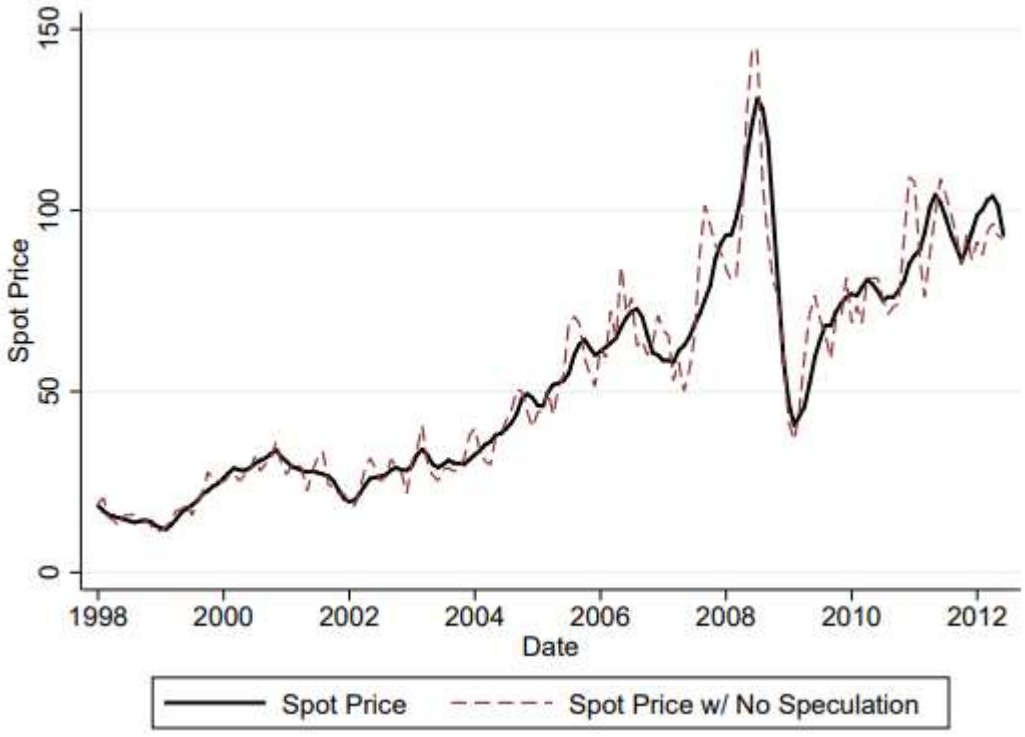

Figure 7. Actual Prices and Implied Prices with No Speculative Activity: Using Inventory Changes, Three-Month Intervals

In studies carried out to reduce future contracts to the spot market, it is assumed that the supply is shifted according to inventories and that no speculative trade is made. In this way, the comparison of the "counterfactual" price (without speculation) formed by the new supply and demand simulation with the actual prices is examined and it is seen that they are very close to each other (Figure 7) and the correlation is high. (Knittel and Pindyck, 2016). This eliminates speculation as an explanation of the 2003-08 oil price surge. Instead, it is found that this surge was caused by fluctuations in the flow demand for oil driven by the global business cycle (Kilian and Murphy, 2014; Knittel and Pindyck, 2016; Fattouh, Kilian and Mahadeva, 2013).

However, since the structure in the electricity markets is formed by the simultaneous interaction of financial and physical trading actors, the determination of prices takes place in a more comfortable environment. Rather than speculation, Jha and Wolak (2018) implies that, this environment in the electricity market increases market efficiency by making significantly reduced the transactions costs associated with attempting to profit from differences between the day-ahead and real-time market prices at the same location in the transmission network. With the motivation to reduce speculation, it shows that limiting financial trading using taxes or transaction costs will increase the bidder's market power and manipulation incentives rather than making the market more efficient (Birge, Hortaçsu, Mercadal and Pavlin, 2018). Similarly, Parsons, Colbert, Larrieu, Martin and Mastrangelo (2015) explains that market rules that encourage the entry and competition of financial actors are key to reaping the benefits these traders bring to the electricity markets as well as avoiding incentives for market manipulation.

In this context, the literature; establishes a connection between non-competitive market, market power of the generators, the forward premiums and consumer surplus. Increasing the real-time or near-real-time trading opportunities which implies arbitrage (lowering transaction cost, increased competiveness of markets etc.) will reduce the generators dominance in the electricity markets, lead to the decrease of the forward premium (Saravia, 2003; Ito and Reguant, 2016; Mercadal, 2022) and ends with consumer welfare (Mercadal, 2022).

2.2 Price Determinants in IDM

Identifying the price determinants in IDM and trading in the market according to the flow of these variables is perhaps indispensable for an arbitrage. As the actors make their predictions and assumptions in the DAM 1 day ago, changes will occur in these predictions as they get closer to real time. Since the forecast with the highest consistency in general is the forecast made closest to the real time, the possibility of significantly seeing the amount of deviation in the forecasts 1 day ago can also increase arbitrage opportunities for the actors (Weber, 2010). Therefore, if market participants are actively trading in both markets, prices in the intraday market are closer to the true fundamental equilibrium (Pape, 2018).

Before deep diving to the IDM literature, it is necessary to briefly mention the factors affecting the general electricity price and the difficulties of establishing a price prediction model. At this point, the most important parameter in the formation of the price has come to the fore as the demand effect (Chen, Wu, Fu, 2012). Although the demand variable can be used as an independent variable in models, it also attracts attention as an element affected by the price, and therefore a multiplier effect should be mentioned when establishing the formula (Heydarian-Forushani, Moghaddam, Sheikh-El-Eslami, Shafie-khah and Catalao, 2014). Because when we shift the demand, the price will also change and accordingly the demand will change again. Along with the demand effect, Conejo, Carrion, and Morales (2010) state that in addition to the uncertainties in the behavior of buyers and sellers carried by a standard stock exchange platform, variables such as seasonality in electricity prices, resource-based power plant effects, political pressures, capacity and grid constraints also increase uncertainty and makes it difficult to predict prices accurately (Bertrand and Papavasiliou, 2018). Although it is a complex and tangled structure, the factors that determine the price have been discussed in the IDM literature and certain conclusions have been reached. Due to the structure of the electricity market, we act with certain predictions and assumptions about the future and the actions taken determine the market.

In the literature, these assumptions are determined as forecast errors in wind and solar power plants, power plants outages, errors in load forecasting, and unexpected foreign supply and demand. The definition of forecast error is the difference between the actual generation and the forecasted generation for the relevant hour (Actual Generation – Forecasted Generation) and as can be understood, forecast errors can be both positive and negative directions. The literature on the subject also focuses on how these deviations affect the IDM price.

Researching these parameters with the German IDM, Hagemann (2015) confirms that wind forecast errors, solar forecast errors and outages have significant influences on intraday prices. The study also compares the effects of these parameters (forecast deviations in renewable production and power plant outages) on the IDM price. The effect of errors in wind forecasts on the price was greater than the effect of power plant outages on the price. In fact, this result is an expected result when considered in the merit order logic, because while wind power plants operate

independently of price, a coal or natural gas power plant has to work at their cost. While sales resulting from positive solar forecast errors give similar output to wind forecast, negative forecast errors affect the price in amounts similar to power plant outages. Wind effects are quantified at 2–3 €/MWh per GWh forecasting error. Solar effects are quantified at 2 €/MWh per GWh in positive forecasting errors, and below 1 €/MWh per GWh in negative forecasting errors. As a surprising result, the positivity and negativity in the solar forecast deviations affect the price to different degrees. Gürtler and Paulsen (2018), who compared the forecast errors in renewable power plants with the merit order effect, which refers to inability to operate due to plant costs or power plant outages, reached similar results. Stating that forecast errors have a much greater impact on the price than the merit order effect and calculated that this impact is 1-5 Eur/MWh per GWh. Emphasizing that this value is average and that there can be found much higher arbitrage opportunities at some hours.

Similarly, Kiesel and Paraschiv (2017) show that prices in the intraday market are largely due to forecast errors in renewable energy sources, and there is a significant correlation between these two parameters. In Ziel (2017), where the effects of forecast errors in wind and solar power plants are investigated in more detail, it is stated that the price in IDM is affected more by the deviation in the wind than the deviation in the solar. In the study, it is stated that the forecast error during the night hours has a greater effect on the market price than during the daytime. Also surprisingly, there was no statistically significant evidence that positive deviations affect the price in IDM, while negative deviations (the position where real-time production is lower than the forecast) affect the price statistically significantly. In a more recent study (Kulakov and Ziel, 2019), the effect of wind and solar deviations on IDM price is explained in an opposite way. An error in the solar forecast has a greater impact on intraday prices than an equally large error in the wind forecast. However, the estimation error of a wind farm is 3 times higher than that of a solar power plant. These two cases should not be confused with each other. In this study, in which the supply curve in DAM is transformed into a supply curve for IDM after including resource-based forecast errors, it has been observed that the effects of wind and solar errors on IDM price are non-linear. Another example of non-linearity is that the price of the IDM depends on the size of the forecast errors. Although there are different thresholds for different sources, it has been observed that the effect of the

forecast error on the IDM price decreases after a certain level (Goodarzi, Perera, and Bunn, 2019; Gürtler and Paulsen, 2018).

Although there is no full consensus in the literature about which parameter affects the price under what conditions and how much, it is a fact that these prediction errors and different power plant outages in renewable energies seriously affect the price. In addition to all these, Hagemann and Weber (2013) bring a different interpretation to the results of forecast errors. It is stated that forecast errors in renewable energy increase market access and stimulate liquidity in the market, and that this liquidity contributes more positively than expected, such as the ability to receive new investments for a market in the long term, protecting balancing elements and strong market balance. The study underlines that the main source of liquidity for a market is especially forecast errors.

2.3 IDM Price Forecasting

The studies carried out for price forecasting in IDM in the literature are most likely country specific. The most important reason for this situation is that electricity markets, especially the existence of IDM, have different dynamics in each country (Shinde and Amelin, 2019). IDM price forecasting, which includes parameters such as different country-specific level of development on a sectoral basis, differences in liberalization levels of markets and political interventions, differentiation of resources required for electricity generation, and variation in the quality and coverage of weather forecast models, would not be facile to handle in a more general and comprehensive literature and it would be difficult to conduct consistent results. Despite these difficulties, the components that make up the IDM price are determined using various modeling methods and price forecasting is established.

The most basic models are regression models that try to predict the weighted average IDM price for each generation hour. The most basic of these models frequently employ exogenous variables or the current and past market data to characterize the IDM price (Kiesel and Paraschiv, 2017; Karanfil and Li, 2017; Ziel, 2017). These statistical models, which work with the autoregression method, try to predict the IDM price in the future by including the past IDM price in the model. Forecasted and actual generation data, especially demand, are frequently used exogenous factors. In order to determine the effect of a specific variable has on the

intraday price, these studies analyze the coefficients of the regression model provides for each variable. Also in the study of Hu, Jaraite and Kažukauskas (2020), how Nordpool market IDM prices are affected resulting from change of outages, transmission capacity, wind and load forecast deviations is examined. The main output of the study is that while unplanned power plant failures or outages do not affect the price, deviations of load and wind forecasts are factors that significantly affect the price. In addition to these studies, Berger, Yalcinoz and Rudion (2020) also employ a parallel regression model. The part where it differs from other studies is that instead of looking at the relationship of the coefficients of the variables in the model, the percentage deviation of the prices obtained after the simulation with the actual prices was examined as the performance criterion of the model. As a result, the autoregression model literature agrees on demand and wind in affecting the IDM price.

In order to develop these partially more basic models, more comprehensive models in which techniques such as variable selection, out of sampling and preprocessing are implemented have found their place in the literature. In the study of Andrade, Filipe, Reis, and Bessa (2017), a regression model is introduced that predicts each auction price separately in the Iberian market, which has an unusual IDM structure (exist 6 intraday auction blocks in the day), it was concluded that the model that best forecasts the IDM price is the model that includes only the most recent DAM and IDM price as variables. Considering the study of Monteiro, Ramirez-Rosado, Fernandez-Jimenez, and Conde (2016), which reached a similar result for the same market with the machine learning method, we can say that these results differ from the previous studies in the literature. When we see that only the most current prices can provide the best explanation in explaining the price, not the generation and load forecast errors, which are considered important in many studies, it can be inferred that the IDM characteristic is not the same everywhere.

Another contrast is found in two separate studies that modeled the price in the German market. In the study of Marcjasz, Uniejewski and Weron (2020), implementing the Lasso regression model, it is stated that the prediction that includes all exogenous variables gives the best results, while the study of Janke and Steinke (2019), in which neural networks and quantile regression method is used, states that the parameter that best explains the weighted average price distribution is

neighboring prices. Neighboring prices are of much greater importance in the European electricity market than in any other part of the world. The integration of countries with a large interconnected network system ensures that these countries balance each other and that the price differences between countries do not become that much high (Janke and Steinke, 2019). In addition, thanks to the developed interconnected system, countries gain a comparative advantage according to the capacity of their own resources and protect themselves from price fluctuations during the year. Of course, although not all of Europe can benefit from this integration to the same extent, this is why prices in small regions are close to each other and ultimately neighboring prices are an important variable. The necessity of estimating electricity prices according to country and regional characteristics, which has been emphasized several times, is once again understood from a different point of view. An another study of Uniejewski, Marcjasz and Weron (2019), while making short-term forecasts for the German market, Lasso regression was used for both variable selection and the price forecasting model, and gave more accurate results than other models used. In addition to all these studies, two more unique studies were conducted for German IDM. The first of these, Narajewski and Ziel (2020) implemented rolling window forecasting method for each forecasted trading window. After each hour in which the price was estimated, a simulation study was conducted by using this new output and forecasting the price in the following hours. The results from the econometric models used in this study show that volatility in the German IDM can be modeled successfully. The second study is (Kulakov and Ziel, 2019) a model, which highlights the significance of renewable energy in the IDM. In order to determine the IDM price, this model adjusts the DAM supply curve according to errors in solar and wind forecasts. The study was completed for also the German market, and the results exceeded the paper's regression benchmark models. Based on the results of their own studies, Narajewski and Ziel (2020) and Marcjasz, Uniejewski and Weron (2020) concluded that German IDM is weak form efficient, means that past price movements, volume, and historical data do not significantly affect the future price.

There has been an expansion in the IDM price prediction literature with the use of deep learning method, which is a subfield of machine learning. In the study conducted for Turkish IDM, Öksüz and Uğurlu (2019) used the neural network method, which forms the basis of deep learning algorithms. Their discovery about

price forcasting is important for the whole electricity price modeling literature. Rather than estimating the IDM price directly, focusing on the difference between DAM and IDM prices and forecasting this difference gives much better results. In the study, it is stated that recurrent neural networks gave better results than other methods for Turkey IDM price forecasting in their study where they compared various methods including deep learning method and econometric modeling. Another conclusion from the study is that IDM is weak form efficient on IDM price forecasting in Turkey. In another study by Scholz, Lehna, Brauns and Baier (2021), in which deep learning methods for the German IDM market were modeled and applied in a much different way than all the studies mentioned here, a similar conclusion was reached and it was observed that deep learning models outperformed other models. The first reason that makes the modeling of this study different from the literature is that it models the last four hours prior to real time at 15 min intervals. These 15-minute updates, which are closer to the German IDM characteristic, are thought to provide more accurate results in following instantly changing forecasts and trends. The second reason why it differs from the literature is; Including data such as order book data, frequently updated wind generation forecasts in place of the DAM price forecast and time series of previous evolution of the IDM price before making a forecast of the price as input to the model. In another study where multiple model methods were used and compared with each other, Kolberg and Waage (2018) added parameters such as regulating price, time dummies, transmission line capacity and urgent market notification, in addition to variables that are frequently used in the literature such as DAM price, IDM price and renewable generation forecast error. In this study conducted for Swedish IDM, the model built with deep learning showed a significant superiority over other model approaches and performed 15-25% better in terms of average percentage deviation value.

If we were to roughly rank the IDM price forecasting studies in the literature according to their deviation rates, various machine learning techniques have performed much better than regression models. To rank the machine learning methods from best to worst, these are; recurrent neural networks (such as long/short term memory or gated recurrent unit), simpler neural networks such as multilayer perceptrons, gradient boosting and random forest methods. “Recurrent neural networks are the most effective because they can accurately capture the temporal

structure of the data, which is crucial for time series data." Cabrol (2021) essentially suggests that in order to predict the intraday market more accurately, non-linear and intelligent methods are required due to its highly complex dynamics.

Chapter 3

Methodology

After examining the trade opportunities in Turkish IDM, which certain hour routines must be met in order to make arbitrage and the impact of changing wind forecasts on prices in spot markets will be investigated. First of all, in order to understand the position and importance of IDM in the electricity market, trading volumes and prices will be analyzed comparatively with other markets. A general result from this analysis will pave the way for the study to deepen arbitrage opportunities.

IDM trading will be categorically classified according to the trading time. By courtesy of it, both arbitrage opportunities in IDM and additional trading opportunities that may arise from possible deviations in DAM will be presented more clearly and strategically. The prices in the IDM trade from 2016 to 2022 will be considered categorically and a certain pattern will be tried to be achieved. After this obtainment, which will help to identify arbitrage opportunities in IDM, boxplot analysis will be applied to the certain trading hours which determined categorically, in order to understand the relationship with MCP in more detail. In this way, it will be more clearly understood how the very large amount of IDM data trends according to MCP on the basis of determined hours. After the sensitivity of the prices of these time zones, which are determined as candidates for possible arbitrage opportunities, to the generation forecasts of wind power plants in the market, is determined by the regression model, arbitrage strategies will be presented for the time zones determined according to the increase or decrease in wind forecasts.

The study may seem confusing to someone who is not familiar with electricity markets, as it consists of several stages and the result of each stage is an inference for the next. For the sake of clarity, we can state that the analysis part of the study is handled in 4 separate stages and list these stages as follows.

As a first stage, the yearly weighted average price of all categories classified according to transaction time in IDM, including MCP, is listed and the categories where the price is low or high are determined. The prices of the categories for each 24 different hour zones are considered from 2016 to 2022, and a specific routine for arbitrage is tried to be achieved. Buying opportunities will be evaluated in categories where the weighted average price is clearly and unremittently low, and selling opportunities will be evaluated in categories where the price is unremittently high. In the second stage, boxplot analysis will be carried out with the identified trade segments. This stage not only confirms the determined segments, but also is considered valuable in terms of explaining the size and distribution of the data to the reader. In the third step, how much the changing wind forecast during the transition from DAM to IDM affects the price will be examined in a regression model in which all data is included, and this average coefficient calculated between wind and price will be taken as a reference. In the last step, the potential arbitrage slices determined in the first step will be included in the same regression model and the effect of the changing wind in these slices on the price will be examined. In this study, where the increase and decrease in the wind will be evaluated separately, the coefficients determined in these arbitrage slices will be compared with the average coefficient in the third step, and the arbitrage strategy will be determined according to the change in the wind.

Before moving on to the main analysis of the study, which and how data is collected, how these data should be read and analyzed, and the reliability of the data will be discussed.

3.1 Data Collection

In Turkish IDM, bids are divided into hourly and block, and the bidding procedure and strategy of both are different from each other. For this reason, a large data set was prepared with all matching hourly offers in Turkey IDM, excluding block offers, in order to elaborate the study and increase clarity. The density of this 7-year data, which was gathered from the beginning of 2016, when the IDM market began, to the end of 2022, varies considerably over time. With the increase in activity in IDM, the data density, which has increased from year to year, has reached significant amounts in recent years, and a more consistent and statistical environment

has been provided in terms of sample size in order to analyze prices and actor behaviors in IDM. The matched hourly bid data includes the match-specific IDM price, the amount of the match, the datetime the match took place, and the hour for which the match was made. Each match in IDM is integrated with the MCP of the related hour in order to observe the relationship between the price in DAM and IDM prices and possible arbitrage opportunities. In addition to these, in the electricity market where the Turkish Lira is valid, USD-based prices were implemented throughout the study in order to be free from the effects of the exchange rate fluctuations and to make comparisons easier.

The wind-based DAM generation plan required for the regression analysis was provided from the forecasts of the private company with the highest market penetration. Since actual DAM generation plans have not been officially published, these data as of October 2020 have been used assuming that they are the closest data to represent the wind generation plan. Additionally, EXIST Transparency Platform was used for the post-IDM wind generation plan required for analysis. This data is created with the most current generation plan before moving to the balancing market for the relevant generation source. Since wind power plants are not included in the balancing market, this data is updated with the revised wind forecasts after DAM.

3.1.1 Data collection instruments. The transaction-based data collected in IDM and the hourly MCP data are obtained from the Transparency platform, where EXIST keeps market data. These data were taken from the first hand as primary data, directly analyzed and interpreted. In addition, the USD/TRY exchange rate data was obtained from the Electronic Data Distribution System of the Central Bank of the Republic of Turkey. All data collected are quantitative data and will be interpreted statistically.

In order to establish the relationship for regression, the change in wind forecasts was used for the independent variable, and subtraction of MCP from IDM price was used for the dependent variable to be explained. The change in wind forecasts is based on the changing generation plans of wind power plants when switching from DAM to IDM. For this reason, the desired value to be achieved by subtracting the generation plan in DAM from the generation plan after IDM will be the change amount in wind forecasts. However, since TETC publishes the DAM generation plan by constantly updating it, we only have the Settlement Based Final

Generation Plan (SBFGP) as official data, which shows the position after IDM. In this context, in order to see the DAM generation plan, the wind generation forecasts of a private company with the largest market share among the wind generators in Turkey were taken as a source. This data, which we will refer to as DAM Forecast (DAMF), is subtracted from SBFGP and creates the independent variable data of the univariate regression model.

3.1.2 Data collection procedures. Each matched transaction in IDM flows to the Transparency Platform and each match contains two separate datetime data. The first is the data of what time the match will take place, and the second is the data about what time the trade will be made, which forms the main lines of this study.

The trade hour is embedded in the contract number, while the match time is given directly for each line. In addition, the type of match is distinguished by the use of letters in the contract numbers. If the data with "B" (block) at the beginning of the contract number is eliminated, only the data containing "H" (hourly) remains. Also, the numbers at the end of the contract number also imply the trading hour. When this part is extracted, all hourly transactions in IDM are ready to be interpreted in such a way that both the matching hours and the trading hours are clear. In the Introduction section, the chronological functioning of the markets was mentioned. From 6 pm onwards, IDM trading starts for each 24 hours of the following day and 1 hour before the relevant trading hour, IDM trading for that hour will be closed. For this reason, there is no need to be stuck with the increase/decrease in MCP and IDM prices for arbitrage opportunity, but also market actors can become buyers or sellers at any time until the door is closed in IDM. By this means, the arbitrage opportunity is not limited to the DAM, but spread over the entire IDM period. In order to better analyze the trading process in IDM, to distinguish its characteristics and to suggest strategic decisions to the actors, the IDM trading period is divided into 7 separate sections. The time remaining between the trade hour and the match hour in IDM was calculated for each match and the related classification was made. This time is calculated in minutes, and the each match is placed in one of the categories "90 - 60", "120 - 90", "180 - 120", "240 - 180", "360 - 240", "480 - 360" and "> 480 min". For example, a matching transaction at 04:47 pm for 8:00-9:00 pm trading time on IDM will be in the "240 - 180" group because the distance from the trading time is 193 minutes. The first group have to start at 60 minutes as the match can take place 60

minutes before at the earliest in IDM. Similarly, the matched transaction for more than 8 hours will be in the last category.

Before examining how to analyze this classified data, it was found useful to make a comparison analysis by showing the amount of transactions in both spot markets, the average prices and the distribution of the matches. It would be unhealthy to make an analysis or inference without knowing these trends in general terms.

3.1.3 Data analysis procedures. The matching amount in IDM, which was 0.84 TWh in 2016 when IDM was implemented, has achieved a remarkable growth by reaching 17.6 TWh at the end of 2022 with an annual average increase of 66%.

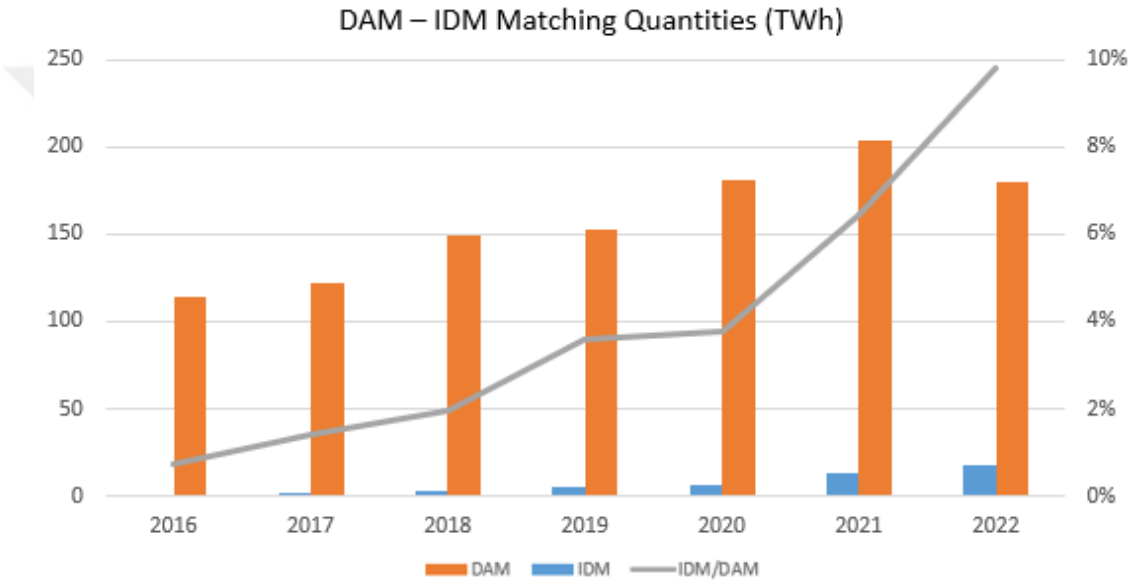

Figure 8. DAM vs IDM Matching Quantities

In the Figure 8 above, the match amount in Day Ahead and Intraday Markets (left axis) and the ratio of match amount in IDM to DAM (right axis) are shown. While the rate of IDM amount in DAM was not even 1% in 2016, this rate increased to 9.8% at the end of 2022. Unlike DAM, which did not increase or even decrease in quantities in some years, an increase was observed in IDM quantities on each year.

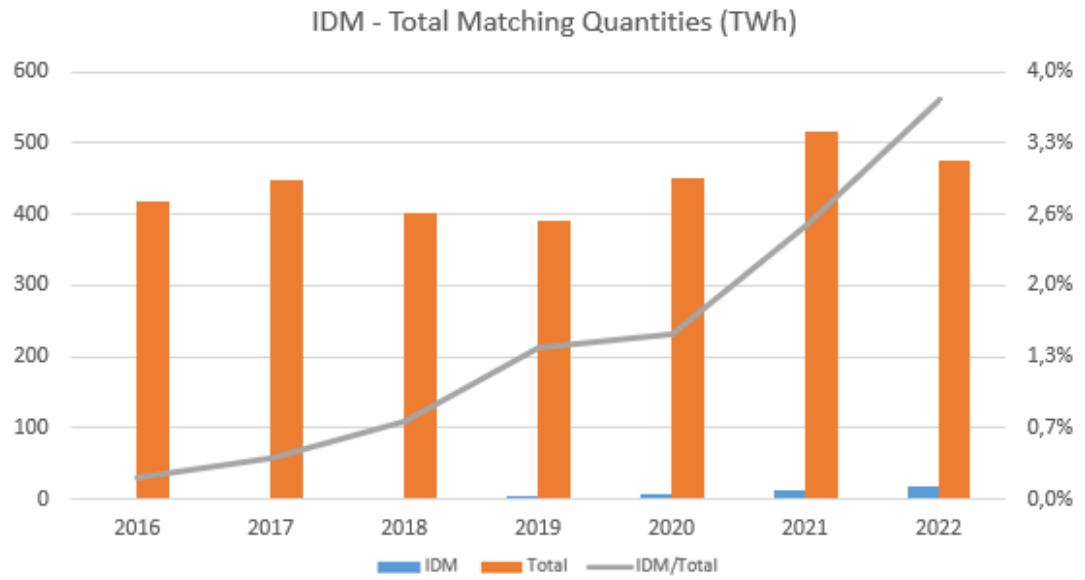

Figure 9. IDM vs Total Matching Quantities

Similarly, when we compare the total buying/selling amounts in the sector with IDM, it is possible to see the proportional growth in IDM here as well. In addition to DAM and IDM, it is possible to see stagnations and regressions in the total matching amount, most of which is composed of BAs. If we detect similar trends in both graphs, the periods of quantitative decline coincide with the crisis and Covid-19 periods. When we look at the past electricity use and the course of the industry, it can be inferred that the general economic trend and therefore the liquidity of the markets are more effective in this decline than concepts such as electricity consumption or sectoral growth.

We can say that the reason why IDM is able to distinguish itself from all these negative conditions is that this market is more up-to-date than other alternatives, and therefore it can maintain a certain growth and expansion trend. In addition, we can say that this is one of the reasons why the sector has positioned this "intermediate market" as a serious "need" besides being a different trade alternative, and not being affected by the negative economic course.

There are 2 different offer types for IDM. Since this study will be done only with hourly offer types and not block affers, it is necessary to consider the ratio of hourly bids to the total amount. It is critical for us that the hourly offers are not small in number for the consistency of the results of the study. Looking from 2019, when IDM was used most intensively, to the end of 2022, the share of hourly matched amounts in IDM in all matches was around 60.5%. From this point of view, it is

thought that there is a considerable amount of hourly offers in IDM, and considering the work in this framework will not only increase the clarity of the work, but also reflect the IDM characteristic in an unbiased manner.

One of the most important statistics of this study will be the relationship between MCP, which is the price in DAM, and prices in IDM. Contrary to the setup in DAM, since the price of each match is different in IDM, annual averages and weighted averages will be determined at this point and the relationship between the two prices will be examined.

The Table 2 is based on matching hourly offers for each hour in IDM (block offers are excluded) and MCP prices in DAM for the relevant year. The arithmetic average prices are the average of all matches in the relevant year and are the same as the number of hours per year for the MCP. When calculating the weighted average, the annual weighted average for both DAM and IDM with the match amounts in IDM is taken. The use of match amounts in IDM for the Weighted Average MCP is due to the importance of weighting both price data with the same hourly values and market expectations. In this way, both price data would be weighted unbiased and the preferences in the DAM would not be included in the calculation, which is an important point for this study. Since the purpose of use and preference reasons of these two spot markets are different in the sectoral approach, the matching characteristic to be taken into account for IDM arbitrage, which is the subject of this study, should be established over IDM matches.

Table 2

Average and Weighted Average Prices in Spot Markets

Year	IDM Average Price	Average MCP	IDM Weighted Av. Price	Weighted Av. MCP
2016	$54,57	$46,33	$54,31	$54,83
2017	$45,72	$45,01	$46,98	$46,91
2018	$47,69	$47,43	$47,72	$47,86
2019	$47,04	$46,00	$46,59	$46,72
2020	$40,40	$40,09	$40,48	$40,57
2021	$58,38	$55,60	$61,01	$61,18
2022	$146,07	$147,41	$146,60	$146,89

When the table is examined a little more, it can be deduced that more than is promised at first glance. The data in each of the 4 columns are numbered from 1 to 4, respectively. Since any match in IDM can be with a very small amount, the first

column does not say much on its own, but the main reason why it is higher than the second column in general is that less transactions are made in IDM during the hours that are thought to be priced low, and sometimes even not. This confirms that IDM is an intermediate market and, in essence, a market offering alternative trading opportunities to DAM. The fact that the weighted data (columns 3 and 4) are higher than the averages (columns 1 and 2) indicates that the frequency and amount of transactions in IDM are concentrated in high-priced hours. Another takeaway is; The fact that the 3rd and 4th columns are so close to each other (even slightly higher in favor of MCP) signals that the prices in the markets are not much surprising and that the price of any hour will be priced more or less similarly in IDM after the MCP is released. This situation may create the idea that there is not much opportunity in the profitability of the market, which offers additional trading "opportunity" in the eyes of the market participant. This situation, which constitutes a positive opinion in terms of the predictability of the market, also supports the fact that MCP is a reference price for the entire sector. In all this framework, it should be known that while evaluating arbitrage opportunities in IDM, market participants should act systematically and that these "opportunities" mature only under certain conditions. In this study, the conditions that need to mature for IDM arbitrage will be determined.

3.1.4 Reliability and validity. Since the data is extracted first hand from the market operator's platform, its reliability or accuracy cannot be doubted. However, since the data in question is not suitable for analysis or interpretation in its raw form and has been subjected to many filters, classifications and weights, the results must be confirmed from different sources. The large volume of data not only makes processing difficult, but also increases the importance of confirmation.

Since hourly matches are filtered from the raw data, the possibility of lost or deleted data is checked in this manner. In EXIST's annual bulletins, the total amount of matches for IDM and the ratio of hourly matches to block matches are given, and the annual hourly matched amount is calculated using these data. All data processed from 2016 to 2022 are exactly the same as the values calculated from these bulletins (EPİAŞ, 2016; 2017; 2018; 2019; 2020; 2021; 2022).

Besides to this confirmation, data was checked for possible loss or deletion while classifying them into each category. Ultimately, the match amount of data in all categories in each year corresponds exactly to the total match amount of each

year.

3.2 Universe and Participants/Working Group

The amount of transactions in the electricity spot markets in Turkey and the prices formed in these markets constitute the universe of this study.

3.3 Research Design

The initial analysis of the study focused on whether there were any routine arbitrage opportunities within the framework of market dynamics during the IDM trading period by looking at historical data and if there is a routine arbitrage opportunity, the increase potential of these arbitrage opportunities will be evaluated as the expectations in wind generation change. It will be investigated how the change in wind forecast during the period from DAM to IDM, which is the time when arbitrage trading will be carried out, affects the price during the same period. Each IDM category whose arbitrage opportunity (both buying and selling) is deemed worthy of evaluation will be examined separately, and arbitrage potentials based on wind change will be concluded separately.

In order to capture this possible routine, each 24 trading hours is considered separately. The average prices in the 7 previously mentioned IDM trading groups plus the average MCP value are shown on an annual basis. The values on the left are the arithmetic mean of all matches based on the relevant year and category, excluding the volume effect. The values on the right show the annual weighted averages that are weighted categorically. The cumulative sum of these 3 years has been calculated so that the matching amounts in 2016, 2017 and 2018 are lower than in other years and the sample sizes can be closer to the data of other years. Each trading hour is placed horizontally over the years so that the chart can be read, interpreted and a strategy can be developed.

Table 3

MCP and IDM Price Fluctuation in the First 6 Hours of the Day

2016 - 2017 - 2018		
0		
MCP	$ 47,77	$ 48,27
>480 min	-	-
480-360	$ 52,24	$ 52,53
360-240	$ 48,15	$ 48,50
240-180	$ 47,43	$ 48,06
180-120	$ 47,10	$ 47,72
120-90	$ 45,96	$ 46,17
90-60	$ 52,81	$ 52,77

2019		
0		
MCP	$ 42,02	$ 41,57
>480 min	-	-
480-360	$ 29,89	$ 25,36
360-240	$ 41,29	$ 41,86
240-180	$ 40,87	$ 41,51
180-120	$ 41,50	$ 41,33
120-90	$ 40,99	$ 41,33
90-60	$ 41,90	$ 40,49

2020		
0		
MCP	$ 38,49	$ 37,70
>480 min	-	-
480-360	$ 20,67	$ 34,48
360-240	$ 37,58	$ 36,07
240-180	$ 37,90	$ 36,72
180-120	$ 37,71	$ 37,25
120-90	$ 38,36	$ 37,78
90-60	$ 37,99	$ 37,79

2021		
0		
MCP	$ 55,33	$ 59,09
>480 min	-	-
480-360	$ 71,52	$ 74,87
360-240	$ 58,60	$ 62,15
240-180	$ 55,65	$ 58,45
180-120	$ 54,24	$ 57,50
120-90	$ 53,26	$ 57,01
90-60	$ 52,80	$ 54,49

2022		
0		
MCP	$ 151,61	$ 155,48
>480 min	-	-
480-360	$ 158,59	$ 147,87
360-240	$ 151,79	$ 144,91
240-180	$ 147,32	$ 140,88
180-120	$ 149,60	$ 142,21
120-90	$ 149,34	$ 144,04
90-60	$ 149,29	$ 146,90

2016 - 2017 - 2018		
1		
MCP	$ 44,08	$ 44,19
>480 min	-	-
480-360	$ 44,60	$ 43,43
360-240	$ 43,56	$ 44,06
240-180	$ 43,09	$ 43,65
180-120	$ 43,08	$ 43,64
120-90	$ 42,85	$ 42,66
90-60	$ 49,47	$ 49,66

2019		
1		
MCP	$ 45,47	$ 45,09
>480 min	-	-
480-360	$ 44,67	$ 45,10
360-240	$ 45,30	$ 45,59
240-180	$ 44,86	$ 44,94
180-120	$ 44,00	$ 42,93
120-90	$ 44,62	$ 44,46
90-60	$ 46,04	$ 45,52

2020		
1		
MCP	$ 42,04	$ 41,70
>480 min	-	-
480-360	$ 41,06	$ 39,53
360-240	$ 42,61	$ 42,61
240-180	$ 42,22	$ 41,75
180-120	$ 41,57	$ 40,91
120-90	$ 41,78	$ 41,57
90-60	$ 41,62	$ 41,73

2021		
1		
MCP	$ 56,17	$ 58,59
>480 min	-	-
480-360	$ 60,11	$ 61,07
360-240	$ 56,49	$ 60,36
240-180	$ 56,31	$ 58,59
180-120	$ 55,19	$ 57,07
120-90	$ 54,31	$ 56,14
90-60	$ 53,87	$ 54,66

2022		
1		
MCP	$ 134,13	$ 136,19
>480 min	-	-
480-360	$ 135,70	$ 135,50
360-240	$ 133,99	$ 132,04
240-180	$ 130,19	$ 125,07
180-120	$ 131,93	$ 125,85
120-90	$ 132,41	$ 128,65
90-60	$ 133,22	$ 129,00

2016 - 2017 - 2018		
2		
MCP	$ 39,32	$ 39,33
>480 min	-	-
480-360	$ 39,41	$ 39,59
360-240	$ 38,41	$ 38,39
240-180	$ 38,38	$ 38,67
180-120	$ 39,00	$ 39,06
120-90	$ 38,89	$ 38,79
90-60	$ 41,73	$ 41,48

2019		
2		
MCP	$ 42,86	$ 42,35
>480 min	-	-
480-360	$ 42,48	$ 42,68
360-240	$ 41,85	$ 42,40
240-180	$ 41,14	$ 41,09
180-120	$ 42,37	$ 41,41
120-90	$ 41,75	$ 41,51
90-60	$ 43,96	$ 42,76

2020		
2		
MCP	$ 37,60	$ 37,00
>480 min	-	-
480-360	$ 35,83	$ 35,10
360-240	$ 37,45	$ 36,96
240-180	$ 36,86	$ 36,81
180-120	$ 36,91	$ 36,31
120-90	$ 37,94	$ 37,46
90-60	$ 37,60	$ 37,64

2021		
2		
MCP	$ 49,66	$ 51,04
>480 min	-	-
480-360	$ 52,62	$ 53,02
360-240	$ 48,72	$ 51,21
240-180	$ 48,72	$ 49,61
180-120	$ 48,97	$ 49,77
120-90	$ 47,74	$ 48,18
90-60	$ 48,63	$ 49,24

2022		
2		
MCP	$ 121,07	$ 122,03
>480 min	-	-
480-360	$ 119,75	$ 120,49
360-240	$ 122,28	$ 122,68
240-180	$ 118,22	$ 115,12
180-120	$ 119,46	$ 114,28
120-90	$ 120,32	$ 116,43
90-60	$ 120,26	$ 116,11

2016 - 2017 - 2018		
3		
MCP	$ 36,79	$ 36,97
>480 min	$ 37,14	$ 36,05
480-360	$ 35,85	$ 36,99
360-240	$ 35,73	$ 36,85
240-180	$ 35,14	$ 34,70
180-120	$ 36,07	$ 36,18
120-90	$ 37,26	$ 37,27
90-60	$ 39,55	$ 38,53

2019		
3		
MCP	$ 37,28	$ 36,61
>480 min	$ 36,26	$ 37,86
480-360	$ 36,98	$ 37,05
360-240	$ 35,08	$ 35,32
240-180	$ 36,11	$ 35,44
180-120	$ 36,91	$ 35,28
120-90	$ 36,81	$ 35,37
90-60	$ 38,68	$ 37,87

2020		
3		
MCP	$ 34,87	$ 34,37
>480 min	$ 32,79	$ 32,72
480-360	$ 34,36	$ 34,79
360-240	$ 33,95	$ 33,74
240-180	$ 34,09	$ 33,52
180-120	$ 34,83	$ 35,48
120-90	$ 34,41	$ 32,73
90-60	$ 35,00	$ 34,67

2021		
3		
MCP	$ 47,64	$ 48,69
>480 min	$ 51,64	$ 51,03
480-360	$ 48,45	$ 48,02
360-240	$ 46,54	$ 48,60
240-180	$ 46,59	$ 46,19
180-120	$ 46,63	$ 47,34
120-90	$ 46,12	$ 46,27
90-60	$ 46,70	$ 47,41

2022		
3		
MCP	$ 118,60	$ 118,89
>480 min	$ 113,97	$ 111,94
480-360	$ 115,26	$ 124,92
360-240	$ 116,27	$ 115,98
240-180	$ 117,17	$ 113,69
180-120	$ 116,41	$ 114,72
120-90	$ 119,60	$ 116,99
90-60	$ 119,68	$ 119,04

2016 - 2017 - 2018		
4		
MCP	$ 35,11	$ 34,92
>480 min	$ 34,80	$ 33,80
480-360	$ 34,29	$ 34,99
360-240	$ 33,91	$ 33,41
240-180	$ 34,28	$ 34,57
180-120	$ 34,91	$ 35,38
120-90	$ 36,18	$ 35,83
90-60	$ 33,16	$ 31,65

2019		
4		
MCP	$ 34,72	$ 33,75
>480 min	$ 33,05	$ 33,46
480-360	$ 32,86	$ 33,68
360-240	$ 32,52	$ 32,01
240-180	$ 34,61	$ 33,02
180-120	$ 34,12	$ 33,98
120-90	$ 34,75	$ 33,25
90-60	$ 36,68	$ 35,38

2020		
4		
MCP	$ 33,45	$ 33,05
>480 min	$ 31,81	$ 31,41
480-360	$ 32,87	$ 32,91
360-240	$ 32,52	$ 32,45
240-180	$ 32,83	$ 33,13
180-120	$ 32,28	$ 32,31
120-90	$ 34,36	$ 34,10
90-60	$ 33,08	$ 32,75

2021		
4		
MCP	$ 46,56	$ 47,64
>480 min	$ 48,80	$ 48,97
480-360	$ 47,21	$ 49,58
360-240	$ 44,80	$ 46,17
240-180	$ 45,86	$ 46,39
180-120	$ 45,81	$ 45,42
120-90	$ 45,63	$ 46,30
90-60	$ 45,49	$ 45,92

2022		
4		
MCP	$ 117,65	$ 116,43
>480 min	$ 113,24	$ 110,36
480-360	$ 116,18	$ 121,66
360-240	$ 116,38	$ 113,42
240-180	$ 116,22	$ 112,71
180-120	$ 117,26	$ 115,28
120-90	$ 118,40	$ 119,78
90-60	$ 117,65	$ 114,32

2016 - 2017 - 2018		
5		
MCP	$ 36,60	$ 36,69
>480 min	$ 36,56	$ 36,86
480-360	$ 35,39	$ 35,90
360-240	$ 35,08	$ 34,97
240-180	$ 35,40	$ 34,84
180-120	$ 35,50	$ 34,49
120-90	$ 37,51	$ 37,46
90-60	$ 41,54	$ 41,94

2019		
5		
MCP	$ 34,63	$ 33,88
>480 min	$ 33,92	$ 34,80
480-360	$ 32,73	$ 33,79
360-240	$ 33,36	$ 33,12
240-180	$ 31,38	$ 29,62
180-120	$ 34,34	$ 32,92
120-90	$ 35,43	$ 34,35
90-60	$ 35,96	$ 34,22

2020		
5		
MCP	$ 32,04	$ 31,64
>480 min	$ 30,83	$ 30,33
480-360	$ 31,25	$ 31,03
360-240	$ 31,51	$ 31,71
240-180	$ 30,35	$ 30,46
180-120	$ 30,82	$ 30,33
120-90	$ 32,35	$ 32,52
90-60	$ 32,19	$ 31,93

2021		
5		
MCP	$ 46,49	$ 46,70
>480 min	$ 48,30	$ 47,97
480-360	$ 45,22	$ 45,41
360-240	$ 45,28	$ 44,79
240-180	$ 44,91	$ 43,55
180-120	$ 44,82	$ 44,76
120-90	$ 45,45	$ 45,77
90-60	$ 45,68	$ 46,06

2022		
5		
MCP	$ 119,06	$ 117,84
>480 min	$ 115,69	$ 113,27
480-360	$ 116,36	$ 116,89
360-240	$ 116,90	$ 114,19
240-180	$ 116,85	$ 107,69
180-120	$ 119,61	$ 114,27
120-90	$ 119,00	$ 116,06
90-60	$ 119,95	$ 115,56

Table 4

MCP and IDM Price Fluctuation in the Second 6 Hours of the Day

2016 - 2017 - 2018		
6		
MCP	$ 38,53	$ 38,84
>480 min	$ 38,61	$ 39,50
480-360	$ 37,04	$ 37,68
360-240	$ 37,47	$ 37,34
240-180	$ 36,89	$ 37,58
180-120	$ 37,08	$ 37,35
120-90	$ 38,06	$ 37,88
90-60	$ 47,27	$ 46,82

2019		
6		
MCP	$ 36,68	$ 35,88
>480 min	$ 35,87	$ 36,74
480-360	$ 35,62	$ 36,65
360-240	$ 34,11	$ 30,87
240-180	$ 35,03	$ 35,80
180-120	$ 35,61	$ 35,22
120-90	$ 37,44	$ 35,74
90-60	$ 37,92	$ 36,31

2020		
6		
MCP	$ 31,33	$ 30,76
>480 min	$ 30,60	$ 30,40
480-360	$ 30,45	$ 30,03
360-240	$ 30,47	$ 29,97
240-180	$ 29,16	$ 29,08
180-120	$ 30,23	$ 30,86
120-90	$ 31,76	$ 30,54
90-60	$ 31,55	$ 31,21

2021		
6		
MCP	$ 46,89	$ 46,56
>480 min	$ 48,02	$ 46,97
480-360	$ 45,85	$ 45,03
360-240	$ 44,99	$ 45,54
240-180	$ 45,58	$ 45,35
180-120	$ 46,31	$ 45,05
120-90	$ 45,28	$ 44,58
90-60	$ 46,56	$ 46,70

2022		
6		
MCP	$ 117,63	$ 117,80
>480 min	$ 116,59	$ 116,89
480-360	$ 115,86	$ 119,17
360-240	$ 114,58	$ 98,49
240-180	$ 116,17	$ 104,49
180-120	$ 116,96	$ 100,93
120-90	$ 115,64	$ 102,73
90-60	$ 117,25	$ 110,61

2016 - 2017 - 2018		
7		
MCP	$ 42,00	$ 41,27
>480 min	$ 41,55	$ 40,98
480-360	$ 40,64	$ 39,38
360-240	$ 40,37	$ 39,52
240-180	$ 41,02	$ 42,03
180-120	$ 41,08	$ 40,82
120-90	$ 41,96	$ 42,22
90-60	$ 47,92	$ 47,69

2019		
7		
MCP	$ 42,41	$ 40,97
>480 min	$ 41,22	$ 41,98
480-360	$ 40,95	$ 38,51
360-240	$ 40,49	$ 39,03
240-180	$ 40,48	$ 37,58
180-120	$ 41,51	$ 38,95
120-90	$ 41,78	$ 40,45
90-60	$ 44,10	$ 42,43

2020		
7		
MCP	$ 33,46	$ 32,63
>480 min	$ 32,56	$ 32,02
480-360	$ 32,77	$ 32,34
360-240	$ 32,16	$ 31,19
240-180	$ 30,56	$ 30,97
180-120	$ 31,63	$ 31,79
120-90	$ 34,07	$ 33,59
90-60	$ 34,06	$ 33,38

2021		
7		
MCP	$ 48,22	$ 48,76
>480 min	$ 48,92	$ 49,66
480-360	$ 47,53	$ 47,83
360-240	$ 46,28	$ 45,01
240-180	$ 46,84	$ 46,78
180-120	$ 47,89	$ 45,74
120-90	$ 46,96	$ 47,21
90-60	$ 46,44	$ 47,15

2022		
7		
MCP	$ 120,48	$ 121,46
>480 min	$ 119,58	$ 122,34
480-360	$ 119,68	$ 121,45
360-240	$ 117,23	$ 99,19
240-180	$ 123,45	$ 99,76
180-120	$ 117,30	$ 101,55
120-90	$ 121,99	$ 103,44
90-60	$ 118,82	$ 110,52

2016 - 2017 - 2018		
8		
MCP	$ 47,76	$ 46,91
>480 min	$ 47,30	$ 46,08
480-360	$ 46,23	$ 46,37
360-240	$ 45,21	$ 43,39
240-180	$ 46,67	$ 46,99
180-120	$ 47,37	$ 47,04
120-90	$ 47,71	$ 47,79
90-60	$ 53,44	$ 53,92

2019		
8		
MCP	$ 47,91	$ 45,27
>480 min	$ 47,31	$ 45,54
480-360	$ 45,97	$ 43,36
360-240	$ 45,18	$ 38,50
240-180	$ 47,16	$ 40,68
180-120	$ 48,13	$ 44,85
120-90	$ 48,59	$ 46,56
90-60	$ 48,61	$ 47,98

2020		
8		
MCP	$ 39,73	$ 38,54
>480 min	$ 38,82	$ 37,10
480-360	$ 39,09	$ 37,71
360-240	$ 38,20	$ 37,74
240-180	$ 38,11	$ 37,83
180-120	$ 39,14	$ 37,73
120-90	$ 40,45	$ 40,42
90-60	$ 40,23	$ 40,19

2021		
8		
MCP	$ 59,76	$ 62,97
>480 min	$ 63,33	$ 65,74
480-360	$ 58,06	$ 60,45
360-240	$ 56,96	$ 61,62
240-180	$ 63,87	$ 61,33
180-120	$ 60,46	$ 63,14
120-90	$ 56,23	$ 55,88
90-60	$ 55,70	$ 57,30

2022		
8		
MCP	$ 152,94	$ 155,95
>480 min	$ 156,94	$ 157,58
480-360	$ 154,99	$ 160,81
360-240	$ 143,42	$ 120,25
240-180	$ 140,89	$ 121,37
180-120	$ 146,52	$ 121,61
120-90	$ 149,17	$ 129,66
90-60	$ 155,79	$ 141,17

2016 - 2017 - 2018		
9		
MCP	$ 52,29	$ 51,81
>480 min	$ 51,90	$ 51,06
480-360	$ 49,53	$ 48,42
360-240	$ 49,36	$ 49,04
240-180	$ 51,37	$ 49,56
180-120	$ 52,50	$ 53,30
120-90	$ 51,73	$ 52,48
90-60	$ 56,43	$ 55,02

2019		
9		
MCP	$ 46,58	$ 43,47
>480 min	$ 44,96	$ 41,68
480-360	$ 42,67	$ 37,45
360-240	$ 44,21	$ 39,33
240-180	$ 43,95	$ 38,50
180-120	$ 47,55	$ 44,24
120-90	$ 47,16	$ 46,52
90-60	$ 47,94	$ 46,36

2020		
9		
MCP	$ 36,70	$ 34,64
>480 min	$ 34,92	$ 32,75
480-360	$ 35,07	$ 32,72
360-240	$ 31,42	$ 28,02
240-180	$ 35,82	$ 33,13
180-120	$ 37,16	$ 37,68
120-90	$ 37,89	$ 36,91
90-60	$ 37,70	$ 36,61

2021		
9		
MCP	$ 59,94	$ 63,49
>480 min	$ 63,49	$ 66,88
480-360	$ 60,01	$ 61,58
360-240	$ 59,96	$ 58,12
240-180	$ 60,15	$ 59,94
180-120	$ 57,42	$ 58,67
120-90	$ 58,92	$ 60,87
90-60	$ 56,84	$ 58,10

2022		
9		
MCP	$ 155,47	$ 157,98
>480 min	$ 157,81	$ 157,06
480-360	$ 150,76	$ 161,56
360-240	$ 141,68	$ 123,77
240-180	$ 152,43	$ 126,03
180-120	$ 156,25	$ 139,44
120-90	$ 155,61	$ 135,78
90-60	$ 156,56	$ 146,14

2016 - 2017 - 2018		
10		
MCP	$ 53,09	$ 53,13
>480 min	$ 52,72	$ 52,12
480-360	$ 50,06	$ 50,63
360-240	$ 50,94	$ 45,52
240-180	$ 51,34	$ 48,27
180-120	$ 53,32	$ 55,37
120-90	$ 52,24	$ 52,87
90-60	$ 56,30	$ 56,32

2019		
10		
MCP	$ 49,42	$ 48,28
>480 min	$ 47,00	$ 45,64
480-360	$ 44,40	$ 36,05
360-240	$ 47,84	$ 41,83
240-180	$ 49,20	$ 47,90
180-120	$ 49,15	$ 47,98
120-90	$ 50,19	$ 50,53
90-60	$ 50,14	$ 49,98

2020		
10		
MCP	$ 39,15	$ 38,01
>480 min	$ 36,08	$ 34,28
480-360	$ 34,71	$ 31,76
360-240	$ 35,87	$ 33,18
240-180	$ 38,25	$ 39,38
180-120	$ 39,87	$ 38,78
120-90	$ 39,91	$ 39,90
90-60	$ 39,81	$ 39,85

2021		
10		
MCP	$ 60,67	$ 64,10
>480 min	$ 65,14	$ 69,23
480-360	$ 61,20	$ 63,76
360-240	$ 60,21	$ 59,64
240-180	$ 60,78	$ 61,19
180-120	$ 59,00	$ 60,50
120-90	$ 59,49	$ 60,98
90-60	$ 58,42	$ 59,32

2022		
10		
MCP	$ 151,22	$ 149,83
>480 min	$ 148,71	$ 146,39
480-360	$ 150,09	$ 153,82
360-240	$ 136,26	$ 123,34
240-180	$ 148,61	$ 133,69
180-120	$ 150,70	$ 131,93
120-90	$ 152,03	$ 135,59
90-60	$ 153,97	$ 140,20

2016 - 2017 - 2018		
11		
MCP	$ 54,64	$ 55,44
>480 min	$ 54,22	$ 53,88
480-360	$ 51,58	$ 49,03
360-240	$ 52,35	$ 51,61
240-180	$ 54,17	$ 56,57
180-120	$ 55,02	$ 56,69
120-90	$ 53,99	$ 55,29
90-60	$ 57,05	$ 57,26

2019		
11		
MCP	$ 51,27	$ 49,96
>480 min	$ 48,90	$ 47,27
480-360	$ 47,50	$ 41,55
360-240	$ 49,75	$ 47,54
240-180	$ 50,86	$ 49,09
180-120	$ 52,16	$ 52,55
120-90	$ 51,26	$ 49,55
90-60	$ 51,76	$ 50,93

2020		
11		
MCP	$ 40,99	$ 40,18
>480 min	$ 38,30	$ 36,80
480-360	$ 36,07	$ 35,62
360-240	$ 38,48	$ 39,30
240-180	$ 41,17	$ 40,18
180-120	$ 41,52	$ 41,71
120-90	$ 41,59	$ 41,30
90-60	$ 41,30	$ 40,75

2021		
11		
MCP	$ 61,43	$ 63,67
>480 min	$ 66,15	$ 69,65
480-360	$ 64,01	$ 65,81
360-240	$ 60,93	$ 62,31
240-180	$ 61,39	$ 60,78
180-120	$ 60,53	$ 62,17
120-90	$ 60,26	$ 61,70
90-60	$ 60,16	$ 59,40

2022		
11		
MCP	$ 149,14	$ 146,34
>480 min	$ 143,11	$ 138,97
480-360	$ 143,71	$ 148,50
360-240	$ 142,74	$ 127,98
240-180	$ 149,94	$ 133,24
180-120	$ 150,04	$ 134,15
120-90	$ 149,67	$ 136,13
90-60	$ 152,33	$ 141,11

Table 5

MCP and IDM Price Fluctuation in the Third 6 Hours of the Day

2016 - 2017 - 2018		
12		
MCP	$ 49,27	$ 49,94
>480 min	$ 48,04	$ 46,57
480-360	$ 46,19	$ 43,46
360-240	$ 47,33	$ 48,60
240-180	$ 49,27	$ 50,61
180-120	$ 49,84	$ 50,85
120-90	$ 48,50	$ 50,14
90-60	$ 54,20	$ 54,10

2019		
12		
MCP	$ 44,71	$ 43,18
>480 min	$ 41,63	$ 40,22
480-360	$ 44,06	$ 39,08
360-240	$ 44,31	$ 42,12
240-180	$ 44,65	$ 43,87
180-120	$ 44,57	$ 43,12
120-90	$ 44,62	$ 43,14
90-60	$ 45,82	$ 44,93

2020		
12		
MCP	$ 37,10	$ 36,25
>480 min	$ 33,74	$ 32,09
480-360	$ 35,25	$ 33,47
360-240	$ 36,45	$ 35,29
240-180	$ 37,85	$ 37,03
180-120	$ 37,47	$ 36,85
120-90	$ 38,07	$ 38,28
90-60	$ 37,31	$ 37,09

2021		
12		
MCP	$ 52,56	$ 55,23
>480 min	$ 57,18	$ 61,28
480-360	$ 53,14	$ 55,58
360-240	$ 53,64	$ 56,98
240-180	$ 52,84	$ 54,53
180-120	$ 52,22	$ 53,68
120-90	$ 50,84	$ 51,95
90-60	$ 51,72	$ 52,44

2022		
12		
MCP	$ 122,26	$ 120,91
>480 min	$ 116,97	$ 114,93
480-360	$ 113,91	$ 122,21
360-240	$ 120,11	$ 113,00
240-180	$ 122,34	$ 113,64
180-120	$ 122,56	$ 111,74
120-90	$ 122,43	$ 114,49
90-60	$ 122,11	$ 114,50

2016 - 2017 - 2018		
13		
MCP	$ 51,10	$ 51,92
>480 min	$ 49,94	$ 48,52
480-360	$ 49,73	$ 50,33
360-240	$ 50,48	$ 52,25
240-180	$ 51,23	$ 52,47
180-120	$ 51,21	$ 52,64
120-90	$ 50,35	$ 52,17
90-60	$ 56,22	$ 56,24

2019		
13		
MCP	$ 44,15	$ 42,32
>480 min	$ 40,94	$ 38,97
480-360	$ 42,91	$ 37,92
360-240	$ 43,96	$ 41,97
240-180	$ 43,65	$ 41,99
180-120	$ 43,70	$ 41,74
120-90	$ 44,55	$ 43,90
90-60	$ 45,23	$ 44,06

2020		
13		
MCP	$ 38,89	$ 38,35
>480 min	$ 35,66	$ 34,09
480-360	$ 38,55	$ 37,73
360-240	$ 39,42	$ 38,72
240-180	$ 39,29	$ 38,73
180-120	$ 38,91	$ 39,48
120-90	$ 39,41	$ 38,99
90-60	$ 39,20	$ 39,22

2021		
13		
MCP	$ 54,38	$ 56,94
>480 min	$ 59,59	$ 64,05
480-360	$ 55,94	$ 58,00
360-240	$ 55,21	$ 57,01
240-180	$ 54,83	$ 55,95
180-120	$ 53,24	$ 54,63
120-90	$ 52,89	$ 54,37
90-60	$ 53,23	$ 53,59

2022		
13		
MCP	$ 133,10	$ 131,73
>480 min	$ 126,38	$ 123,58
480-360	$ 126,15	$ 129,91
360-240	$ 132,95	$ 124,54
240-180	$ 132,96	$ 118,70
180-120	$ 133,31	$ 121,29
120-90	$ 130,28	$ 119,00
90-60	$ 133,21	$ 124,63

2016 - 2017 - 2018		
14		
MCP	$ 53,93	$ 54,36
>480 min	$ 51,97	$ 50,67
480-360	$ 51,54	$ 49,76
360-240	$ 53,99	$ 55,37
240-180	$ 53,66	$ 54,65
180-120	$ 53,93	$ 54,37
120-90	$ 52,78	$ 53,63
90-60	$ 56,95	$ 56,52

2019		
14		
MCP	$ 48,32	$ 47,20
>480 min	$ 45,35	$ 43,45
480-360	$ 47,74	$ 43,73
360-240	$ 48,65	$ 47,39
240-180	$ 47,50	$ 45,70
180-120	$ 48,65	$ 48,64
120-90	$ 48,08	$ 47,85
90-60	$ 48,87	$ 48,31

2020		
14		
MCP	$ 41,24	$ 40,89
>480 min	$ 38,34	$ 36,97
480-360	$ 40,71	$ 39,82
360-240	$ 41,94	$ 41,65
240-180	$ 41,27	$ 41,51
180-120	$ 41,55	$ 41,69
120-90	$ 41,46	$ 41,15
90-60	$ 41,22	$ 41,36

2021		
14		
MCP	$ 59,53	$ 61,23
>480 min	$ 65,00	$ 67,37
480-360	$ 62,12	$ 63,20
360-240	$ 61,35	$ 61,93
240-180	$ 59,58	$ 60,64
180-120	$ 58,51	$ 59,10
120-90	$ 57,50	$ 58,98
90-60	$ 57,66	$ 56,58

2022		
14		
MCP	$ 149,79	$ 148,03
>480 min	$ 143,22	$ 139,46
480-360	$ 146,17	$ 159,56
360-240	$ 152,62	$ 133,95
240-180	$ 149,15	$ 127,18
180-120	$ 149,31	$ 130,34
120-90	$ 150,63	$ 136,47
90-60	$ 149,63	$ 138,06

2016 - 2017 - 2018		
15		
MCP	$ 52,24	$ 52,71
>480 min	$ 50,99	$ 48,47
480-360	$ 52,11	$ 53,72
360-240	$ 52,38	$ 53,29
240-180	$ 52,10	$ 52,99
180-120	$ 51,98	$ 53,32
120-90	$ 51,51	$ 52,35
90-60	$ 57,83	$ 58,20

2019		
15		
MCP	$ 47,26	$ 46,38
>480 min	$ 43,37	$ 41,25
480-360	$ 48,36	$ 47,20
360-240	$ 46,58	$ 45,00
240-180	$ 47,11	$ 47,34
180-120	$ 46,11	$ 45,39
120-90	$ 46,85	$ 46,88
90-60	$ 48,88	$ 49,23

2020		
15		
MCP	$ 41,27	$ 40,82
>480 min	$ 37,82	$ 36,04
480-360	$ 42,62	$ 42,56
360-240	$ 42,13	$ 41,74
240-180	$ 41,27	$ 41,55
180-120	$ 40,18	$ 40,45
120-90	$ 42,11	$ 42,08
90-60	$ 41,41	$ 41,52

2021		
15		
MCP	$ 60,73	$ 62,13
>480 min	$ 66,22	$ 67,84
480-360	$ 62,74	$ 64,11
360-240	$ 61,78	$ 62,71
240-180	$ 60,47	$ 60,59
180-120	$ 57,94	$ 58,03
120-90	$ 58,44	$ 58,18
90-60	$ 59,51	$ 59,20

2022		
15		
MCP	$ 151,97	$ 150,43
>480 min	$ 145,42	$ 143,41
480-360	$ 155,48	$ 165,12
360-240	$ 154,44	$ 131,13
240-180	$ 150,79	$ 127,24
180-120	$ 148,82	$ 130,87
120-90	$ 148,81	$ 128,93
90-60	$ 154,29	$ 141,82

2016 - 2017 - 2018		
16		
MCP	$ 51,92	$ 52,56
>480 min	$ 50,34	$ 49,51
480-360	$ 52,43	$ 53,86
360-240	$ 51,78	$ 52,41
240-180	$ 50,94	$ 52,37
180-120	$ 52,37	$ 53,30
120-90	$ 50,94	$ 51,59
90-60	$ 57,73	$ 57,64

2019		
16		
MCP	$ 48,86	$ 48,28
>480 min	$ 45,76	$ 44,26
480-360	$ 49,13	$ 48,53
360-240	$ 48,16	$ 47,24
240-180	$ 47,10	$ 46,25
180-120	$ 48,87	$ 49,10
120-90	$ 48,89	$ 49,81
90-60	$ 50,04	$ 50,14

2020		
16		
MCP	$ 42,65	$ 42,79
>480 min	$ 39,86	$ 38,84
480-360	$ 44,62	$ 45,44
360-240	$ 43,16	$ 43,55
240-180	$ 41,34	$ 42,09
180-120	$ 42,25	$ 42,79
120-90	$ 43,04	$ 43,23
90-60	$ 42,96	$ 43,31

2021		
16		
MCP	$ 61,48	$ 63,36
>480 min	$ 67,69	$ 70,56
480-360	$ 63,48	$ 64,21
360-240	$ 62,03	$ 62,87
240-180	$ 58,59	$ 59,21
180-120	$ 60,58	$ 60,66
120-90	$ 59,28	$ 59,56
90-60	$ 60,05	$ 59,87

2022		
16		
MCP	$ 160,20	$ 160,44
>480 min	$ 158,33	$ 160,79
480-360	$ 167,40	$ 177,05
360-240	$ 159,64	$ 130,96
240-180	$ 156,25	$ 126,74
180-120	$ 157,80	$ 133,15
120-90	$ 159,59	$ 135,22
90-60	$ 162,73	$ 145,72

2016 - 2017 - 2018		
17		
MCP	$ 50,49	$ 51,47
>480 min	$ 50,06	$ 51,15
480-360	$ 50,74	$ 51,34
360-240	$ 49,11	$ 49,84
240-180	$ 50,60	$ 52,74
180-120	$ 50,20	$ 51,19
120-90	$ 50,06	$ 51,46
90-60	$ 57,48	$ 57,43

2019		
17		
MCP	$ 51,44	$ 50,97
>480 min	$ 49,74	$ 48,25
480-360	$ 51,29	$ 51,13
360-240	$ 50,37	$ 50,38
240-180	$ 51,57	$ 52,12
180-120	$ 51,57	$ 51,36
120-90	$ 50,89	$ 50,34
90-60	$ 52,15	$ 51,95

2020		
17		
MCP	$ 44,63	$ 45,21
>480 min	$ 43,27	$ 43,42
480-360	$ 45,57	$ 45,42
360-240	$ 44,44	$ 45,98
240-180	$ 44,09	$ 45,25
180-120	$ 44,60	$ 45,74
120-90	$ 45,35	$ 45,85
90-60	$ 44,50	$ 45,04

2021		
17		
MCP	$ 65,93	$ 68,32
>480 min	$ 72,77	$ 75,59
480-360	$ 67,08	$ 67,16
360-240	$ 64,25	$ 66,24
240-180	$ 65,50	$ 66,12
180-120	$ 65,22	$ 66,28
120-90	$ 63,38	$ 65,01
90-60	$ 64,24	$ 64,30

2022		
17		
MCP	$ 165,86	$ 166,97
>480 min	$ 167,27	$ 169,41
480-360	$ 168,35	$ 173,67
360-240	$ 163,82	$ 138,21
240-180	$ 164,45	$ 135,83
180-120	$ 162,49	$ 136,61
120-90	$ 166,59	$ 143,73
90-60	$ 168,26	$ 151,53

Table 6

MCP and IDM Price Fluctuation in the Last 6 Hours of the Day

2016 - 2017 - 2018		
18		
MCP	$ 49,50	$ 50,19
>480 min	$ 49,11	$ 49,84
480-360	$ 49,18	$ 49,66
360-240	$ 48,59	$ 49,50
240-180	$ 48,89	$ 49,90
180-120	$ 49,34	$ 50,54
120-90	$ 49,10	$ 49,89
90-60	$ 57,15	$ 57,13

2019		
18		
MCP	$ 52,35	$ 51,83
>480 min	$ 51,43	$ 51,11
480-360	$ 51,72	$ 51,44
360-240	$ 52,17	$ 51,33
240-180	$ 51,78	$ 51,51
180-120	$ 52,28	$ 52,27
120-90	$ 52,32	$ 52,13
90-60	$ 52,71	$ 52,03

2020		
18		
MCP	$ 45,09	$ 45,42
>480 min	$ 44,63	$ 44,36
480-360	$ 45,27	$ 45,68
360-240	$ 45,24	$ 45,92
240-180	$ 45,25	$ 45,68
180-120	$ 45,18	$ 45,93
120-90	$ 45,30	$ 46,08
90-60	$ 44,79	$ 44,85

2021		
18		
MCP	$ 67,10	$ 69,54
>480 min	$ 73,20	$ 75,91
480-360	$ 68,63	$ 69,76
360-240	$ 66,58	$ 68,38
240-180	$ 67,04	$ 67,83
180-120	$ 66,04	$ 66,66
120-90	$ 64,68	$ 65,64
90-60	$ 64,58	$ 64,21

2022		
18		
MCP	$ 166,39	$ 165,57
>480 min	$ 168,05	$ 166,78
480-360	$ 167,50	$ 169,35
360-240	$ 165,00	$ 138,99
240-180	$ 162,21	$ 135,31
180-120	$ 166,84	$ 140,45
120-90	$ 164,53	$ 142,84
90-60	$ 169,22	$ 153,47

2016 - 2017 - 2018		
19		
MCP	$ 49,81	$ 50,22
>480 min	$ 49,65	$ 50,12
480-360	$ 49,50	$ 49,86
360-240	$ 49,37	$ 50,06
240-180	$ 49,58	$ 50,52
180-120	$ 49,19	$ 49,50
120-90	$ 49,58	$ 50,48
90-60	$ 55,99	$ 55,49

2019		
19		
MCP	$ 53,73	$ 53,23
>480 min	$ 53,20	$ 52,72
480-360	$ 53,18	$ 52,61
360-240	$ 53,48	$ 53,44
240-180	$ 53,43	$ 53,14
180-120	$ 53,89	$ 53,80
120-90	$ 53,65	$ 53,27
90-60	$ 53,74	$ 52,96

2020		
19		
MCP	$ 47,09	$ 47,60
>480 min	$ 47,02	$ 47,94
480-360	$ 46,91	$ 46,95
360-240	$ 47,19	$ 47,64
240-180	$ 47,30	$ 47,85
180-120	$ 46,96	$ 47,89
120-90	$ 46,99	$ 47,09
90-60	$ 46,75	$ 46,76

2021		
19		
MCP	$ 66,94	$ 69,20
>480 min	$ 71,80	$ 74,38
480-360	$ 68,16	$ 69,39
360-240	$ 66,36	$ 67,44
240-180	$ 65,86	$ 67,18
180-120	$ 65,36	$ 65,01
120-90	$ 65,12	$ 65,50
90-60	$ 64,19	$ 63,82

2022		
19		
MCP	$ 166,64	$ 165,69
>480 min	$ 166,65	$ 164,80
480-360	$ 168,78	$ 169,93
360-240	$ 164,97	$ 142,19
240-180	$ 164,16	$ 138,48
180-120	$ 166,11	$ 144,28
120-90	$ 164,95	$ 146,84
90-60	$ 170,07	$ 158,00

2016 - 2017 - 2018		
20		
MCP	$ 50,44	$ 50,86
>480 min	$ 50,38	$ 50,98
480-360	$ 49,78	$ 50,06
360-240	$ 50,18	$ 50,84
240-180	$ 50,13	$ 51,13
180-120	$ 49,89	$ 50,39
120-90	$ 49,62	$ 49,76
90-60	$ 56,57	$ 56,63

2019		
20		
MCP	$ 53,90	$ 53,44
>480 min	$ 53,41	$ 52,98
480-360	$ 53,59	$ 53,07
360-240	$ 53,55	$ 52,72
240-180	$ 53,67	$ 53,75
180-120	$ 53,77	$ 53,82
120-90	$ 53,83	$ 53,45
90-60	$ 53,93	$ 53,40

2020		
20		
MCP	$ 46,67	$ 46,65
>480 min	$ 46,37	$ 46,00
480-360	$ 47,00	$ 46,72
360-240	$ 46,96	$ 46,98
240-180	$ 46,86	$ 47,52
180-120	$ 46,59	$ 46,93
120-90	$ 46,33	$ 46,47
90-60	$ 46,49	$ 46,34

2021		
20		
MCP	$ 66,80	$ 69,05
>480 min	$ 71,71	$ 74,41
480-360	$ 66,66	$ 67,59
360-240	$ 65,67	$ 66,87
240-180	$ 65,51	$ 67,13
180-120	$ 64,68	$ 63,70
120-90	$ 63,70	$ 62,54
90-60	$ 64,83	$ 64,45

2022		
20		
MCP	$ 169,72	$ 166,84
>480 min	$ 168,37	$ 164,27
480-360	$ 170,01	$ 173,74
360-240	$ 170,38	$ 153,63
240-180	$ 169,34	$ 149,63
180-120	$ 168,25	$ 149,94
120-90	$ 169,13	$ 154,26
90-60	$ 172,25	$ 165,33

2016 - 2017 - 2018		
21		
MCP	$ 49,50	$ 49,74
>480 min	$ 49,38	$ 49,83
480-360	$ 49,22	$ 49,89
360-240	$ 48,94	$ 49,44
240-180	$ 49,15	$ 49,65
180-120	$ 49,02	$ 49,24
120-90	$ 48,56	$ 48,66
90-60	$ 56,14	$ 56,35

2019		
21		
MCP	$ 53,31	$ 53,16
>480 min	$ 52,86	$ 52,66
480-360	$ 52,71	$ 52,32
360-240	$ 53,17	$ 53,26
240-180	$ 53,06	$ 53,36
180-120	$ 53,03	$ 53,03
120-90	$ 52,80	$ 52,67
90-60	$ 53,51	$ 53,32

2020		
21		
MCP	$ 45,09	$ 44,86
>480 min	$ 44,81	$ 44,37
480-360	$ 44,97	$ 44,66
360-240	$ 45,74	$ 45,96
240-180	$ 45,21	$ 45,47
180-120	$ 44,77	$ 44,70
120-90	$ 45,05	$ 45,17
90-60	$ 45,11	$ 44,64

2021		
21		
MCP	$ 64,96	$ 66,82
>480 min	$ 69,20	$ 71,87
480-360	$ 65,50	$ 65,92
360-240	$ 63,19	$ 65,22
240-180	$ 63,93	$ 63,81
180-120	$ 62,39	$ 60,85
120-90	$ 62,84	$ 62,25
90-60	$ 62,76	$ 61,26

2022		
21		
MCP	$ 165,61	$ 164,19
>480 min	$ 164,68	$ 163,95
480-360	$ 162,91	$ 164,03
360-240	$ 166,25	$ 149,43
240-180	$ 162,52	$ 146,90
180-120	$ 165,09	$ 148,15
120-90	$ 165,13	$ 149,95
90-60	$ 167,05	$ 159,49

2016 - 2017 - 2018		
22		
MCP	$ 45,83	$ 46,00
>480 min	$ 45,77	$ 45,90
480-360	$ 45,58	$ 46,23
360-240	$ 45,57	$ 45,89
240-180	$ 45,67	$ 46,15
180-120	$ 45,11	$ 45,34
120-90	$ 44,74	$ 45,31
90-60	$ 52,40	$ 52,75

2019		
22		
MCP	$ 51,25	$ 50,98
>480 min	$ 50,83	$ 50,47
480-360	$ 51,00	$ 50,70
360-240	$ 51,19	$ 51,47
240-180	$ 50,79	$ 51,02
180-120	$ 51,00	$ 50,99
120-90	$ 51,05	$ 50,98
90-60	$ 51,28	$ 50,87

2020		
22		
MCP	$ 43,17	$ 42,90
>480 min	$ 43,01	$ 42,60
480-360	$ 43,23	$ 43,12
360-240	$ 43,58	$ 43,76
240-180	$ 43,33	$ 43,43
180-120	$ 42,63	$ 41,67
120-90	$ 43,35	$ 43,18
90-60	$ 43,15	$ 43,28

2021		
22		
MCP	$ 60,30	$ 62,53
>480 min	$ 63,98	$ 67,14
480-360	$ 59,58	$ 60,85
360-240	$ 59,47	$ 60,86
240-180	$ 57,81	$ 56,60
180-120	$ 58,01	$ 57,24
120-90	$ 58,55	$ 59,18
90-60	$ 58,53	$ 58,09

2022		
22		
MCP	$ 150,53	$ 148,98
>480 min	$ 150,37	$ 148,43
480-360	$ 149,66	$ 151,56
360-240	$ 151,14	$ 136,82
240-180	$ 147,02	$ 131,82
180-120	$ 149,27	$ 131,60
120-90	$ 148,33	$ 138,60
90-60	$ 150,66	$ 143,98

2016 - 2017 - 2018		
23		
MCP	$ 42,36	$ 42,50
>480 min	$ 42,36	$ 42,89
480-360	$ 42,22	$ 42,79
360-240	$ 42,19	$ 42,59
240-180	$ 42,02	$ 42,01
180-120	$ 41,86	$ 41,91
120-90	$ 41,60	$ 41,59
90-60	$ 49,25	$ 49,15

2019		
23		
MCP	$ 46,59	$ 46,19
>480 min	$ 46,24	$ 45,54
480-360	$ 46,36	$ 46,40
360-240	$ 46,41	$ 46,98
240-180	$ 45,79	$ 46,39
180-120	$ 45,50	$ 45,04
120-90	$ 46,60	$ 46,20
90-60	$ 46,79	$ 46,22

2020		
23		
MCP	$ 40,11	$ 39,71
>480 min	$ 39,67	$ 38,99
480-360	$ 40,60	$ 40,99
360-240	$ 40,38	$ 39,84
240-180	$ 38,80	$ 37,73
180-120	$ 40,03	$ 40,11
120-90	$ 40,24	$ 40,46
90-60	$ 40,08	$ 40,26

2021		
23		
MCP	$ 53,73	$ 55,39
>480 min	$ 56,29	$ 58,63
480-360	$ 53,20	$ 54,53
360-240	$ 52,37	$ 52,84
240-180	$ 52,27	$ 51,66
180-120	$ 52,71	$ 52,92
120-90	$ 52,15	$ 52,58
90-60	$ 52,94	$ 53,45

2022		
23		
MCP	$ 132,80	$ 131,06
>480 min	$ 130,00	$ 128,57
480-360	$ 133,73	$ 136,24
360-240	$ 132,75	$ 121,17
240-180	$ 132,85	$ 117,14
180-120	$ 131,23	$ 118,19
120-90	$ 132,66	$ 124,47
90-60	$ 134,23	$ 129,97

When the 4 tables above are examined in detail, it can be said that there are many categories that appear to have arbitrage opportunities. However, as this study repeatedly emphasizes, the categories determined for arbitrage should be routine and unremittent. The main purpose of this emphasis is to determine the healthiest and

most guaranteed strategies in a chaotic environment such as the electricity market. In addition to this purpose, although market operations are being carried out by automated systems, the human factor has a serious impact on transactions. People have a certain working hours, sleeping hours, and life hours, and this order usually follows a routine (Farrahi and Gatica-Perez, 2008). It cannot be expected that the dynamics in the spot market will not be affected by this life routine. Although it is the subject of another sociological study, when the determined arbitrage tranches in Table 7 are examined, prices seem to be affected by labor and leisure times. We can clearly say that the transactions with low prices are at night sleeping hours (1.00-4.00 am), during lunch breaks and after-work hours (7.00-8.00 pm). Similarly, we can state that the hours with high prices are at the beginning of the morning work (7.00-8.00 am) or the beginning of the afternoon work.

Table 7

Transaction Hours and Trading Times Determined for Arbitrage

Buy-Oriented Arbitrage Tranches		**Sell-Oriented Arbitrage Tranches**	
IDM Transaction Hour	**Trading Time Before the Transaction**	**IDM Transaction Hour**	**Trading Time Before the Transaction**
7	360 - 240 min	6	>480 min
9	360 - 240 min	15	480 - 360 min
10	360 - 240 min	16	480 - 360 min
16	240 - 180 min	19	>480 min
22	180 - 120 min	23	480 - 360 min
23	240 - 180 min		

After determining the routine and unremittent trading hours, a boxplot analysis was performed to understand the distribution of these slices against the MCP. Each transaction in IDM has a price and quantity. Because the boxplot must reflect quantity-weighted price, the data has been expanded so that each lot in quantity is a sample. The price level on the Y axis in the boxplots was obtained by subtracting the MCP from the IDM price of each sample. For example, if the price of the transaction with 15 lots in IDM is $45 for an hour when the MCP is $50, there will be 15 separate samples at -5 level in the boxplot.

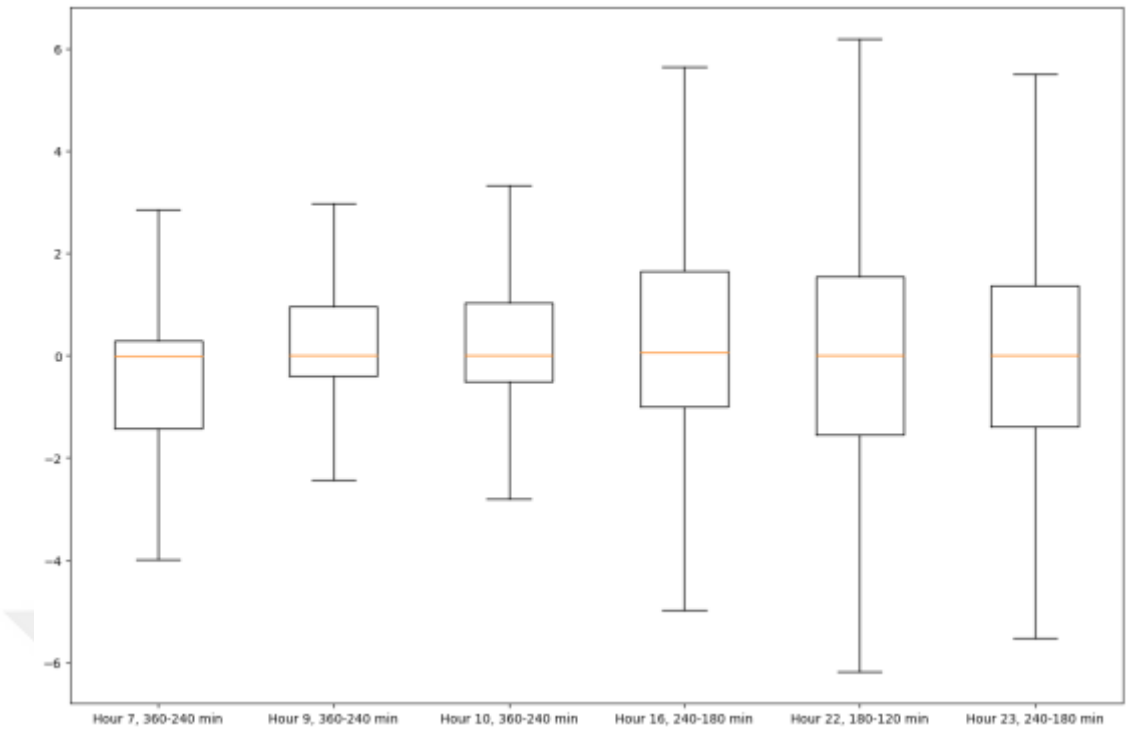

Figure 10. Boxplot Display of Buy Trends

Figure 10 shows the boxplot in which the buy categories were prepared by excluding outlier samples. When we make inferences from both the graph and the quartile table in Table 8, the expected result does not appear except for the box at Hour 7. Since the IDM price is lower than the MCP on average in buying arbitrage tranches, it is expected to cluster more below zero.

Table 8

Quartiles, Inter-Quartile Range and Bounds for Buy Trends

Buy Hours	Q1	Q2 (Median)	Q3	IQR	Upper Bound	Lower Bound
7	-1.429	-0.003	0.289	1.718	2.866	-4.006
9	-0.401	0.001	0.957	1.358	2.995	-2.439
10	-0.502	0.005	1.034	1.536	3.338	-2.805
16	-0.999	0.053	1.657	2.656	5.641	-4.983
22	-1.554	0.001	1.543	3.098	6.190	-6.201
23	-1.394	0	1.367	2.761	5.508	-5.535

When we look at the boxplot with the entire sample, including the outlier samples (Figure 11), the uncertainty becomes clear. It is seen that the downward

oscillation is much greater than the upward oscillation, and therefore there are more sample clusters below zero, both in terms of price and volume.

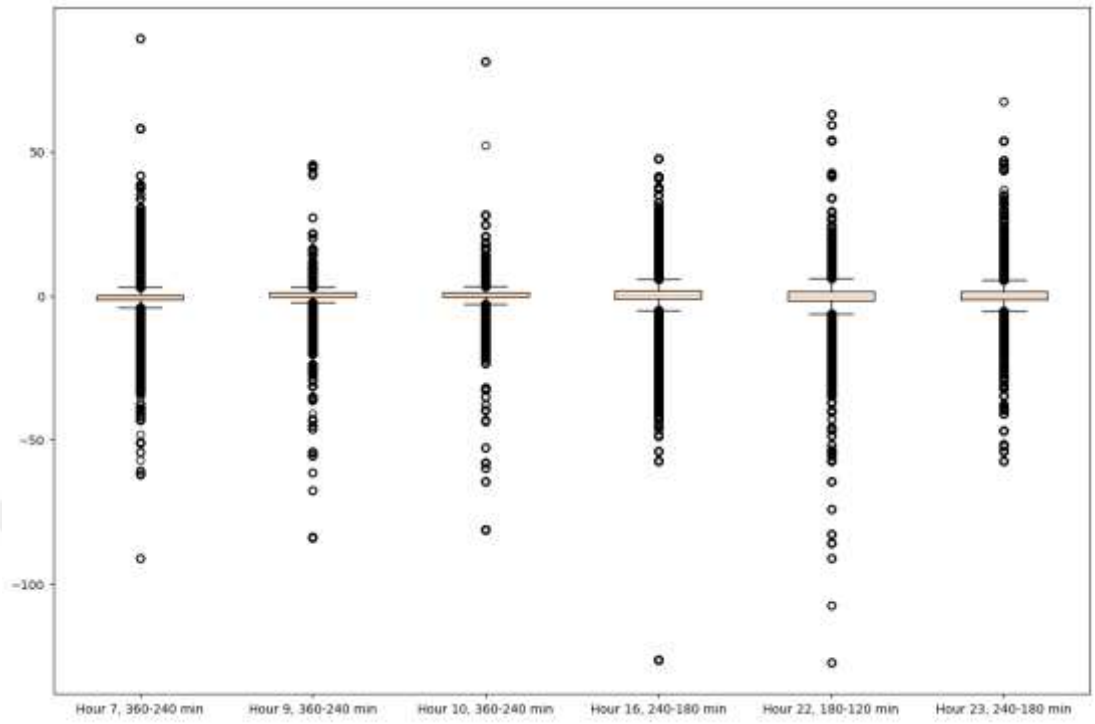

Figure 11. Boxplot Including Outliers for Buy Trends

If we evaluate the data of the buy-positioned IDM arbitrage hours, we can state that the determined buy tranches have been confirmed. Even though the part where the data density is located is at a level close to the MCP on average, it is seen that the main arbitrage opportunities lie in catching the outliers points. In this context, this situation carries a risk in itself for a market participant who wants to engage in strategic arbitrage. If a poorly established model cannot detect outliers, it may have to buy in the region where the data density is located.

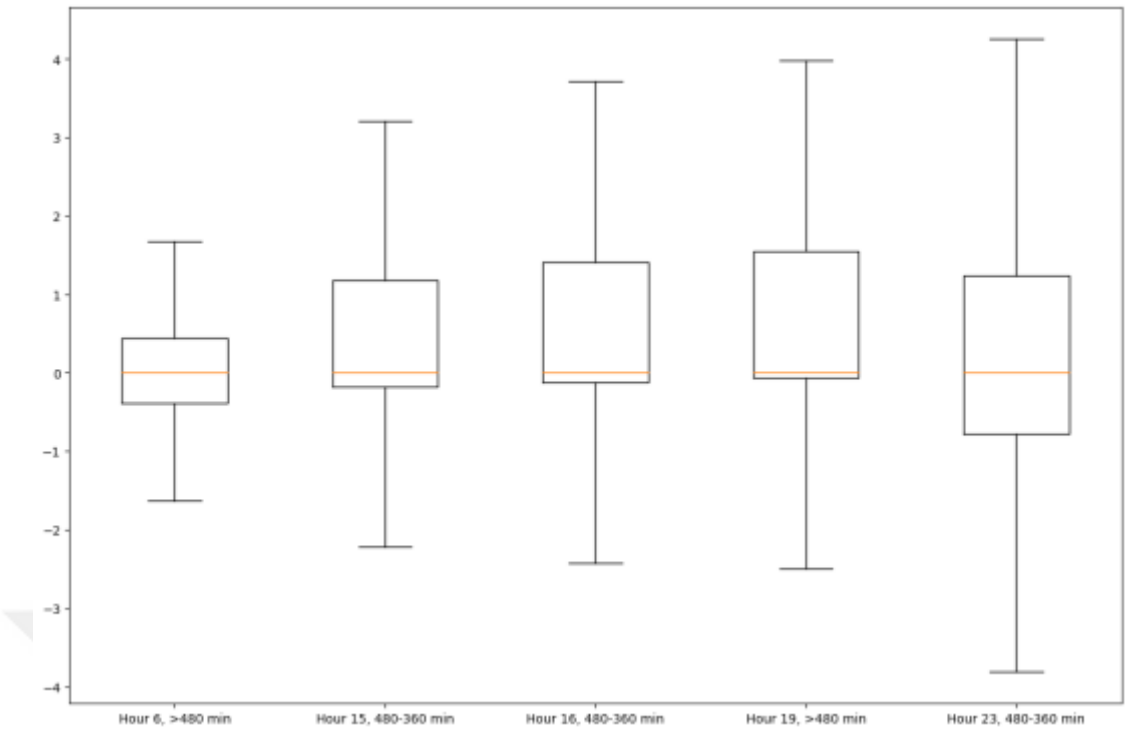

Figure 12. Boxplot Display of Sell Trends

Figure 12 shows the boxplot in which the buy categories were prepared by excluding outlier samples. A much more accurate chart can be seen than the buying tranches. Additionally, it can be seen from the quartile table in Table 9 that the densities of sell tranches are generally above zero. It can already be said that the risk for selling hours is less than for buying hours.

Table 9

Quartiles, Inter-Quartile Range and Bounds for Sell Trends

Sell Hours	Q1	Q2 (Median)	Q3	IQR	Upper Bound	Lower Bound
6	-0.388	0	0.438	0.827	1.678	-1.628
15	-0.183	0	1.176	1.360	3.216	-2.223
16	-0.123	0.010	1.412	1.535	3.715	-2.426
19	-0.069	0.008	1.552	1.621	3.983	-2.500
23	-0.781	0	1.241	2.021	4.273	-3.813

The expectation in sell directional tranches is that the samples in the boxplot will oscillate upwards. However, when we look at the boxplot with the entire sample, including the outer samples (Figure 13), it can be observed that there is no oscillation like the buying boxplot trend. We cannot say that neither price nor volume trend is

above zero. This indicates that the return that can be obtained from the hours captured for arbitrage will be relatively less.

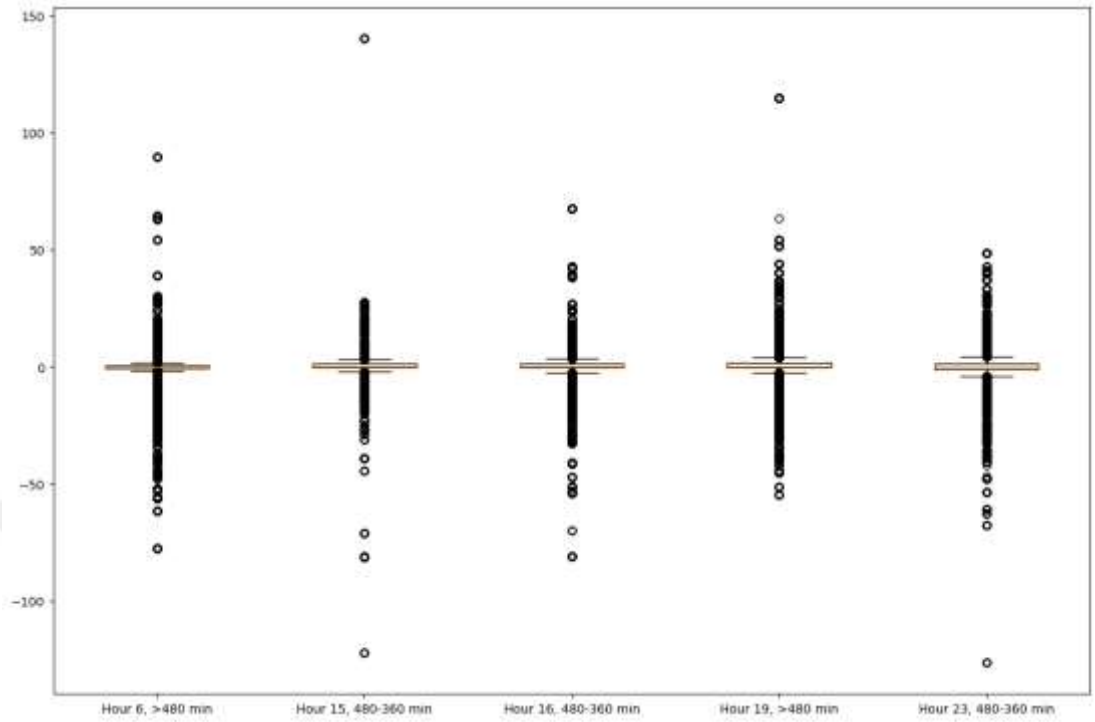

Figure 13. Boxplot Including Outliers for Sell Trends

The most important conclusion from this short observation is that if the buying hours are followed, transactions can be made in a slightly riskier but higher return framework. Sell hours offer a more guaranteed and modest return. Market participants do not have to choose between these two options, they can even choose both options simultaneously in line with their strategies. Another achievement is the confirmation of the determined categories. Even though they have different angles and strategies, both positions offer arbitrage opportunities. Following this conclusion, it will be examined how these arbitrage opportunities change according to the change in wind forecast.

In order to understand how arbitrage tranches react to wind change, we first need to see how much wind change affects the price on average for all traded hours and make a comparison. The hypothesis that the potential of arbitrage will increase with the detection of the change in the wind will be analyzed whether it is valid for all tranches determined. Before moving on to the model definition, it should be underlined that the increase and decrease in wind will be examined separately. Although the degree of impact of wind on spot prices may be different in each

market, it is known that there is a negative relationship. In order to give a clear strategy to market participants, the effects of the increase and decrease in wind on both buy tranches and sell tranches will be examined. The regression model to measure the effect of the change in the wind plan on the price is as follows.

$$IDMP - MCP = \beta_0 + \beta_1(SBFGP - DAMF) + \epsilon$$

If the SBGFP data is larger than the DAMF data, it represents that the wind forecasts increase when passing from DAM to IDM, and if it is smaller, it represents that the wind forecasts decrease. When the samples of all IDM transactions with an increase and decrease in wind as of October 2020 are listed separately, the β_1 coefficients are **-0.0023** and **-0.00156**, respectively, and the *P-values* of the variables are very close to zero. Every 1 GWh increase in wind reduces the IDM price by **$2.3** on average compared to MCP, and every 1 GWh decrease in wind increases the price by **$1.6** on average.

In the last stage of the analysis part, each 11 arbitrage hours with sell and buy directions will be included in the same regression model and the improvement of arbitrage potential depending on the wind change will be examined. Low-priced tranches shown in red are an opportunity for buying, while high-priced tranches shown in green are an opportunity for selling. In order to minimize unbalance penalties, anyone trading in the spot market acts with the instinct of balancing its own electricity. If there is excess electricity available in advance (either as a result of generation or purchased from the market), it is expected that it will also be sold. On the contrary, it is expected that there will be a buying position for the electricity sold in advance. For this reason, it is not necessary to buy in the first place to trade in the market; the electricity of the relevant hour can be sold in advance and purchased in a later period. The effect of wind change on 11 different arbitrage tranches will be examined in this flexibility and 4 different strategies will be listed depending on the wind change. In the wind increase scenario; In addition to the general price decrease, lower price tranches and relatively higher price tranches despite the general price decrease will be determined. In the wind decrease scenario; In addition to the general price increase, higher price tranches and relatively lower price tranches despite the general price increase will be determined.

Increasing wind forecasts when moving from DAM to IDM create a low price buying strategy for red arbitrage hours and a relatively high price selling strategy for green hours. For red hours, if the β_1 coefficient in the increasing wind is less than -

0.0023 (the average coefficient calculated with all the data in the increasing wind), a recommendation will be given that it can be purchased at a lower price. For green hours, if the coefficient to be calculated is higher than -0.0023, a recommendation will be given that they can be sold at a relatively high price. Although increasing wind forecasts generally reduce the price, the reason for the sales recommendation is that it represents a sale that can be made with the need for balancing. These strategies can be followed in order to survive the unexpected drop in prices after previously purchased electricity with the least damage. To summarize, the aim of the study here is to capture the segment whose price decreases the most in increasing wind and to capture the segment whose price can remain relatively high despite the increasing wind.

Decreasing wind forecasts when passing from DAM to IDM create a high price selling strategy for green arbitrage hours and a relatively low price buying strategy for red hours. If the β_1 coefficient in the decreasing wind for green hours is less than -0.00156 (the average coefficient calculated with all the data in the decreasing wind), a recommendation to sell at a higher price will be given. For red hours, if the coefficient to be calculated is higher than -0.00156, a buying recommendation will be given at a relatively low price. Although decreasing wind forecasts increase the price in general, the reason for the buying recommendation is that it represents a purchase that can be done with the need for balancing. These strategies can be followed in order to survive the unexpected increase in prices after previously sold electricity with the least damage. To summarize, the aim of the study here is to capture the segments whose prices increase the most in decreasing wind and to capture the segments whose prices can remain relatively low despite the decreasing wind.

Table 10

Buy Arbitrage Tranches with Coefficients and P-Values

Buy-Oriented Arbitrage Tranches		Coefficients		P-Values	
IDM Transaction Hour	Trading Time Before the Transaction	Increasing Wind Forecast	Decreasing Wind Forecast	Increasing Wind Forecast	Decreasing Wind Forecast
7	360 - 240 min	**-0.00287**	-0.00164	0.00000	0.02533
9	360 - 240 min	-0.00132	**-0.00121**	0.00557	0.01740
10	360 - 240 min	-0.00144	0.00082	0.00336	0.30228
16	240 - 180 min	0.00030	-0.00392	0.44303	0.00000
22	180 - 120 min	**-0.00340**	-0.00273	0.00000	0.00000
23	240 - 180 min	-0.00111	0.00095	0.01013	0.06212

Table 11

Sell Arbitrage Tranches with Coefficients and P-Values

Sell-Oriented Arbitrage Tranches		Coefficients		P-Values	
IDM Transaction Hour	Trading Time Before the Transaction	Increasing Wind Forecast	Decreasing Wind Forecast	Increasing Wind Forecast	Decreasing Wind Forecast
6	>480 min	**-0.00084**	-0.00082	0.00004	0.00049
15	480 - 360 min	**-0.00122**	-0.00082	0.00010	0.00645
16	480 - 360 min	**-0.00129**	-0.00096	0.00000	0.00002
19	>480 min	**0.00076**	-0.00006	0.00000	0.67190
23	480 - 360 min	**0.00348**	0.00147	0.00000	0.00297

Table 10 and Table 11 show the regression model outputs of both buy and sell tranches. According to the results, with the increase in wind, the decreasing price for the "Hour 7, 360-240 min" and "Hour 22, 180-120 min" tranches decreased more than the average price ($2.3 per 1 GWh increase). The impact of a 1 GWh wind increase was a decrease of $2.9 and $3.4, respectively. Another result from Table 9 is that the increasing effect of decreasing wind on the price increases less in the "Hour 9, 360-240 min" tranche compared to the average ($1.6 for 1 GWh decrease), which is $1.2 increase for 1 GWh decrease.

In the sell tranches in Table 10, the price increased by the decreasing wind was not higher than the average for any hour. However, for all green tranches identified, increased wind reduced the price less than average. In fact, the increasing wind in the "Hour 19, >480 min" and "Hour 23, 480-360 min" periods also increased the price. Although this is an unlikely outcome due to the nature of the market, it is valuable as it shows that the price in these slices can routinely be high.

3.4 Limitations

The fundamental limitation of this study is that it is limited to only interpretation of historical data. In today's world, where the markets are changing very rapidly, observation of historical data will not be enough to fully understand arbitrage opportunities in the big picture, until the reasons for the determined arbitrage tranches are revealed. Sociological investigation of daily human routines, which are thought to constitute a large part of these reasons, will be effective in correlating the results. Although all market data since 2016 has been used to reduce this limitation and a trend has been tried to be captured, the biggest limitation of this study is that DAMF data cannot be obtained from official sources and the data used

for this exists as of October 2020. In addition, such a large amount of data should be examined at more frequent intervals and with higher resolution tools. Considering that there are hundreds of thousands of data in each IDM category, categorization at more frequent intervals may show more specific results.

Chapter 4

Findings

Different findings were obtained for each stage of the study, which consisted of 4 stages. In the first stage, annual data for arbitrage in the spot market, divided into different categories according to trading time, enabled routine low and high prices to be detected. In the analysis, it would be more accurate to base the weighted average data instead of the arithmetic mean data. The arithmetic mean will deviate inconsistently because there are many operations that match very small amounts. Based on the weighted average data, routine arbitrage opportunities for the relevant trading hour have been captured. In the boxplot made to understand the distribution of these arbitrage tranches determined for selling and buying, seen in Table 7, it is observed that buy-oriented tranches are more aggressive and sell-oriented tranches are more assured.

In the outputs of the regression model, it was found that when switching from DAM to IDM, a 1GWh wind forecast increase reduced IDM prices by $2.3 on average, and a 1GWh wind forecast decrease increased IDM prices by $1.56. In the strategy developed accordingly, the decreasing effect of the increasing wind on the price in all sell oriented arbitrage tranches identified was much less than $2.3, which is the gain of being able to survive unexpected wind increases with the least damage. The increased wind also creates an opportunity for two buy oriented arbitrage tranches, which are "Hour 7, 360-240 min" and "Hour 22, 180-120 min". The IDM price, which decreases by $2.87 and $3.4 respectively for a 1GWh wind increase, provides a buying-oriented arbitrage opportunity. In addition, the price increasing effect of the decreasing wind was found to be $1.2 in the "Hour 9, 360-240 min" tranche, which can be considered as an escape strategy with minimum damage from unexpected wind drops.

Chapter 5

Discussion and Conclusion

Since there is a very dense and complex data structure in the electricity market, it is very difficult to make sense of and interpret both actor behavior and market dynamics at the same time. As a matter of fact, researches show that these markets are weak-form efficient (Marcjasz, Uniejewski and Weron, 2020; Öksüz and Uğurlu, 2019), which means that it is very difficult to derive forecasts and strategies. However, as a result of 7 years of retrospective data analysis, arbitrage opportunities were observed in 11 different hours in different time zones. Although there are arbitrage opportunities in 8 different tranches in the strategies developed depending on the change in wind forecasts, a suitable strategy for the two-way change of wind could not be found in any of them. Instead of predicting the IDM price, the difference between MCP was used in the study because the difference is a better indicator for forecasting (Öksüz and Uğurlu, 2019) and is more valuable for the arbitrage decision. It is thought that the price is most affected by the wind, a fact that all literature agrees on, and since the sectoral experience for the Turkish market is parallel to this, it will be the most significant variable for the arbitrage decision. It is thought that this study will bring a different perspective to the IDM literature, which remains relatively weak within electricity markets. Considering that trading for the same product at different times has not been the subject of almost any study before, it is important that this area of the literature, which is open to development, be addressed in different studies. This subject can be expanded with a study that is more advanced in terms of modeling and where the effects of different variables are seen. Further study is needed at higher resolution, including other sectoral parameters such as other forecast error, load forecast error, grid constraints and unbalance positions.

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