Impact of COVID-19 on the Indian Power Market
IEX Day-Ahead Contracts

Author: Steven Witzand
University of Twente
P.O. Box 217, 7500AE Enschede
The Netherlands

ABSTRACT

This thesis aims to research the impact of COVID-19 upon the Indian Power Market with the day-ahead contracts that are offered. For an economy to sustain its development(s) and to initiate further growth the energy sector is of significant importance. The Indian economy showed enormous growth within the past few years and has the potential to further increase in the future. Financial analysis will be done on day-ahead contracts which are of relevance concerning COVID-19 because effects are likely to become obvious immediately, opposed to long-term contracts. This thesis will conclude with possible future implications for the Indian power market after analysis has been conducted on the COVID-19 effect.

Graduation Committee members:

Dr. E. Svetlova (1st Supervisor)
Dr. X. Huang (2nd Supervisor & Coordinator)

Keywords

COVID-19 – Lockdown(s) – India – Power Market – Financial – Events

1. Introduction

The World Health Organization (WHO) held a meeting on January 30 2020 with its emergency committee regarding the outbreak of the COVID-19 virus (WHO – statement, 2020). During this meeting, a consensus was reached to declare COVID-19 as a Public Health Emergency of International Concern (PHEIC). Following this statement another statement by the WHO was made that would shock and affect the economies of countries on a worldwide scale. March 30 2020 was the date on which the COVID-19 virus and its outbreak were declared a pandemic.

This novel virus received a lot of attention within the academic literature, especially the magnitude of the financial impact it has on the stock market(s) and certain sectors for instance. Now, an interesting sector to research concerning COVID-19 and the broader topic domain of this thesis is the energy sector. It should be mentioned that while researching this sector literature about the financial effect of COVID-19 on energy-related stocks and indices have been conducted. However, rather than solely studying the financial impact on those stocks it would be interesting to investigate the physical markets and their price dynamics. Such a physical market of energy are the so-called power market exchanges. This specific market type will be studied within this thesis, as the title says. In essence Power market exchange(s) could be seen as a whole trade mechanism of electricity in which generators, industrial producers and utility organizations are brought together. By studying the power market exchange a lot more information and insights within such physical markets are discovered. Such as actual absolute demand, supply, electricity amounts, sentiments of power market participants and actual prices changes of electricity. The importance of studying the financials of this physical market concerning COVID-19 is that it provides transparent guidance in addition to studies about the stock market(s). The literature review that the next section will cover had shown that not that much literature covered the COVID-19 effect on certain Indian market sectors. However, further research on the discussed energy industries showed that India is an enormous player within the generation of electricity. Over the year 2019, it showed that India produced a total of 1,558,700 GWh of electricity (BP World Energy Review, 2020). To put this into perspective, only China and the U.S both had higher levels of electricity production than India with a production of 27,644,800 GWh and 4,401,300 GWh respectively. In terms of the population of those countries, China, India and the U.S have 1,439 billion, 1,380 billion and 331,003 million respectively (Worldometer Info, 2021). In addition, because India as of 2021 is still seen as a developing country it brings a lot of opportunities in their energy industry. This together with the above discussed specific topic was the reason for this thesis to focus upon the power market exchange of India to research the financial effect within this physical electricity market. The dominant power market of India is called the IEX (Indian Power Exchange).

Now, within such power market exchanges multiple ‘sub-markets’ exist, this thesis will specifically focus upon the so-called day-ahead power contracts. These contracts allow purchasers of electricity to ‘order’ amounts of electricity needed for the next operating day. In this thesis, attempts are made to try and to do research on what the financial effect of COVID-19 is on the price dynamics of these contracts traded at the IEX. These contracts are considered short-term which is perfect for studying the financial electricity price impact on COVID-19 events. An event can be explained by an announcement or governmental action for instance concerning COVID-19. Next, financial analysis can be performed of this impact on the unit of analysis in question. This thesis will focus on three of those events from which electricity price impact will be measured. What will follow next is the significant part of this thesis and potential contribution to the existing literature; comparison between the events. The studied events in question are (1) 1st nationwide lockdown India (24, March 2020), (2) WHO declared COVID-19 pandemic (30, March 2020) and (3) Indian states imposing 2nd lockdown in 2021 (May 8 2021). These event dates are chosen to identify how the electricity price dynamics change with varying levels of COVID-19 events. All related to COVID-19 but different in events being announced on a : (1) National, (2) Global and (3) Regional-scale.

The overall research question of this study is: What is the financial impact of COVID-19 within every event scale on the daily average electricity price (MWh) of day-ahead contracts.

Following this research question a hypothesis needs to be introduced that can be tested and will provide an answer to the stated research question. According to the previous discussion the hypothesis for events 1, 2 and 3 is:

“The daily average MWh prices within the event window are negatively impacted by COVID-19”

The hypothesis test will be conducted via the paired two sample t-test, this will be elaborated further on in the methodology section.

2. Literature review

This literature review/research uses a funnel approach in which it starts with overall literature about the financial effect of COVID-19 with certain topics and gets more and more specific at the end.

As mentioned in the introduction and as will be seen in this section one popular theoretical framework of assessing financial impact on certain announcements are Event Studies. Mackinlay, (1997) is a paper that explains and describes the interpretation of such a method. It starts with picking a unit of analysis which could be a certain stock or index on which the financial effect wants to be assessed. Next, you pick a major stock index which is the leading indicator of a country it's economy. Via the previous share price(s) of both your unit of analysis and the major stock index expected returns can be calculated of your chosen event window. The event window in COVID-19 studies often looks like this: [-3, 3] which indicates that analysis is conducted on the financial effect between three days before and three days after the event. Abnormal returns are calculated by subtracting the expected returns in this period from the realized returns. These returns describe the effect of an event on the stock market(s). Examples will now follow in the remainder of this section.

First of all, some studies were conducted that made comparisons between the sectoral performances within countries. An example of this Alam et al, (2020) analysed the sectoral performance of the Australian stock market affected by COVID-19. The performances are measured over the sectoral indices of; Transportation, Pharmaceutical, Healthcare, Energy, Food, Real-estate, Telecommunications and Technology during a (-10, 10) window. In this cross-sectoral study, the results were that the Food, Pharmaceuticals, Telecommunications and Healthcare industries showed positive stock performances over the event windows. The energy industry performed the worst with an abnormal return of -13.76%.
Another similar kind of study is conducted by He et al, (2020) the sectoral financial performances of the Chinese stock market on COVID-19 are measured. The event date that was chosen is January 23 2020 the day that the Chinese city Wuhan where COVID-19 originated, was supposedly closed off from other cities in China. The financial performance of the sectors was divided into three groups: severely positive affected, mildly affected and severely negatively affected. Public management was the most severely positively affected sector, the mining sector was the most negatively affected.

Some studies rather focused on a single sector and applied a multi-country focus. In Farooq et al, (2021) the COVID-19 impact on the abnormal returns in the insurance industry is studied. Five developed countries were chosen; Australia, Canada, Germany, the USA and the UK and three developing countries were chosen; Brazil, Indonesia and India. The study showed that the developing countries immediately experienced negative abnormal returns when COVID-19 information and statements were disclosed. Developing countries showed abnormal returns in later phases when the situation got more severe and the normally minimal volatility could not hold it anymore.

An interesting discovery in the literature was that geographically dispersed areas react differently on COVID-19. Liu et al, (2020) shows the response of the major stock market indices of COVID-19 affected countries. It analyses in total twenty-one countries such as; USA, Italy, Japan, Korea, Germany etc. The focusing point in this study was to show at what point certain countries experienced negative abnormal returns. It showed that European countries almost did not respond to COVID-19 information disclosures about Asian countries. However, when the outbreak in Italy started they were the first to respond. Which in hindsight might even seem obvious or as ‘expected’.

One of the few COVID-19 related event studies of India is conducted by Behera et al, (2021). The study aims to analyse the stock performance of Indian Pharmaceutical companies. In total for twelve Pharmaceutical companies, abnormal returns were calculated. It showed that the majority of the twelve companies has significant positive returns except for two of the companies. The two companies that had negative returns were in contradiction with the prior literature about the Pharmaceutical sector.

The energy sector is quite an important one, every economy worldwide revolves around an efficient and steady energy sector in terms of supply and maintenance. In the literature, both COVID-19 energy event studies and non-event studies were found. Two non-event studies and two event studies to be precise.
Amir et al, (2021) analysed the opportunities and challenges for renewable energy sources in Africa presented by the COVID-19 outbreak. In the article, it is said that currently in general a lot of African countries do not have the right and efficient energy grid infrastructures in place. COVID-19 in this situation is challenging because COVID-19 brings uncertainty which slows down projects from global

investors. A lot of renewable energy projects have been delayed but the perspective for renewable energy sources is quite high because of the potential capacity of renewable energy sources. Especially solar power is set to be a major renewable energy source of African countries because of the abundance of sun-hours that its climate brings.
In Kuzemko, (2020) the relationship between COVID-19 and the sustainable energy transitioning in politics is studied. It is stated that in the COVID-19 short-term GHG (greenhouse gas) emissions are indeed reduced however these are temporary. When countries get out of 'lockdowns' again it is likely that the GHG emissions will rise to their previous levels again. That is why in the article four factors are really important that should be addressed in politics; Energy System Change, Financing and Investments, Multi-Scalar Policies and Social & Political Practises.

In Kamran et al, (2020) an event study is conducted that is focussing on the stock returns within the Energy Industry of the U.S relating to the COVID-19 effects. Thirty-three listed companies on the U.S stock market in the Energy Industry were analysed. On the event day itself, only five out of the thirty-three companies showed significant abnormal returns. During the (-3,3) event window ten stocks were experiencing significant cumulative average abnormal returns.
In Polemis et al, (2020) the COVID-19 financial stock market impact on Greek Energy Firms are assessed. In total eleven Greek listed Energy Firms are analysed. Especially right before and right after the event date, there seem to be quite some significant abnormal returns. Besides the individual abnormal returns of the stocks, the study also calculated the cumulative average abnormal return for the (-10,10) event window.

During the research within the energy and power literature, the physical type of market analysis in combination with COVID-19 was quite scarce. However, in Bompart et al, (2020) the effects of COVID-19 on the European electricity system were assessed. Demand is the factor that is directly affected by COVID-19. However, it should be mentioned that this study does consider the indirect factors. One of those factors is the day-ahead price on the Europe-wide power exchange (EPEX). The electricity price analysis is done via the historical time series. Via this methodology, the expected electricity prices can be forecasted by its historical data. Specifically, the study uses a weekly moving average of hourly electricity prices in the day-ahead market. to forecast the expected electricity prices between Jan 1 – Jun 30, 2020. What could be observed is that COVID-19 indeed did have a considerable effect on electricity prices. The effect is especially observed from around the 15th of March till the end of June when most European governments loosened their lockdown measures or announced all current measures to be lifted entirely. The prices observed per MWh were even lower than the prices in 2016 which low prices were caused by low oil prices (ACER, 2016 as cited in Bompart et al, 2020).

Now, it does make a difference whether the data for a time series show seasonality or not since different models to forecast are then applicable. When data shows seasonality there are two ways of forecasting with moving averages: multiplicative model and additive model (Hyndman, Athanasopoulos, 2018). Both of these models decompose the data into seasonal component, irregular component and trend (or smoothing) components. These separate components in presence of a form of seasonality can be used to forecast quite accurately. The additive model is more often used for forecasting in datasets for an economic purpose such as electricity prices since the authors used this additive model. Seasonality within decomposing means cyclical patterns that repeat themselves.
When the data seems to be non-seasonal another model or approach can be taken: the simple moving average (Oracle Forecasting Methods, n.d.).

3. Characteristics and Dynamics of the IEX Power Exchange

Before financial analysis can be conducted on the prices within the IEX day-ahead contracts it should be clear how the IEX is set up and what the characteristics are of the day-ahead contracts in particular.

As became clear in the previous section the IEX power exchange was implemented and functioning from June 27, 2008, onwards. Although with the introduction of the power exchange less governmental control is needed this does not mean it can regulate itself entirely on its own.
The Central Electricity Regulatory Commission (CERC) is a legal governing body of India to which the main task is to as said in its name to regulate the electricity market within India (IEX, n.d.). Traded electricity is distributed from the generators towards purchasers which both parties can via the national power/electricity grid. Now, CERC is India its regulator for the power market it does not have the task and obligation to observe and maintain the power/electricity grid availability.
The institution which fulfils this task is the Power System Operation Corporation (POSOCO) with activities to act responsibly for the efficient flow and distribution/transmission of electricity within India.

The relationship between CERC and POSOCO is briefly described in a quote by an Executive Engineer of POSOCO. "In simple terms, CERC regulates the power for the better economy, efficiency and competition determines the tariff of power while POSOCO keep accounts of the amount of power flow between buyer & seller, operates certain energy & deviation accounts, collects & disburses the money among beneficiaries and maintains the record. All the works POSOCO carries under the regulations of CERC." (Nikhil, 2018).

The structure of an energy market is in general compromised of two groups; Power Exchange and Over the Counter Trading (OTC) (Next Kraftwerke, 2021). The main difference between the two types is that the Power exchange offers 'short-term' power contracts and over the counter trading offers 'long-term' contracts. So, before the introduction of power exchanges electricity was purchased and sold via OTC contracts. These contracts were not normalized which in essence means that every industrial producer or distributor to residential areas had to contact the supplier of electricity by themselves. These contracts fall under the name Power Purchase Agreements, which are as said long-term contracts.

Power exchanges could further be divided into two groups as well; Spot-Market and Derivative Market. In the derivative market futures and forwards are traded on this exchange but this market rather revolves around speculating the financial electricity prices than trading the physical asset itself. This kind of market is not included in all of the countries their power exchanges. India is one of these countries that do not provide trading of derivative power assets (Kritika, Pankaj, 2014)

In the spot-market physical electricity, assets are traded where suppliers of electricity which are the generators and purchasers of electricity which are the industrial producers and distributors all come together. Spot-market(s) could be defined as markets in which electricity in this case is traded for contemporary prices instead of future prices which is the case for derivative markets.
The spot-market again is divided into two products offered by exchanges; Term-Ahead Market (TAM) and Day-Ahead Market (DAM) (IEX, n.d.).

Within TAM it is offering contracts with durations up to 7 days as opposed to DAM contracts. This market includes day-ahead contingency contracts, intra-day contracts, daily contracts and weekly contracts. With the term, it is meant that trades are made according to certain predetermined conditions. Within this range of products offered by the IEX exchange intra-day contracts are the best known. Intra-day contracts are offered for participants in immediate need of electricity on the same operating day.
Within DAM participants are allowed to buy/sell wholesale electricity the day before the electricity is needed. This reduces volatility risk since intra-day trading is quite volatile and more expensive in general. Both DAM and TAM information was acquired via the IEX power market website.
Kritika, Pankaj, (2014) have already been mentioned briefly. These authors wrote a report in 2014 which assessed the characteristics of day-ahead contracts trading at the IEX.
In a certain section within the report, a comparison was made between the electricity volume traded at the IEX for both day-ahead contracts and term-ahead contracts. The comparison period was set between 2008-9 to 2013-14. Initially, both types of contracts increased well the first few years. In the following years, the growth of the term-ahead contract stagnated/declined whereas day-ahead contracts kept growing exponentially.

In the report, it is excellently been documented how the trading process of the electricity wholesale market in itself is functioning. Within the Indian IEX, power exchange blocks of 15 minutes are traded. Within these blocks, both generators of electricity and purchasers can list bids to indicate their volume availability or demand respectively. This corresponds to 4 blocks of 15 minutes every hour which means there are 4 x 24 = 96 blocks in total during a day. The electricity that is traded at day-ahead contracts will be delivered the next operating day. Both the sell bids and purchase bids happen every day of the year, with no exceptions. The bidding happens via an auction in which both selling bids and purchasing bids are the inverses of the demand function. In essence, this means how much are participants willing to pay or sell per trading amount of electricity. Between 10 AM and 12 AM, both bidder sides can list their bids for the 15min blocks at the IEX power exchange. However, two types of bids can be listed by purchasers these are (1) single bids and (2) block orders. Single bids are several bids on different 15min blocks with different quantities and prices traded on the IEX. Partial execution is provided for single bids on the IEX. Partial execution means as much as part of your orders could be accepted and the rest could be declined. Block orders could be seen as linked blocks with the same bid price for all of them. Those block orders opposing to single bids are not provided with partial execution on the IEX. So, either all the blocks that were requested in the bid get accepted or none of the requested blocks will get accepted. The IEX power market is divided into 12 bidding areas which was done to make sure that the transmission capacity of the grid will not be overloaded.

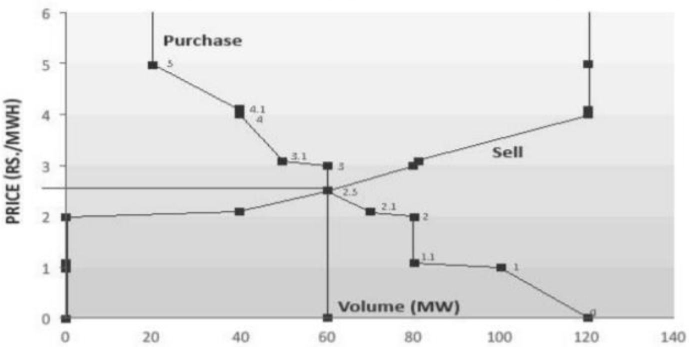
National Load and Dispatch Centre (NLDC) is run by POSOCO, the system and grid operator. The NLDC plays a significant role in the IEX power exchange. After the auction closes after 12 AM the algorithm determines the market clearing price (MCP) and the market-clearing volume (MCV). This price and volume is the equilibrium at the intersection of the aggregated supply and demand curve of participants in the closed auction. In this equilibrium, it means that no excess electricity is left or that there is a shortage of energy. This means that every participant in the auction will pay the same market-clearing price per MWh. The NLDC will intervene during the next steps of finalizing the trade(s). The NLDC will determine whether or not the transmission of the sold electricity is within the peak load capacity on its national grid at certain moments during the day. If the so-called power flow is higher at a certain point than its load capacity on the grid the power exchange need to adjust pricing.

The method of adjusting prices because of grid load is called market splitting. As explained previously the Indian power market IEX is divided into twelve bidding areas. Now after the MCP and MCV are calculated it could be that the NLDC assessed that some areas are over the transmission capacity and some areas are in a deficit of total transmission capacity in their area. So, instead of pricing the purchasers of the twelve bidding areas the same way the pricing now will be adjusted to the situation within those areas. A bidding area that is over their transmission capacity will be priced a bit higher than the previously MCP. The effect is that demand for electricity drops by the amount that was over the transmission capacity in that area. The area that was in deficit of the available transmission capacity will see that the prices decrease so that the available transmission capacity is now reached. Now instead of the beforementioned overall MCP for every area, the pricing is called; Area Clearing Price (ACP).

Generators of renewable energy that supply towards the IEX power exchange are rewarded with a Renewable Energy Certificate (REC) for every 1 MWh that is traded on the IEX power market. When RE generators exceed the RPO target within a certain year then they are allowed to sell these RECs to obligated entities that could not comply with their targets in that year. Participants with RPO obligations can purchase these REC's which again has a value of 1 MWh. The Indian ministry of new and renewable energy created a website for the sole purpose of providing information and knowledge about RPO/REC regulations and targets. Not only within the day-ahead market but rather in the entire wholesale market of electricity including the long-term contracts via Power Purchase Agreements electricity sources are treated differently. Merit Order Dispatch is the order in which electricity is being offered/supplied to the grid. This order is determined by assessing the electricity prices of the various power generators. The generators with the 'lowest' prices are 1st to be supplied to the grid. Afterwards, the electricity from generators with 'increasing' prices are supplied to the grid until all demand is met. This order should serve and act in the best interest of consumers of electricity However, there is one exception that impacts the Merit Order Dispatch. This exception comes from another term which is called the must-run status. This status is rewarded to generators of electricity that used a renewable energy source. What happens is that generators with this status will be allowed to supply their electricity to the grid regardless of their original order and so electricity price. This exception was implemented to make sure that the growth development of renewable energy technologies was sustained. Above mentioned information was acquired from Sharma, (2017)

Graph 1:

Demand Supply graph utilised for determining MCP and MCV



Source: IEX Website

4. Methodology

A lot of COVID-19 financial studies used the event study method. It should be mentioned that this kind of method is designed and in practice most often only used to perform analysis on companies and indexes listed on the stock exchange. This is the reason that only the event study its framework is used rather than the stock-market related formulas and calculations. The event-study framework consists of Estimation Window and Event window (Mackinlay, 1997). The event window portrays besides the financial impact on the event date the days prior and post-event as well. The benefit is that you could see how it leads up to an effect or develops a few days later. Especially this event window is the component within its framework that

is important to set boundaries in the analysis of this thesis.
These event dates are (1) 1st nationwide lockdown India (24, March 2020), (2) WHO declared COVID-19 pandemic (30, March 2020) and (3) Indian states imposing 2nd lockdown in 2021 (May 8 2021). The event window in which the financial analysis of day-ahead electricity prices will be observed is [-3,3]. This means that for all the event dates the three days before the event itself and three days afterwards are measured. In total 7 days will be observed, the event date itself and as stated above the three days prior and afterwards. A full year before the event(s) will be used as an estimation period so that the average of normally expected errors can be identified.

Normally in original event studies conducted on the stock market formulas are needed to calculate via your unit of analysis and a benchmark (index most often) the alpha and beta. Via this alpha and beta further calculations are made to determine what the expected return in a normal situation without COVID-19 would have been. The spread between the actual returns – expected returns are then formulated as abnormal returns.
Now, in this thesis, the focus is not on returns but the daily average electricity prices in Indian Rupees per MWh (INR / MWh). Forecasting what expected daily prices might have been without COVID-19 is done via historical time series. This method was observed in the literature analysis E. Bompart et al, (2020). However, this particular study used hourly electricity prices on a moving average of a week. Electricity prices on an hourly basis indeed show seasonality as the time of the day influences demand. This is the reason that this study used an additive type of time series for its financial analysis as explained in the literature. However, the average daily electricity price data used in this thesis is averaged down which then seems to not show any seasonality. As seen in the literature this is where the simple moving average (SMA) type of time series model is applicable (Oracle Forecasting Methods, n.d.). SMA historical forecasting of daily average electricity prices formula **(1)**:

$$\text{SMA} = (\text{A1} + \text{A2} + \cdots + \text{An}) / \text{n}$$

N is the number of periods that are used within the moving average. N is set to seven days as it is the event window length. A price forecast on a certain day is then made by averaging the historical data of seven days prior. For events one and two the SMA dataset contains all average daily electricity prices in 2019 until both events windows their date(s) March/April 2020. The third event the SMA dataset contains all daily average prices of 2020 until the event window date(s) in April 2021. The forecasting error statistic that will be used is the Mean Absolute Percentage Error (MAPE):
(A and F = Actual and SMA Forecasted respectively)

(2) $$\text{MAPE} = \frac{\sum \frac{|\text{A-F}|}{\text{A}} \times 100}{\text{N}}$$

Via this forecasting error statistic, individual datapoint errors within event windows can be put into perspective to the mean error in the dataset and portray a better picture of the actual financial effect. The financial effect significance within event windows will be tested via null and alternative hypotheses.

Via the website of the IEX Indian power market itself, all the historic electricity prices and volumes have been made public. This is where the data and information is extracted from which then further during the analysis is processed in software which can do this analysis, Microsoft Excel.
Now it should be mentioned, to clear everything up, that the daily average price forecast is the equivalent of 'normal' expected returns in event studies with a focus towards stock market(s). Instead of abnormal returns (actual returns – expected returns) this study formulates it as forecasting errors. These forecasting errors are calculated the following; actual daily average electricity price – forecasted price. The purpose of the estimation periods prior to the events is to calculate the MAPE metric which in full means; Mean absolute percentage error. In essence, this metric represents the average of all absolute error percentages within the estimation period. This metric is quite convenient since it complements the hypothesis testing in the event window(s) that will be explained next.

The hypothesis for events 1, 2 and 3 was formulated in the introduction section as the following:

"The daily average MWh prices within the event window are negatively impacted by COVID-19"

Now, how could this hypothesis be tested since the individual forecasting errors within the event window(s) by itself do not quite provide any useful information. Via hypothesis testing the hypothesis can be tested whether or not it is statistically significant or not. Since this study conducts financial analysis this hypothesis testing is quite important because obviously if the errors are not significant than it is unlikely that there is an underlying financial effect as the hypothesis tells us.

The specific test that will be used in this study is the; paired two sample t-test. This test is excellent for our data and study purpose. Every day within one of the three event studies in essence has two values of the same metric; both the actual daily average price and the forecasted price. As made clear before electricity prices can in the short-term be a bit irregular. This is also why was not chosen to formulate an hypothesis that that would only test the significance on the event-day. Rather via this paired two sample t-test the significance over the entire window is calculated which provides a more reliable and overall snapshot.

The paired two sample t-test formula is:
($\overline{X}_D$ = Mean difference Actual and SMA Forecasts)

(3) $$t = \frac{\bar{X}_D - \mu_0}{s_D/\sqrt{n}}$$

Null hypothesis: $\mu_d = 0$, Alternative hypothesis: $\mu_d \neq 0$ (two-tail). The null hypothesis thus tells us that there is no difference between forecasted and actual data in the event window. The alternative hypothesis says the opposite and tells us that there is difference between the values of forecasted and actual. Since this study is interested in any difference between forecasted and actual data we want the test to be two-tailed. In the analysis section next the computations of the hypotheses are performed via Excel and then the output is presented in a graph.

In the analysis section per event-study the financial effect(s) will be presented in a table + the individual forecasting error that was found on those days. The reason why those individual errors are presented as well is that the significance test on it own of the event window sometimes does not provide enough information. In fact an event-window or in case of taking the other hypothesis tests individual days can be stamped as significant but this does not automatically mean that the effect is caused by COVID-19. So, that is where the individual errors and MAPE of the estimation period come in to check and provide a more detailed view on the true financial effect cause.

The next section will entirely be devoted towards the financial analysis of the event studies and financial details will be disclosed in the analysis.

5.1 Financial Analysis of IEX Day-Ahead Power Contracts Concerning COVID-19

As mentioned and set out in the methodology the three-event dates will be analysed regarding the financial impact of COVID-19 on the daily average MWh prices of days within the event window in the day-ahead power market. The observations and analysis that has been done will be presented in chronological order. In essence, first will be the nationwide lockdown of India in March 2020, next is the WHO that declares COVID-19 a pandemic and finally will be the state-wide lockdown of India in 2021.

In the characteristics section, it mentioned that prices are calculated and the overall price for participants is the Market Clearing Price (MCP). The average daily MWh price of this MCP on the IEX website is called the Round The Clock (RTC) (IEX – Build-in Database)

<u>(1) Event Window 1 – Nationwide Lockdown India, March (2020)</u>

The nationwide lockdown of India was imposed on the 24th of March, 2020. The WHO did declare COVID-19 a pandemic on the 30th of March as briefly mentioned before. The major first lockdown of India was imposed before the WHO assessment of COVID-19. This means that India together with a lot of other countries found themselves already in the position to impose measures (lockdowns) to protect the health of its residents. What was found is that the increase in electricity demand from domestic households could not make up for the decreased demand from industrial organizations and utility organizations. (IEA Report, 2020 as cited in Bompart et al, 2020).

In the table on the following page the financials of the analysed data can be found regarding the 1st nationwide lockdown of India in March 2020.

Table 1: Event Window 1 – Financials

	Days	**Actual Daily average MWh Price**	**Forecasted Daily average MWh price**	**Individual Forecasting Error %**	**Mean Absolute Percentage Error %**
2020, March	21	INR 2,591.16	INR 2,684.19	-3.59	8.12
	22	INR 2,195.48	INR 2,682.21	-22.17	8.12
	23	INR 2,462.63	INR 2,668.38	-8.35	8.12
	24	INR 2,012.07	INR 2,647.82	-31.60	8.12
	25	INR 1,952.24	INR 2,538.39	-30.02	8.12
	26	INR 2,271.16	INR 2,400.54	-5.70	8.12
	27	INR 2,029.29	INR 2,322.70	-14.46	8.12

All financial data is presented in India its main currency the Indian Rupee (INR). The financial effect on the event day itself could be identified by its bold text type. Now, the mean absolute percentage error (MAPE) metric can be seen in the right column of the table above. The error is calculated over the entire dataset. Besides the MAPE metric also the individual forecasting errors of days within the event window are shown. In this way, the financial effect can be observed quite a bit better rather than simply listing the MWh monetary differences between actual data and forecasted data.

Sidenote, because the daily average electricity prices did not show cyclical patterns the seasonality and irregularity could not be decomposed. Which in essence means that any excess error effects (individual forecasting error(s) plus-minus the MAPE error) could be caused by interfering irregularities rather than COVID-19 effects.
On the event day itself, it shows an enormous individual forecasting error of 31.6 % in comparison to the 8.12 % MAPE error. The day after once again has a serious considerable effect with a 30.02 % forecasting error. Especially on the event-day itself and the day after with such large-displayed errors irregularity and cyclical effects are not much into play. 22 March has quite a considerable forecasting error as well of 22.17 %. Often an important government decision is already known to some extent to the public a few days before the official public announcement which might have been the cause of this particular error on this day. All in all, there is a clear financially

observable impact that was caused by the event date shock related to COVID-19.

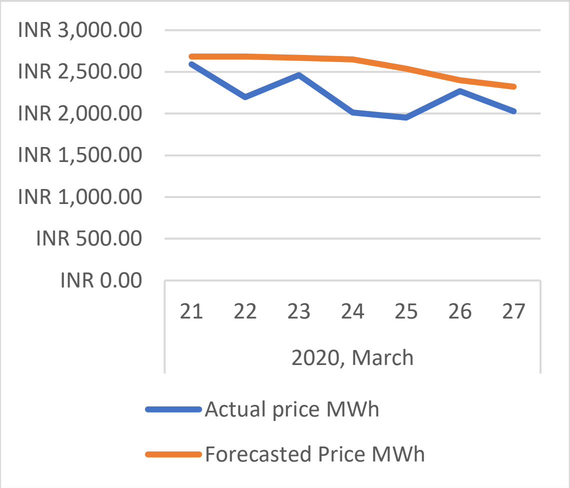
The calculations of the paired two sample hypothesis test provided by Excel can be found in table 2.

Table 2: Significance Testing

t-Test: Paired Two Sample for Means		
	Forecasted	*Actual*
Mean	2563.461	2216.29
Variance	21989.82	58508.65
Observations	7	7
Pearson Correlation	0.437271	
Hypothesized Mean Difference	0	
df	6	
t Stat	4.144025	
P(T<=t) one-tail	0.003026	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.006051	
t Critical two-tail	2.446912	

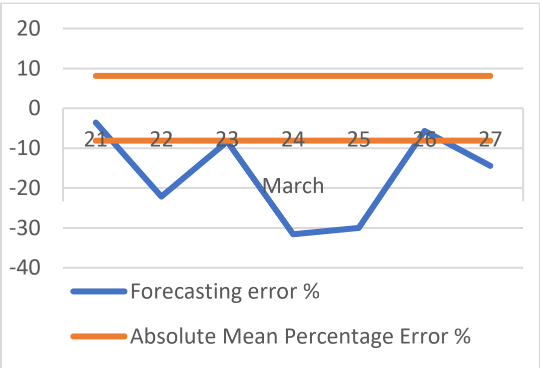
Null hypothesis: $\mu_d = 0$, Alternative hypothesis: $\mu_d \neq 0$ (two-tail).
P-value (two-tail): $0.00605 < 0.05$. So, there is enough evidence to reject the null hypothesis and accept the alternative hypothesis which says the difference between variables is indeed significant.

Graph 2: Nation-wide Lockdown Event Window – Actual vs Forecasted MWh Prices



Graph 2 gives a visual representation of the actual daily MWh price movements in comparison to the forecasted MWh prices. Now it can also be observed that the individual forecasting errors shown in the table above are indeed substantial.

Graph 3: Nation-wide Lockdown Event Window – MAPE Error vs Individual Errors



Graph 3 shows the absolute percentage error both positive and negative in comparison to the individual forecasting errors. Now, this graph comes in quite useful because between the absolute error lines the financial effect could in essence be affected by irregularities and cyclical patterns rather than a COVID-19 effect as discussed before. The interesting thing is intersections, either positive or negative, in which effects are more and more explained by the event effect rather than the irregularities.

The next sub-section will discuss event window 2: WHO announced COVID-19 a pandemic.

(2) Event Window 2 - WHO Declaring COVID-19 Pandemic, March / April (2020)

The World Health Organization (WHO) declared COVID-19 a pandemic on March 30, 2020. So, although the event dates of this first and second event window are quite close those are not interfering with each other. This second event window starts on March 27 and ends on April 2.

On the next page the financials of this event window can be observed in table 3. It is especially interesting to have a look again at the day prior, the event date and the day after the event.

Table 3: Event Window 2 – Financials

	Days	**Actual Daily Average MWh Price**	**Forecasted Daily Average MWh Price**	**Individual Forecasting Error %**	**Absolute Mean Percentage Error %**
March 2020	27	INR 2,029.29	INR 2,322.70	-14.46	8.12
	28	INR 2,204.51	INR 2,216.29	-0.53	8.12
	29	INR 2,210.35	INR 2,161.05	2.23	8.12
	30	INR 2,151.67	INR 2,163.18	-0.53	8.12
	31	INR 2,121.15	INR 2,118.76	0.11	8.12
April 2020	1	INR 2,307.04	INR 2,134.34	7.49	8.12
	2	INR 2,499.07	INR 2,185.02	12.57	8.12

The financials within this second event window look entirely different than the ones in the first event window with massive financial effects caused by COVID-19. The individual forecasting errors in this event window are so small that those nearly perfectly track the actual daily prices per MWh. Such small errors could not be the effect of COVID-19 considering that the MAPE itself 8.12 % is.

This 'flatline' kind of situation could be explained by the moment in time. This second event study is exactly the week after the Indian government imposed the nationwide lockdown with its COVID-19 shock effects included. Indian citizens are now at home and entire businesses and industries are closed when the WHO its announcement reaches India. As explained in the first event window the closure of large industrial companies and decrease of demand exceeded the rise of demand in the domestic area. The WHO announcement in addition does not just affect India so the effect is not as directly impacting in comparison to its government imposing a lockdown.

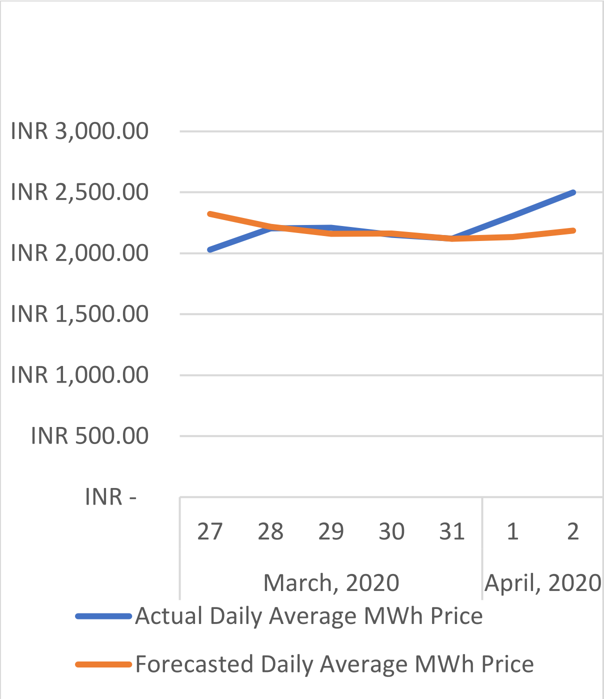
On the following page as in the first event window, the significance will be tested between the difference of actual- and forecasted prices.

Table 4: Significance Testing

t-Test: Paired Two Sample for Means		
	Forecasted	*Actual*
Mean	2185.906	2217.583
Variance	4656.417	22759.8
Observations	7	7
Pearson Correlation	-0.37016	
Hypothesized Mean Difference	0	
df	6	
t Stat	-0.44774	
P(T<=t) one-tail	0.335026	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.670051	
t Critical two-tail	2.446912	

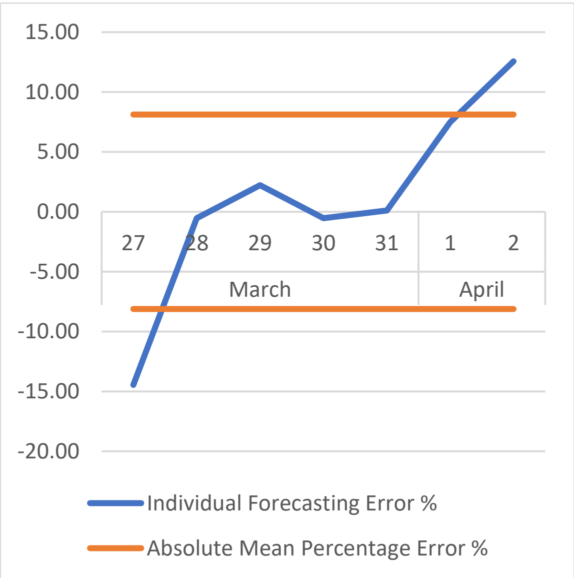
Null hypothesis: $\mu_d = 0$, Alternative hypothesis: $\mu_d \neq 0$ (two-tail). Excel calculations were used as can be seen in the table
P-value (two-tail): 0.67 > 0.05. So, there is not enough evidence to reject the null hypothesis. This means that the null hypothesis is accepted which says that the difference between forecasted and actual variables is not significant.

Graph 4: WHO Event Window – Actual vs Forecasted MWh Prices



Via the financials table at the beginning of this sub-section, it could already be seen that the differences between actual and forecasted price data were very slim. The significance testing showed the difference in prices were insignificant which the visualisation of actual vs forecasting in graph 4 shows once again. From 28 March to 31 March the daily average prices per MWh almost entirely intersect.

Graph 5: WHO Event Window – MAPE Error vs Individual Errors



In the visualisation in graph 5 the low individual forecasting error(s) are shown. It is interesting to see that the individual forecasting errors lay between the MAPE error(s) lines as said discussed in the first event window. This means that the individual forecasting errors are too small as briefly discussed for COVID-19 to be the cause of these individual forecasting errors.

Now, that the financial analysis of the second event window has been discussed it is time to move on towards the third and final event window.

<u>(3) Event Window 3 – Regional Lockdown, May (2021)</u>

The first two events both took place in March 2020 and were quite impactful in terms of their financials pre-, event date itself and after the event took place. In the news, various virologists have both been discussing COVID-19 ‘waves’. So, the novel virus seems to have peaks in terms of total cases (infected people) spread over some time. The reason behind these ‘waves’ consist of many factors in which one stand out which is the measures tightening and loosening. When cases seem to be in an downward trend citizens are expected to be granted more ‘freedom’ by the government in loosening the measures a bit. If cases seem to be in an upward trend the opposite is true. Especially in the former situation with loosened measures, it could cause a certain ‘snowball’ effect in which people that are infected rise exponentially.

During May some states independently imposed state lockdowns because of the volume of cases and the second wave in general. Because of the autonomy of the state, a lot of those lockdowns do not align with each other so it is difficult to measure the multitude of those. However, on May 8th the states of Karela and Tamil Nadu both imposed lockdowns. With populations of 33.4 million and 72.15 million respectively (Office of the Registrar General & Census Commissioner, 2011). National share of residents from India its total for both states combined is 8.72%. As mentioned before the IEX exchange divides India into multiple regions with states combined. Karela finds just itself in region S3 and Tamil Nadu finds itself together with other southern states in region S2. In the financial data and analysis that will follow it will be clear whether or not this message in those states had any impact on the pre, event date and after the event itself.

Table 5: Event Window 3 – Financials

	Day	Actual Daily Average MWh Price	Forecasted Daily Average MWh Price	Individual Forecasting Error %	Absolute Mean Percentage Error %
May 2021	5	INR 3,050.84	INR 3,283.27	-7.62	7.43
	6	INR 2,901.98	INR 3,254.73	-12.16	7.43
	7	INR 3,220.59	INR 3,183.41	1.15	7.43
	8	INR 3,087.37	INR 3,092.41	-0.16	7.43
	9	INR 2,902.04	INR 3,068.29	-5.73	7.43
	10	INR 3,051.09	INR 3,061.34	-0.34	7.43
	11	INR 2,808.35	INR 3,045.38	-8.44	7.43

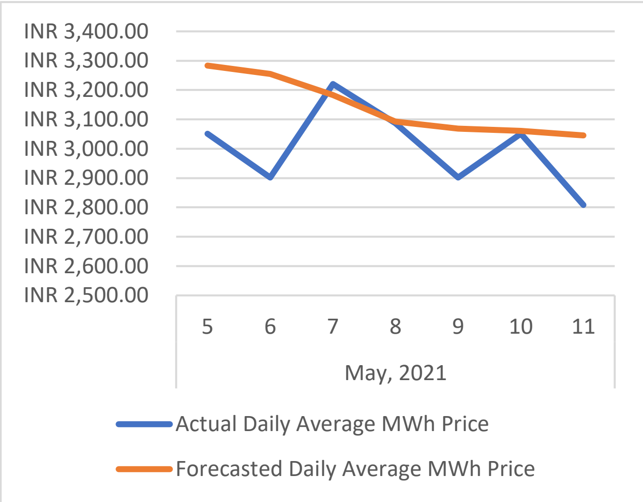
In the previous event windows, it could be seen that the first and second were quite different regarding their forecast errors. Now, it seems that this third event window can be grouped with the second event window. Since the 7th of May, 8th of May and 9th of May respectively have individual forecasting errors of 1.15 %, -0.16 % and -5.73 %. Once again these individual forecasting errors are quite low. It also seems just like the second event window that COVID-19 did not affect the daily average MWh prices within this event window all too harsh. Rather the individual forecasting errors could be explained by the irregularities and cyclical patterns.

Table 6: Significance Testing

t-Test: Paired Two Sample for Means		
	Actual	*Forecast*
Mean	3003.18	3141.261
Variance	19558.56	9685.005
Observations	7	7
Pearson Correlation	0.273286	
Hypothesized Mean Difference	0	
df	6	
t Stat	-2.47882	
P(T<=t) one-tail	0.023941	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.047882	
t Critical two-tail	2.446912	

Null hypothesis: $\mu_d = 0$, Alternative hypothesis: $\mu_d \neq 0$ (two-tail). Excel calculations were used as can be seen in the table
P-value (two-tail): 0.0479 < 0.05. So, there is enough evidence to reject the null hypothesis. This means that the alternative hypothesis is accepted which says that the difference between forecasted and actual variables is indeed significant.

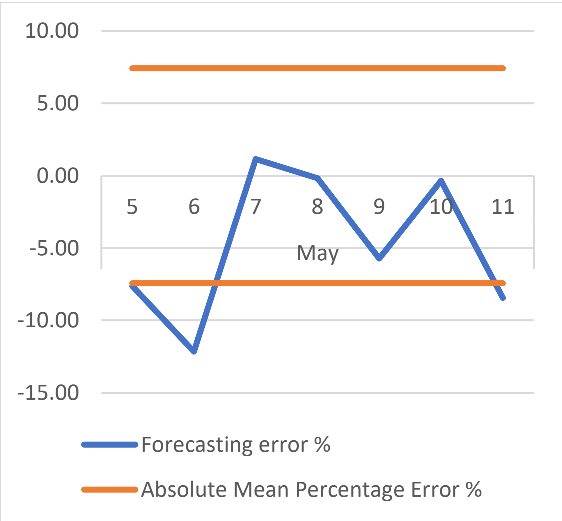
Graph 6: Regional Lockdown India Event Window – Actual vs Forecasted MWh Prices



Graph 6 once again shows the actual versus forecasted prices of daily average MWh prices. What can be observed is that from the 7th of May forward till the 9th of May there is a negative trend. Now, when taking a closer look it seems that the negative trend on the 8th of May accelerated the slightest bit.
The graph looks a bit like the one of the first event window. Now, this is not meant in absolute terms

because it does not show forecasting errors as high as 500 INR but rather in the range of 150 INR. However, the shape of the actual MWh price does to some extent resemble the one within the first event window. This can potentially be explained by the fact that in May 2021 COVID-19 has been more than a year around. It could mean that the situation in this third event window and the first event window can be considered 'normal' before those events happen. That is also why the pattern of the actual MWh prices seem to show an up and downward trend. However, it cannot be considered a clear cyclical pattern. As mentioned before it is entirely possible that with hourly MWh prices a clear cyclical pattern could be observed. As explained before this is not within the scope of this thesis.

Graph 7: Regional Lockdown India Event – MAPE Error vs Individual Errors



Graph 7 shows that on the 8th of May, the event day, there indeed is a downward acceleration of its trend which started on the 7th of May. As seen with the MAPE vs individual errors in the second event window the majority of errors in this third do not exceed that one of the MAPE.

5.2 Comparison between the events their financials

Now that the financials and the impact of the three events individually have been evaluated it is time to draw a comparison between the three events. So, what are the similarities and especially what are the differences in those financials?

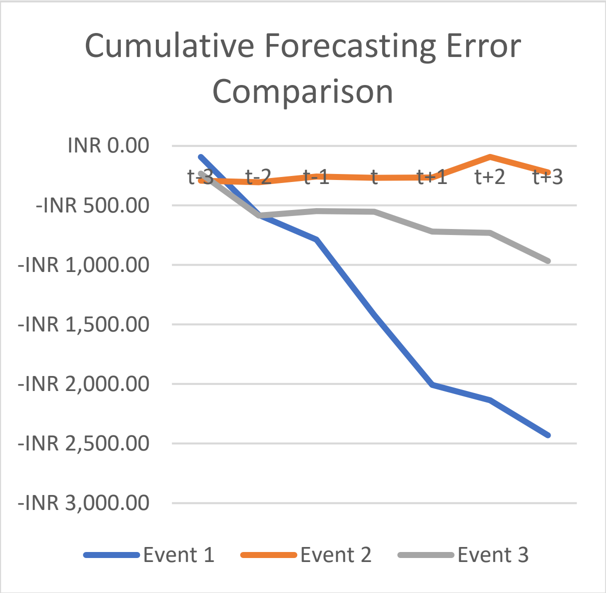
In Table 7 the differences in the percentage of forecasted and actual daily average MWh prices of the three events during the pre-event, the event itself and post-event days can be observed. These pre-event, event itself and post-event days could be categorized as; t-1, t and t+1 respectively. This categorization is convenient for making normalized comparisons between those days within the three separate event(s).

Overall when looking at the percentages of the individual events and days it can be observed that the imposed Lockdown (2020) in India by its government had the largest impact on the event day itself. The average daily MWh prices had a forecasting error of -31.6% which indicates actual prices were significantly lower than forecasted. Followed by the WHO event and the partial lockdown (2021) of several Indian states with forecasting errors of -0.53% and -0.16% respectively. Only for the first and third events, it is observed that the post-event forecasting error was quite substantial in comparison to the event. In event 1 the post-event forecasting error is -30.02% and in event 3 the forecasting error is -5.73%. Now, in the previous section, it was already mentioned briefly what was 'special' about event 2 which shows itself quite well in this comparison. The special aspect was the almost flatlining of the forecasting error. With 2.23%, -0.53% and 0.11% forecasting errors respectively to the dates within the event it can be considered as no financial effect of COVID-19. This was confirmed as well via the t-test which resulted in a non-significant outcome between actual and forecasted data.

Table 7: Event Window 1,2 and 3 Comparison – Individual Forecasting Errors %

Date	**Event 1**	**Event 2**	**Event 3**
t-1	-8.35	2.23	1.15
t	-31.6	-0.53	-0.16
t+1	-30.02	0.11	-5.73

Graph 8: Event Window 1,2 and 3 Comparison – Cumulative Forecasting Errors (absolute)



Now that a comparison has been made between the events their forecasting errors on the pre-event, event itself and post-event an interesting cumulative forecasting error comparison is made. In graph 8 above, the three events and their cumulative forecasting error paths have been shown. With paths, it is meant the entire event window reaching from t-3 till t+3. What can be observed is that event 1 had the largest amount of negative forecasting errors. This shows that when India imposed a lockdown (2020) indeed a financial effect of COVID-19 on the IEX day-ahead market were identified. For event 2 as discussed before the forecasting errors flatlined which can be observed nicely in this graph. It means that it is safe to say that the WHO announcing COVID-19 a pandemic did not have a financial effect on the IEX day-ahead market.

The third event window in this graph shows about the same 'flatline' as in event window 2 until its event date. After the event itself, a downward slope of cumulative forecasting errors starts to appear. However, the t-test showed that the actual data in the event was barely significant different from the forecasted prices. Now, the MAPE is measured over a year before the event this would give quite a well indicator of what the standard amount of error might be expected in a normal situation. Since in event 3 the individual average did not exceed the MAPE it is quite hard to say whether or not this could be the financial effect of COVID-19. As mentioned a few times before it could in this case be the effect of irregularities and some form of cyclical patterns rather than COVID-19.

After the individual analysis of the event and these event comparisons, the events themselves can be labelled following three categories: severe, mild, none concerning the financial impact. Event 1 showed that it deserved the severe label, events 2 and 3 are given the labels none and mild respectively.
In the upcoming final section, this thesis will be concluded and the discussed content is briefly mentioned again as a recap to set everything straight.

6. Conclusion

The financial analysis and the comparisons between the three events showed that the electricity prices during the first and third events were negatively impacted from severe to mild respectively. Within the first event-window on the event day itself forecasting error was found higher than -30%. In comparison the MAPE from the estimation period was only 8.12% (absolute value). The third event window is mildly impacted with a p-value that barely accepted the alternative hypothesis stating there is in fact a significant difference. The second event only showed a forecasting error 'flatline' which shows COVID-19 did not have a financial effect. Besides, there was not enough reason to reject the null hypothesis so the difference between actual and forecasted was not significant.

A possible explanation that applies to the differences of the events can be found in one of the studies that were mentioned in this literature analysis. The study Liu et al, (2020) analysed the COVID-19 related announcement disclosures by a few European and Asian countries and its interplay effect. So, to what extent are European countries financially negatively impacted by COVID-19 announcements within an Asian country. It showed that European countries, in general, did not notice any adverse financial effects. Financial effects only start appearing when COVID-19 made its introduction in a European country.
This explains why India its nationwide lockdown in the 2020 event had the largest adverse financial effects because uncertainty was high and the government had to take some form of action immediately. The WHO announcement event took place after India its government already announced a nationwide lockdown. Therefore uncertainty was already high and the shock would not be as adversely impacting. Also, this WHO announcement event is not just directed towards India but rather internationally thus no immediate action is required. India it's partially lockdown 2021

of several states only had a mild financial effect from which causality with COVID-19 is not clear at all. It has to be said that this is a partial lockdown of a few states and the timespan since COVID-19 has been over a year now. This means that there is a sense of what to expect and the federal government is not involved but rather the state(s) government which reduces magnitude and uncertainty.

7. Discussion

This thesis used a nonseasonal form of forecasting. This method was chosen because the daily average MWh prices did not show any cyclical patterns and thus seasonal forecasting was not quite applicable. It is not applicable because this thesis is focusing on average daily prices rather than average hourly prices. To extract hourly prices from the IEX database would be too time-consuming and does not fit within the scope of this thesis.

It should be said that the hourly prices do show cyclical patterns and can then use seasonal forecasting methods. In such a method the data is decomposed into; Irregular-, Seasonality- and Trend component. Then these components are used to forecast prices that account for these components. This could mean that forecasts are closer to the actual prices, then the MAPE might be lower. Eventually, this could mean that when COVID-19 has a financial effect it will be shown since it now can exceed the MAPE more often rather than staying within the MAPE. In essence, mild financial effects, in this case, could be assigned to COVID-19 with more confidence.

For further research, this concern is something that should be considered before setting up the study and gathering data.

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9. Appendix A

Indian Power Market History

In 2014 the IEX issued a report which explained what had been done to that point and what future scenarios may be encountered (IEX report 2014 – Journey So Far and Way Forward). Now, in this section the ‘Journey So Far’ is of great importance since it would be interesting to see how the IEX power market was set up and what factors have played a role in this.

Before the power exchange was introduced electricity was mainly traded via so-called ‘long-term contracts’. The long duration of these contracts both has advantages and disadvantages in terms of optimal market functioning. These contracts involve the hourly electricity needs and supply. For industrial companies for instance these contracts do provide certainty in terms of electricity supply to sustain their operations in the long run. On the other hand, these industrial companies do not have the flexibility to react to adjustments in their operations, in essence, a lack of agility. So, excess electricity cannot be stored and shortages cannot be replenished. This means that in essence, the drawbacks might be greater than the benefit of electricity certainty. With certainty here, it is meant the availability of electricity not the amounts of electricity. These drawbacks of excess and shortage are mainly caused by the fact that it is quite hard to predict electricity needs for every hour in the long run.

The power market back then looked entirely different in comparison to the contemporary structure of the power market. Up to 1990 the generators, distributors and transmission-related actors of electricity were all owned by the state(s) or were separate companies that had to follow the government its regulations (Next – Kraftwerke, 2021). After 1990 in quite a bit of the European countries the power market was analysed and researched regarding restructurings of the sector. The first European country to launch a liberalized power exchange was England in 1990.
This conventional state-owned and controlled power market was also the status-quo for India as well until the government decided it was time for a shift in the power sector. In the IEX report, it was mentioned that an act was issued which would ‘liberalize’ the power sector and enhance the competition within the sector. These new reforms fall under Electricity Act 2003. ‘Liberalize’ in this context could be defined as providing freedom (from a governmental perspective) to industrial companies, private generators and distributors to act on their behalf. As said liberalizing of sectors is done in the hope of increasing the competition which tries to increase investments and innovations. These investments and innovations are needed to let the sector be as efficient and allow for growth. Adam Smith, an 18th-century great economist, is especially known for a concept which is called the ‘invisible hand’. The invisible hand is compromised of two factors; competition and self-interest (Federal Bank of St Louis). Although at first, it seems producers and consumers do not act in the interest of the greater society they tend to do so in practice.
Here is an example: “The bread you buy at the store arrived as the result of hundreds of self-interested people cooperating without a government bread agency managing production at each step along the way. The farmer grew the grain, the mill prepared the flour, the bakery produced the bread, the truck driver delivered the bread to the grocery store, the grocer stocked the shelves and sold the loaf to the consumer all without a Government Secretary of Bread Production telling any of them what, where, when, or how much to produce. It's as if they were being guided by an invisible hand that guided resources to their most valued use” (Federal Bank of St Louis). This invisible hand could be seen as an ‘invisible’ force outside of government its control that regulates sectors/markets.

After the liberalization of the power market within India in 2003, there is still not a power exchange where traders can trade electricity in the short term. From the IEX report, it shows as well that in 2006 CERC (regulatory body electricity market) issued a staff paper in which the initial development of the exchange is communicated. Following in 2007 the guidelines regarding specifics about setting up of the exchange is communicated. In 2008 advancements were being finalized when CERC issued information about the guidelines regarding transactions and collective transactions for all participants on the exchange. Finally from the report, it becomes clear that the IEX power exchange was implemented and fully operating on June 27 2008.