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Impacts of COVID-19 on Industrial Growth in the United States

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Introduction

When the coronavirus disease (COVID-19) pandemic was first reported in Wuhan China, it began a catastrophic disruption across 215 countries and areas with many sectors of industry disrupted or halted all together.[1] With 90% of global trade occurring in the shipping sector and being essential for international trade, there was a 25% decline in revenue observed in the first half of 2020 with many European and Asian countries shutting down entirely.[2] Many unexpected and unprecedented effects on the United States economic policy and the stock market volatility have been studied with finding that during the period between 24th of February and the 24th of March 2020 there were 18 stock market jumps with 16 having a “bad news” response that has been attributed to the COVID-19 outbreak or related policies in response to COVID-19 by the US government.[3]

With hundreds of thousands of people now being stuck at home, the hospitality and travel industries were facing reductions of over 90% in demand impacting not only those workers but also the manufacturers of automotive and aeronautic parts and materials along with financial institutions supplying loans for people to buy cars.[4] There have been many major changes in various industries and businesses over the last three years, but what were the trends going to be without consideration of COVID-19 happening? What businesses had the most impact and change from COVID-19?

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[1] Noraida Darom et al, “An inventory model of supply chain disruption recovery with safety stock and carbon emission consideration,” *Journal of Cleaner Production* Vol. 197, Issue 1 (2018): Pages 1011-1021, https://doi.org/10.1016/j.jclepro.2018.06.246.
[2] S.M. Mizanur Rahman, Junbeum Kim, and Bertrand Laratte, “Disruption in Circularity? Impact Analysis of COVID-19 on Ship Recycling Using Weibull Tonnage Estimation and Scenario Analysis Method,” Resources, Conservation and Recycling 164 (January 2021): 105139, https://doi.org/10.1016/j.resconrec.2020.1
[3] Arshian Sharif, Chaker Aloui, and Larisa Yarovaya, “COVID-19 Pandemic, Oil Prices, Stock Market, Geopolitical Risk and Policy Uncertainty Nexus in the US Economy: Fresh Evidence from the Wavelet-Based Approach,” International Review of Financial Analysis 70 (July 2020): 101496, https://doi.org/10.1016/j.irfa.
[4] Jan Jakub Szczygielski et al., “The Impact and Role of COVID-19 Uncertainty: A Global Industry Analysis,” International Review of Financial Analysis 80 (March 2022): 101837, https://doi.org/10.1016/j.irfa.2021.101837.

There are many other external factors that have caused changes in revenue and profitability for the various industries that are going to be discussed later in this report, but the primary intention is to:

a. Determine the difference between forecast and actual on average for revenue and profit, respectively, that occurred during the COVID-19 outbreak.
b. If those major changes can be related to COVID-19 directly or indirectly through research and forecasted analysis

Literary Review

In this section, we conduct a literature review of different studies that have been conducted on COVID-19 impacts on supply chain and financial disruption risks. Based on the current literature below, we will identify knowledge gaps and highlight the contributions of this study.

Supply Chain and Consumerism Risks

During the beginning of the pandemic, there was a substantial amount of panic buying that occurred, which in turn lead to a drastic and unpredicted increase in demand of certain items such as soap, toilet paper, or preserved/canned food.[5] With people buying these essential items in very large quantities with limited restrictions from supermarkets, this left people that had limited ability to get to the stores like the elderly empty handed.

Now there are many ideas and suggestions to solve this problem using modeling methods for a potential future pandemic, but nonetheless these solutions were not used during the beginning of the pandemic as they were not developed yet. Many of the supply chain losses that

[5] Sanjoy Kumar Paul, "Strategies for Managing the Impacts of Disruptions During COVID-19: An Example of Toilet Paper," SpringerLink, July 12, 2020, https://link.springer.com/article/10.1007/s40171-020-00248-4?utm_source=getftr&error=cookies_not_supported&code=b06f4e6b-7f0a-4b58-b3ea-5ec287b57cbe.

occurred, especially during the initial months of the pandemic, are also dependent on the restrictions that countries imposed and the approaches that were put in place once a country decided to start lifting those restrictions.[6] Our research will solely focus on the companies that are headquartered in the United States, so we will look at the United States Occupational Safety and Health Administration (OSHA) federal guidelines on COVID-19 worker safety and health.

OSHA gives a definition of "At-Risk Workers" as those who are immune compromised individuals who should limit physical contact with others regardless of their vaccination status or the vaccination status of other employees they may be interacting with.[7] They also go into detail about personal protection equipment (PPE) that all workers should be wearing regardless of vaccination status, maintaining proper social distance, and quarantining when exposed or positive with COVID-19.[8] All of the limitation above though were adopted under the "mandatory OSHA COVID-19 Temporary Standard," but the word "mandatory" was more of a suggestion and not a legitimate requirement.[9]

Job Market Risks

With all these shifts in workplace restrictions and spacing, a majority of companies shut down or went completely remote for an unknown period of time. In July 2020, there were 9.6 million people of the total 16.9 million unemployed because their employer was forced to close or lost business due to the pandemic.[10] With a majority of those that were unemployed during the first six months of the pandemic, the unemployment rate from 3.6% in the fourth quarter of 2019

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[6] Dabo Guan, "Global Supply-Chain Effects of COVID-19 Control Measures," Nature, June 3, 2020, https://www.nature.com/articles/s41562-020-0896-8?error=cookies_not_supported&code=1d5f1877-f169-445a-abce-c779b26a59b4.
[7] "Protecting Workers: Guidance on Mitigating and Preventing the Spread of COVID-19 in the Workplace | Occupational Safety and Health Administration," n.d., https://www.osha.gov/coronavirus/safework .
[8] ibid
[9] ibid
[10] "Effects of the Coronavirus COVID-19 Pandemic (CPS): U.S. Bureau of Labor Statistics," December 6, 2022, https://www.bls.gov/cps/effects-of-the-coronavirus-covid-19-pandemic.htm.

to 13.0% during the second quarter of 2020.[11] The inflation rate was also 3.6% higher annually in 2021 than 2020 which has led to a dramatic shift in cost of services and goods for not only the conventional consumer, but also for the manufacturing and financial services along with many others.[12]

Social Media and News

There have been a conglomerate of news articles and reports on the disruptions that have occurred in supply chains ranging from demand increases for goods such as toilet paper and economic instability causing interest on loans to increase.[13] Many news articles discussed the change that is happening with companies returning to "normal operations and restrictions," but using their resilience and efficiency to reduce operational stress into the main view of things.[14] Lead times for necessity items increased along with the demand at such a rate that companies were unable to prevent bottlenecks from occurring.[15] With all these bottlenecks occurring and the demand increasing at such a drastic rate, the prices of the effected items skyrocketed upwards.[16]

Knowledge Gaps

With the COVID-19 pandemic causing drastic shifts in the global economy with countries shutting down and massive layoffs, the existing research and studies on supply chains and COVID-19 have not yet analyzed what the current industry outlook was going to be if the

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[11] Sean M. Edwards Smith, "Unemployment Rises in 2020, as the Country Battles the COVID-19 Pandemic: Monthly Labor Review: U.S. Bureau of Labor Statistics," June 10, 2021, https://www.bls.gov/opub/mlr/2021/article/unemployment-rises-in-2020-as-the-country-battles-the-covid-19-pandemic.htm.
[12] Lee Smales, "Investor Attention and the Response of US Stock Market Sectors to the COVID-19 Crisis," Emerald Publishing 13, no. 1 (November 23, 2020): 20–39, https://doi.org/10.1108/RBF-06-2020-0138.
[13] "COVID-19: Impact on the Banking Sector," KPMG, June 24, 2020, https://kpmg.com/xx/en/home/insights/2020/07/covid-19-impact-on-banking-m-and-a-2020.html.
[14] Sean Harapko, "How COVID-19 Impacted Supply Chains and What Comes Next," EY - US, January 6, 2023, https://www.ey.com/en_us/supply-chain/how-covid-19-impacted-supply-chains-and-what-comes-next.
[15] The White House, "Why the Pandemic Has Disrupted Supply Chains," The White House, November 30, 2021, https://www.whitehouse.gov/cea/written-materials/2021/06/17/why-the-pandemic-has-disrupted-supply-chains/.
[16] House, "Why the Pandemic Has Disrupted Supply Chains."

COVID-19 epidemic never occurred. Moreover, what industries in the United States saw extreme growth or loss if any. Hence, the forecasting strategies used in this article will consider trending and seasonality of various industries and companies to try and determine if there were drastic changes in the quarterly sales and profits. At which point, we will investigate the global and country situations that might have contributed to these changes and if they can be associated to COVID-19 procedures and fallouts. With the prices of raw materials and transportation of materials increasing, the existing literature also fails to address how these disruptions and major shifts from COVID-19 ate into the bottom line for many industries even with seeing record high sales for some.

Dataset Acquisition and Creation

Using the Forbes Global 2000 companies list as the beginning of the dataset we created, we took the top 100 companies according to Forbes ranked on their methodology list and filtered to only have the companies that are based in the United States.[17] The timeframe of their yearly financial data is from April 22 to April 22 of the following year, so the data for 2022 is the financial statements from April 22, 2021 to April 22, 2022. Forbes collected their data from the databases of FactSet Research systems and then cross verified with financial data using other sources and any available company financial statements[18]. We are not relying on or factoring in the ranking given to each company, but solely looking at the first 100 companies as they are listed and creating a convenience sample of data from the list generated by Forbes. We have found the datasets from the Forbes Global 2000 list of annualized data for the years 2009 – 2022

[17] Isabel Contreras and Andrea Murphy, "Forbes Global 2000," Forbes, May 12, 2022, https://www.forbes.com/lists/global2000/?sh=3de5a22b5ac0.
[18] Isabel Contreras and Andrea Murphy, "Inside The Global 2000: Sales and Profits For The World's Largest Companies Are Soaring As Economies Reopen," Forbes, May 12, 2022, https://www.forbes.com/sites/isabelcontreras/2022/05/12/inside-the-global-2000-sales-and-profits-of-the-worlds-largest-companies-recovered-as-economies-reopened/?sh=2be5b82d1141.

and created a complete dataset for our use using the above description and exclusions labeling each point by year. This however did not feel like enough data to work with for a more accurate forecasting plot, so we created a subset version of it.

Our next created data set is collected from specific companies themselves or macrotrends.net. We have collected the quarterly data for the same companies as collected from the Forbes annual dataset created above for revenue and profit. This then took us from about 13 data points to 56 data points total, which makes for a more accurate overall forecast. Having more points allows us to track for any trending over a shorter time frame and keep from any large spikes or drops from being missed in a yearly averaging.

Classification and Categorization

To fairly analyze companies that are in different sectors of industry, we have recorded the North American Industry Classification System (NAICS) codes for each company and found a total of 59 different classification codes.[19] From there, we took the Cybersecurity and Infrastructure Security Agency (CISA) identification list of critical infrastructure and infrastructure protocols during COVID-19 to consolidate the NAICS classes from 59 to nine different sectors using CISA's identification.[20]

Methodology and Analysis

Our analysis will be on the average sales and profits of each sector and using various forecasting methods of the quarterly data to look at the actual vs. the forecasted values. The forecasted values will not include the values starting at Q2 of 2020 until Q4 of 2022 so that we can properly analyze any trends from before the virus began spreading internationally and major

[19] "North American Industry Classification System (NAICS) U.S. Census Bureau," n.d., https://www.census.gov/naics/?58967?yearbck=2022.
[20] "Critical Infrastructure Sectors | CISA," n.d., https://www.cisa.gov/critical-infrastructure-sectors.

shutdowns began in the United States. We will create and compare three different forecasting methods: double exponential smoothing, and autoregressive model AR (1). The double exponential smoothing model is being used due to its ability to calculate and untrended and a trended point for each forecast point to be able to. The reasoning behind only doing an AR(1) model is due to how small the dataset is and it is the simplest model in time series. The forecasting methods will calculate the forecast from Q1 of 2009 until Q1 of 2020 to predict how the next two years will turn out based on the historical data to compare to the actual of COVID-19. The following methodology will proceed as follows:

1. Industry Breakout with COVID-19 Data – Revenue
2. Industry Breakout without COVID-19 Data – Revenue
3. Industry Breakout with COVID-19 Data – Profits
4. Industry Breakout without COVID-19 Data - Profits

Double Exponential Smoothing

To calculate the double exponential smoothing model for revenue with COVID-19 data, we have broken up each sector by quarters and taking the average revenue generated in a quarter. We are using the two formulas to calculate the untrended forecast and the trend variable.

$$S_t = (A_{t-1} * \alpha) + (1 - \alpha) * (S_{t-1} + b_{t-1})$$

$$b_t = \gamma * (A_{t-1} - S_{t-1}) + (1 - \gamma) * b_{t-1}$$

$$S_0 = A_0$$

$$b_0 = 0$$

$$0 \leq \alpha \leq 1, 0 \leq \gamma \leq 1$$

With t being the current quarter and $t-1$ being the 1 lag period, S_t being the untrended forecast, b_t being the trend variable, and A_{t-1} being the 1 lag actual average. Alpha (α) and

Gamma (γ) are two chosen constants that will be calculated using the minimum mean squared error value summation.

Once the actual averages are calculated for each quarter and we assign $\alpha = 0.5$ and $\gamma = 0.5$ for now. Taking the first untrended forecast equal to the first quarterly average, we can then begin calculating the untrended forecast for the remaining periods. Once all the quarters have been calculated for untrended forecast, we can begin calculating the trend variable. Starting with the first trend variable equal to zero, we can again begin calculating the trend variable for the remaining periods. The complete forecast, F_t, for each quarter then becomes the summation of each period untrended forecast and trend variable, shown below.

$$F_t = S_t + b_t$$

Once the complete forecast is adjusted, we can begin working out the error between the actual average revenue versus the predicted revenue. Then from there calculated the mean squared error and summing it using the following formulas:

$$E_t = A_t - F_t$$

$$\varepsilon(MSE) = \varepsilon(E_t^2)$$

Once the summed MSE is calculated, we can use the solver add-on in Excel to change α and γ to get the minimum MSE summation. This procedure will be completed for each of the nine industries in our dataset.

To complete the second portion of the revenue analysis by sector, we will complete the same initial steps of calculating the averages, untrended forecast, and trend variable for all quarters until Q2 of 2020. At that point we will use our adjusted F_t formula to calculate the forecasted values from Q2 2020 until Q4 2022

$$\hat{F}_{t+m} = S_t + m * b_t$$

With m being the number of periods from t and t being a chosen start point; in this case we will be using $t = 0$ at Q1 of 2020 since that is the most recent data without too many implications and restrictions from COVID-19 as this was when it was just starting to spread but things hadn't changed or shut down too much.

A confidence interval has also been generated around the forecasted values of what should have happened during Q2 2020 – Q4 2022 based on the historical data. First calculating the standard deviation of the forecasted lines without the COVID data, getting a count of the number of rows in each sector and choosing the significance level to be 0.05. Using the confidence function in Excel, we can add and subtract that from the values generated by the forecasting function above for Q2 2020 through Q4 2022 to get a 95% confidence interval range for each quarter around our forecasted value of what would have happened based on historical trending and values.

For parts three and four of this methodology, we will do the same respective parts as we did for revenue but with the profits data for each industry. Then calculating the confidence intervals for each industry around the forecasted line without the COVID-19 data.

For the outlook of what revenue will look like with COVID-19 settling down and restrictions lifting, we will use:

$$\hat{F}_{t+m} = S_t + m * b_t$$

Similarly, as before when predicting what revenue and profit should have looked like without COVID-19 based on historical data. We will only be doing this for revenue as profit is contingent on revenue and not as value added when predicting versus comparing to actual average during COVID-19 versus what should have happened without COVID-19.

<u>Stationarity and Time Series Analysis</u>

To calculate the time series AR(p) model for revenue with COVID-19 data, we have broken up each sector by quarters and taking the average revenue generated in a quarter.

First order autoregression process, AR (1), if defined as

$$X_t = \phi * X_{t-1} + \epsilon_t$$

Where $\epsilon_t \sim WN(0, \sigma^2)$

Φ is a real-valued constant. ϵ_t is the only random error generated each time and $WN(0, \sigma^2)$ is a wrapped normal distribution.[21]

Stationarity of a model involves three parts. Those are: Mean does not depend on time, Variance does not depend on time, and correlation does not depend on time. There are three tests that can check for if a time series is stationarity. The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test has the null hypothesis of the time series is trend stationarity and the alternate hypothesis of the time series is not stationarity. A large p-value means "stationarity." The second test for stationarity is the Augmented Dickey-Fuller test (ADF). ADF has a null hypothesis of Y_t is not stationary and an alternative hypothesis of Y_t is stationary. Y_t is the stationary error. A small p-value rejects the null hypothesis of non-stationarity and means "Stationary." The third test for stationarity is the Phillips-Perron (PP) test. It has the same hypothesizes as the ADF test, so a small p-value means "Stationarity."[22] In RStudio, the Stationarity.tests() can be used to see if all the tests indicate stationarity for a time series. Large, small, small means all three indicate stationarity, small, large, large indicates non-stationarity. Any other combinations of results from these tests are conflicting conclusions and are inconclusive. If the data is non-stationary, it cannot be forecasted using traditional time series models. Transformation must be done to the data in order to flatten the variance.

[21] Nao Mimoto, "477/577 TimeSrs," n.d., https://nmimoto.github.io/477/index.html.
[22] ibid

The two types of transforming are either differencing or logarithmic transforms. Differencing helps stabilize the mean of the time series and differencing helps eliminate trend and seasonality. The first-order difference transform involves using the data point at the current time and subtracting it with the point before. It results in the difference between points at time t. Logarithmic transform takes the log of each point and changes the data into a logarithmic scale.[23] Stationarity needs about 200 data points to trust Stationarity.tests(). Due to having a small scope for each sector and not enough data points, we assumed stationarity to create a time series model.

The data can be clearly non-stationary and a time series model can still be created. The model can be created as a linear regression and AR(1) model.

The following was done in RStudio for each of the nine models involving revenue for each sector. The average for each quarter was done by taking the sum of revenue for the quarter divided by the number of companies in the given quarter. The data has 56 data points for each model. The data was transferred into RStudio and converted into a time series with a frequency of 4 (Quarter) and starting at (2009,1) which is the starting point of the graph. Stationarity.tests() were performed on each model but due to having a small scope we could not trust the tests. The ACF and PACF of each model were plotted. The ACF is the autocorrelation factor and PACF is the partial autocorrelation factor. Auto.arima function allows us to find the best AR(p) model for the data. ARIMA(p,d,q) allows to change p by setting d and q to zero. In ARIMA(p,d,q), p refers to the number or order of autoregressive (AR) terms, d refers to the number or order of differences, and q refers to the number or order of moving average (MA) terms. Auto.arima reports the best model by finding the model with the lowest AICc. AIC is the Akaike information criterion (AIC). AICc is the sample-size adjusted formula for AIC. The smaller the AICc, the

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[23] Rayhaan Rasheed, "Why Does Stationarity Matter in Time Series Analysis?," Medium, December 15, 2021, https://towardsdatascience.com/why-does-stationarity-matter-in-time-series-analysis-e2fb7be74454.

better the model fit. The next process was to fit AR (1) with non-zero mean to the data. The parameters were determined significant if its significance level is below the alpha level of .05. We used this alpha because it is the industry standard. This helped determine how good our model would be at forecasting. After this randonness.tests(Fit$resid) were performed to test the residuals for randomness, conditional heteroscedasticity, and normality. The randomness test is a custom function created by Dr. Mimoto, to test the model's residuals for randomness, conditional heteroscedasticity, and normality. The reasoning for the randomness test is to ensure series is uncorrelated, the square of the series is also uncorrelated and the series comes from a normal distribution. Finally, the AR (1) model was forecasted with the forecast() function and plotted with the mean of the data and a 80% and 95% confidence intervals for the following quarters. The model was compared to what happened versus what should have happened if COVID-19 did not happen. These coding steps were performed in each sector and for steps three and four regarding the profit data to create time series models. The time series models were compared to the double exponential smoothing models to see which ones better accurately predicted revenue and profit based on what actually happened.

Results

Revenue

Taking the average difference between actual average quarterly data versus the forecasted values without COVID-19 data. We get Figure 1.1 on the right showing that the biggest difference is in the energy sector. The next closest differences on average are in transportation, communication, food and agriculture. However, looking at

Industry	Error Percentage between Actual vs Forecasted
Chemical	8%
Commercial Facilities	4%
Communication	15%
Energy	112%
Financial Services	6%
Food and Agriculture	20%
Healthcare	1%
Manufacturing	12%
Transportation	17%

Figure 1.1: Average difference between quarterly points from Q2 2020 – Q4 2022

Appendix A for food and agriculture average revenue vs forecasted values, we can see that the actual average revenue generated per quarter is much more sporadic and irregular for this modeling method and we will not be discussing it in terms of exponential smoothing or time series analysis even though it has a 20% difference between actual revenue on average and forecasted revenue without COVID-19 data. Instead, we are going to focus on manufacturing as looking at Appendix B, we can see that the increase in actual revenue on average has a similar slope compared to the actual revenue generated by the transportation industry.

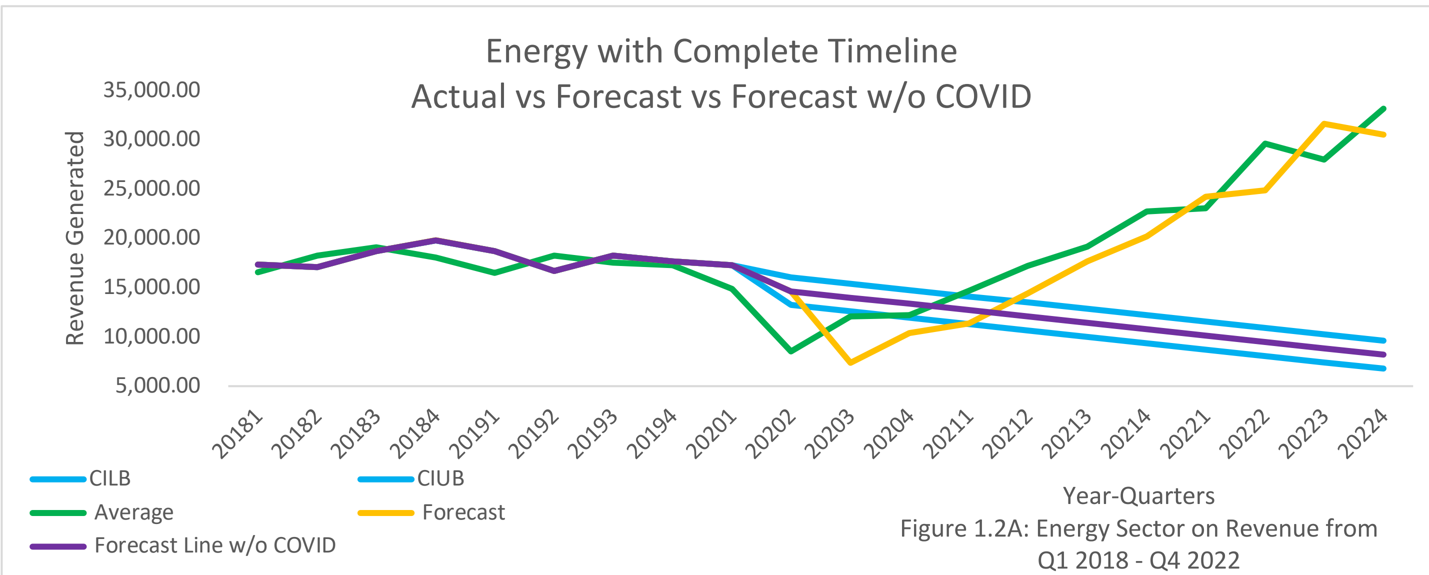

Figure 1.2A: Energy Sector on Revenue from Q1 2018 - Q4 2022

Looking at a snapshot of the entire dataset plot of the forecast from 2018 – Q4 2022) for the energy industry, we can see that in Figure 1.2A and Figure 1.2B there was as step decline in energy at the start of 2020 and into the beginning of COVID, so the forecasted model is showing that decline and the predicted values based on the historical data. From the methodology for the time series analysis, we calculate a Φ value of 0.9278 which is used for this prediction gives us a significance value of 0.0494; below our alpha value of 0.05. So that, in collaboration with the double exponential smoothing model, we can determine that our forecasted outcomes are statistically significant and accurate.

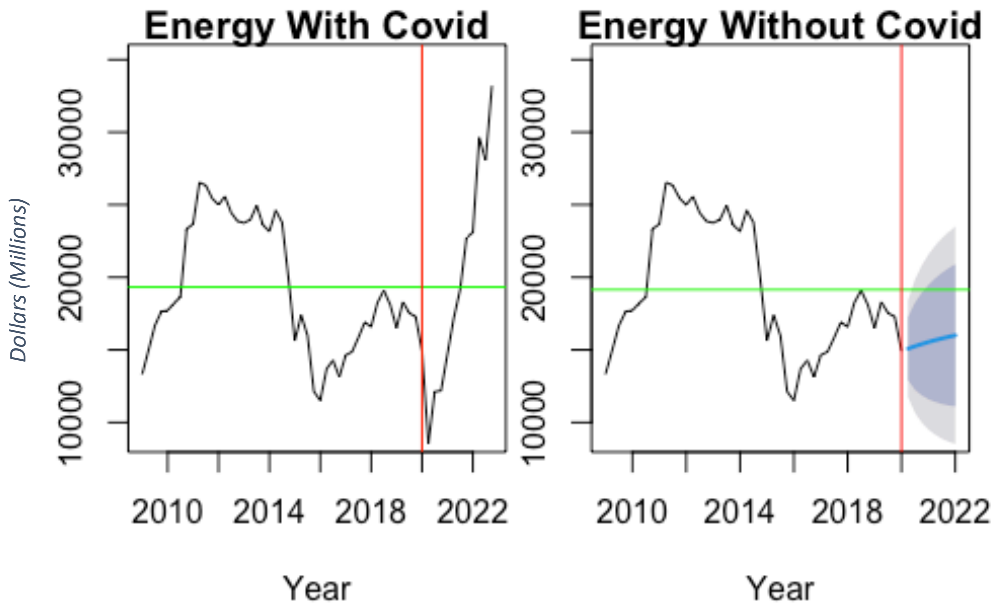

Figure 1.2B: Time series model on energy sector for revenue with complete timeline from 2009-2022. Green line represents the mean of the energy sector and the red line represents when Covid occurred

The confidence intervals show that if COVID-19 had not happened, the energy industry would not have reached the current high spike. It would have been a gradual or stagnate rise versus the steep drop off and then immediate spike. In fact, since 2011, the energy industry has been slowly decreasing in overall revenue, so now the question becomes: what caused this major increase in energy sales? As discussed earlier in the article, during the beginning of COVID-19 millions of Americans were at home working or having nothing to do but stream new shows and this use grew their energy bill. While less people were out driving and during the early weeks we saw fuel prices at their lowest level in decades, natural gas prices in Europe and Asia have caused the fuel prices in the US to triple since October 2020 to reach higher levels than during the recession of 2008.[24] With most natural gas and crude oil imported into the US from countries that experienced much stricter and limiting COVID-19 policies, when the US employees and employers began commuting and/or using more electricity that demand increased drastically.[25]

[24] "What Is behind Soaring Energy Prices and What Happens next? – Analysis," IEA, n.d., https://www.iea.org/commentaries/what-is-behind-soaring-energy-prices-and-what-happens-next.
[25] ibid

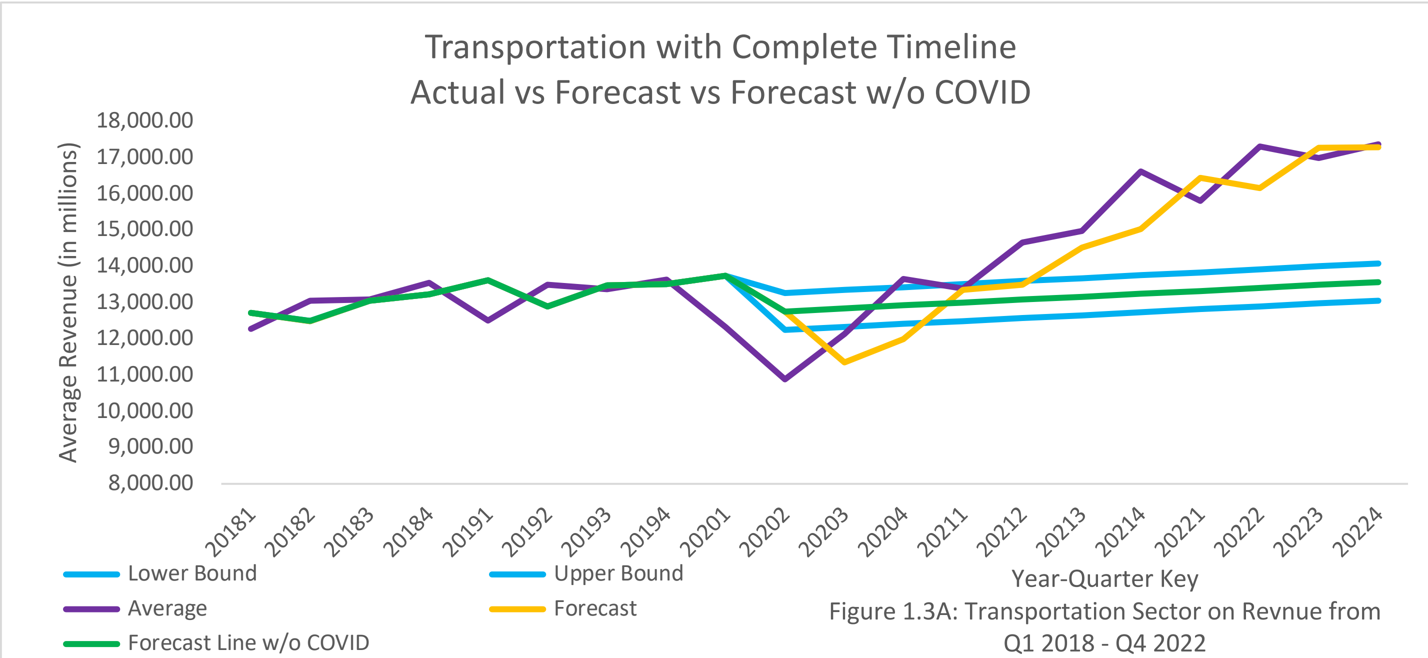

Figure 1.3A: Transportation Sector on Revnue from Q1 2018 - Q4 2022

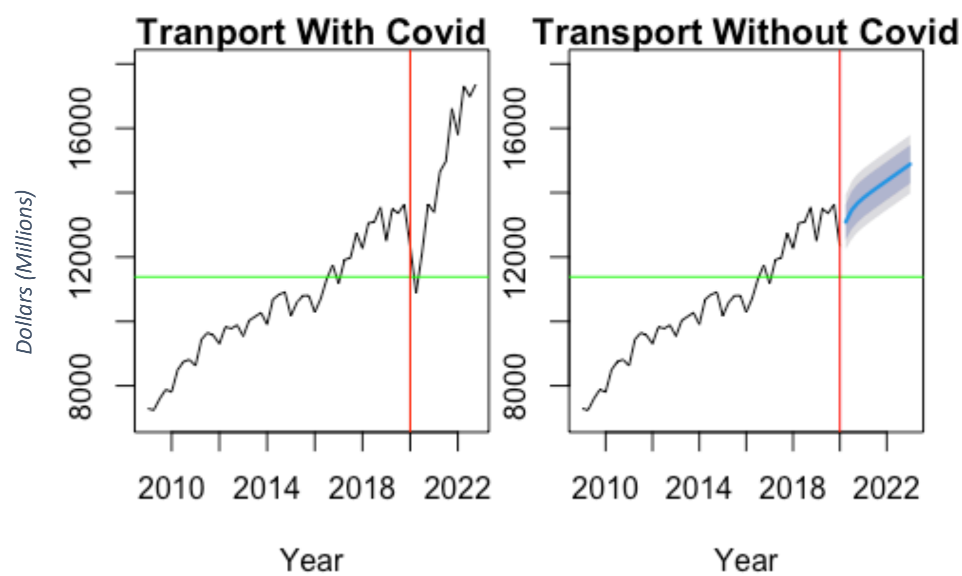

Figure 1.3B: Time series model linear regression and AR(1) on transportation sector for revenue with complete timeline from 2009-2022. Green line represents the mean of the transportation sector and the red line represents when Covid occurred

Moving to the transportation industry and viewing Figure 1.3A and Figure 1.3B of actual versus forecasted values like Figure 1.2A and Figure 1.2B, respectively. We can see the demand was trending steadily upward until the beginning of COVID-19 during Q2 of 2020 with a decline and then a steady increase in revenue and exceeding all previous revenue generated since Q1 2009. The forecasted value excluding the COVID-19 data does continue that small linear trend up as the previously forecasted data shows, but the rate at which that upward trend shifts quarter by quarter is drastically higher since

COVID-19. The time series model, Figure 1.3B, had a *Φ* value of .3773 and a significance level of 0.1484 which is greater than our α threshold of 0.05. It a intercept of -1025823.41 and a regression value of 514.4376. However, the model from Figure 1.3B is not the best fit due to the parameters not being statistically significant. Time series AR(1) models can only be accurately interpreted with data that has about 200 data points and no trend to the data but if you do have linear trend you can fit with linear regression to get a better model. We can compare the model from Figure 1.3B to the model on financial services, Appendix C, which has little-to-no trend found and is more appropriate for time series analysis. That does not invalidate the conclusions and reasoning below, however it does mean that we will rely on the double exponential smoothing model for all forecasting and reasoning for the transportation industry.

As discussed with the Energy sector's dramatic revenue dramatic increase, fuel prices have tripled and continued to increase since 2020 and that would have a major impact for freight and logistics transportation business terms.[26] Transatlantic costs have double and transpacific costs have tripled in 2021 along with many major retailers projecting another 10-20% growth of these costs as the providers are charging more. [27]The demand for motor transportation has seen a huge increase since the beginning of 2020 as it has become more cost effective than rail or ocean shipping overseas, and in doing so we can see the revenue generated by this industry grow in turn.[28]

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[26] ibid
[27] Michael Zimmerman et al., "Out of Sync," State of Logistics 33 (June 21, 2022).
[28] ibid

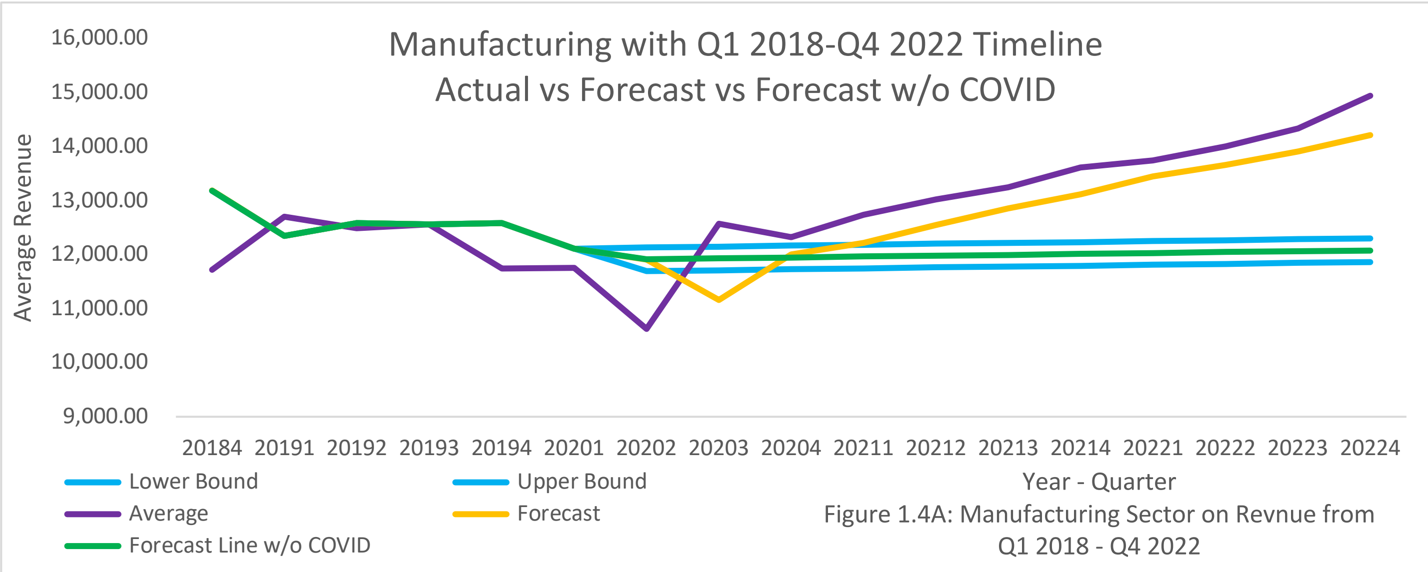


Figure 1.4A: Manufacturing Sector on Revnue from Q1 2018 - Q4 2022

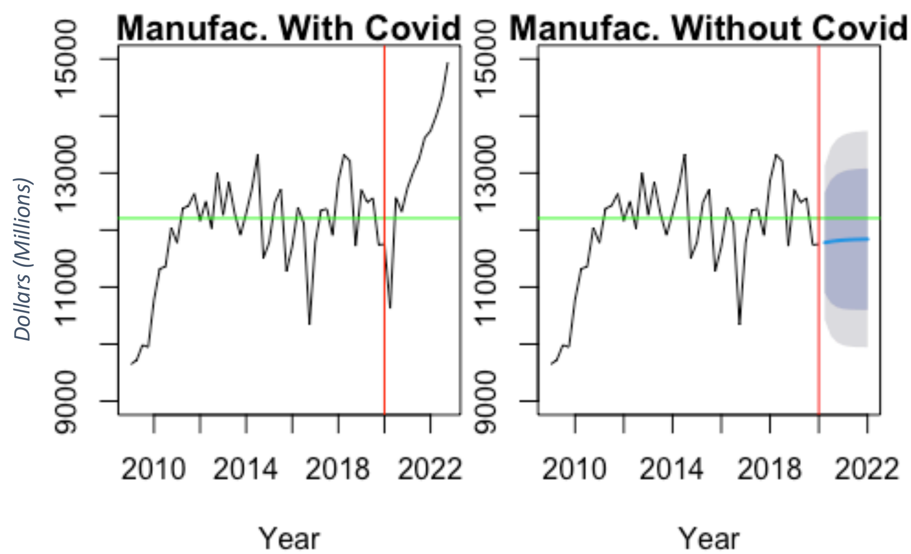


Figure 1.4B: Time series model on manufacturing sector for revenue with complete timeline from 2009-2022. Green line represents the mean of the manufacturing sector and the red line represents when Covid occurred

Moving to the manufacturing sector in our research, we can see that overall, it does not have the highest error percentage difference on average, but Figure 1.4A shows that the actual was a much steadier trend with the historical data than the actual average and the forecasted averages using the COVID-19 data. Figure 1.4B was the time series analysis comparison as well and the Φ value calculated to be 0.7014 with a significance of 0.1158 which does not pass our α value of 0.05. We are not going to be using the time series model for forecasting the manufacturing industry because parameter in not statistically significant, so when interpreting the forecasted values below we will rely on the double exponential smoothing model.

With automobile and aeronautical manufacturing being two of the significant sectors in this industry, the car-buying industry has been forced to shift focuses and adapt to the growing idea of buying a car online or virtually.[29] We can see that during the beginning stages of COVID-19 taking effect in the US, the sales in the manufacturing industry saw a dramatic decline, but there has been a sudden boom during the last two years. Many companies have shifted their focus to smart and renewable cars with consumers factoring in "sustainability into their buying decisions helped electric vehicles sales increase by 43 percent in 2020."[30]

Many consumers are also trading in their larger SUVs for a car as gas prices continue to rise and in office work begins to return for many companies. This has caused a considerable increase in demand for cars leaving many dealerships out of stock and customers with long waits for a car at a high cost.[31]

Profit

Using the time series modeling and double exponential smoothing for profit, we can look at Figure 2.1 and see that the highest percentage difference is energy, communication, commercial facilities, manufacturing, and transportation for profit. To continue with three, we are going to be looking at the profit of energy, communication, and commercial facilities.

Industry	Error Percentage between Actual vs Forecasted
Chemical	12%
Commercial Facilities	15%
Communication	18%
Energy	94%
Financial Services	5%
Food and Agriculture	11%
Healthcare	8%
Manufacturing	15%
Transportation	15%

Figure 2.1: Average difference between quarterly points from Q2 2020 – Q4 2022

[29] Russell Hensley, Inga Maurer, and Asutosh Padhi, "How the Automotive Industry Is Accelerating out of the Turn," McKinsey & Company, July 19, 2021, https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/how-the-automotive-industry-is-accelerating-out-of-the-turn.
[30] Hensley, Maurer, and Padhi, "How the Automotive Industry Is Accelerating out of the Turn."
[31] Jane Ulitskaya, "Inventory Shortage Update: Should You Wait to Buy a Car?," cars.com, January 13, 2022, accessed February 27, 2023, https://www.cars.com/articles/inventory-shortage-update-should-you-wait-to-buy-a-car-445723/.

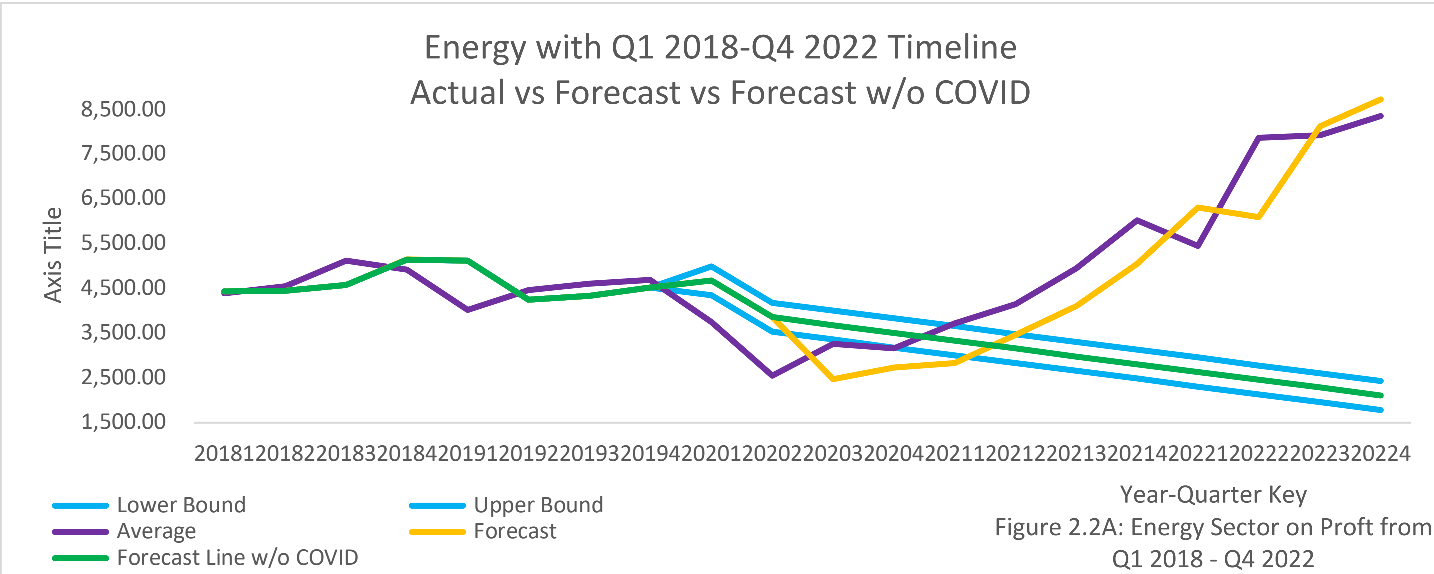


Figure 2.2A: Energy Sector on Proft from Q1 2018 - Q4 2022

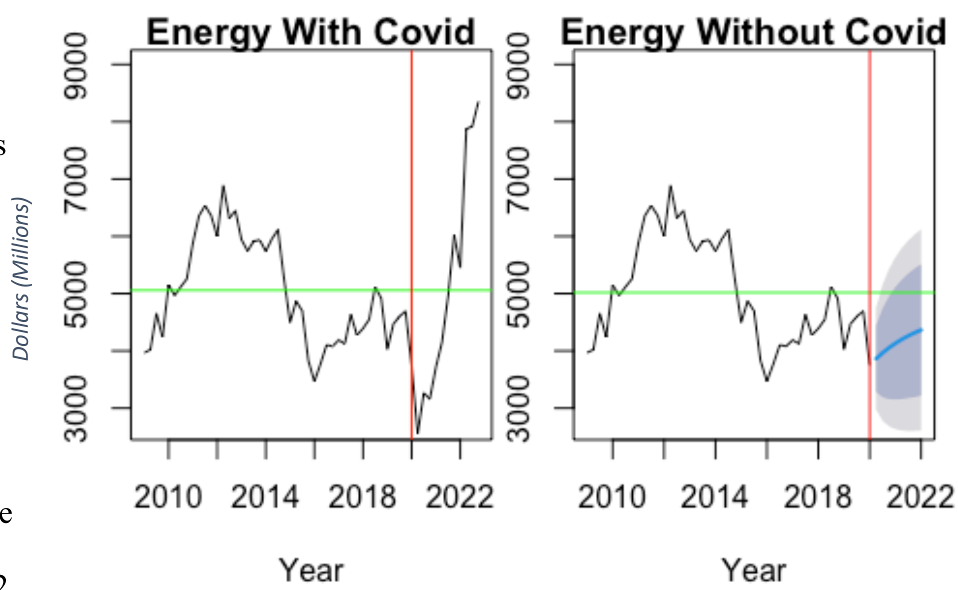


Figure 2.2B: Time series model on energy sector for profit with complete timeline from 2009-2022. Green line represents the mean of the energy sector and the red line represents when Covid occurred

We can see that in Figure 2.2B for the time series analysis, along with Figure 2.2A, the forecasted profit for energy is substantially lower than the actual profit generated by this industry. The Φ value calculated was 0.8832 which gave a significance value of 0.0676. That value is just outside the α threshold of 0.05, but with the minimization process of error in the double exponential smoothing models, we are going to use both models as forecasted in terms of trend lines and specific values created. Based on the forecasting models discussed above, we can conclude that the energy industry for profit would have had a gradual slope and not the drastic increase in profit as seen in Figure 2.2A for what did occur during the pandemic.

Now as discussed before, there was more revenue for the energy sector and that increase in demand for things such as natural gas and oil along with the restrictions for countries that are heavy exporters in the energy sector. As previously discussed, the amount of private consumer energy used from this industry drastically increased due to direct ramifications of COVID-19. However, from Q1 2022 to present, the line between COVID-19 implications become muddied as Russia invaded Ukraine causing a spike in oil prices as importation of oil and natural gas becomes more difficult. [32]So, in the beginning stages of the pandemic, we can attribute this increase in profit unexpectedly to COVID-19, but after Q1 2022 we cannot determine if the increase is more due to COVID-19 or the Russo-Ukrainian war.

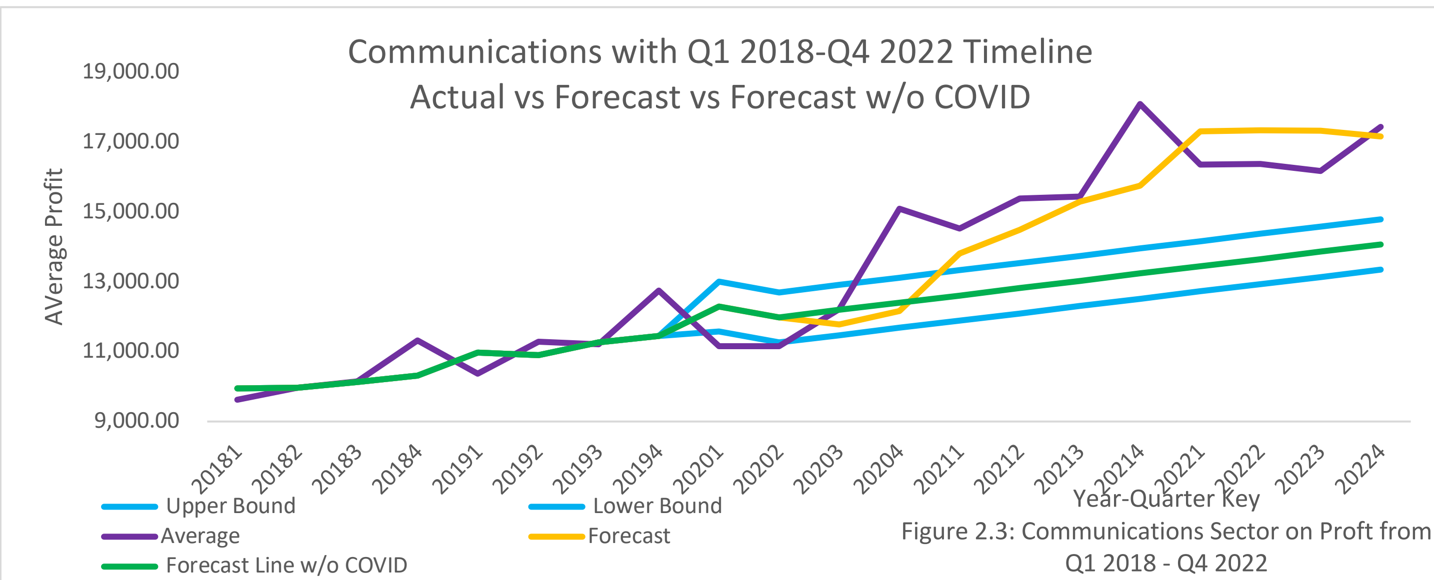


Figure 2.3: Communications Sector on Proft from Q1 2018 - Q4 2022

Moving to the communications sector for profits, the revenue of these models did have a 15% difference overall. With the major lockdowns and the restrictions on visitation of family and friends, many telecommunications companies have seen an increase of 50% more phone

[32] Sam Meredith, "Big Oil Poised to Smash Annual Profit Records — Sparking Outcry from Campaigners and Activists," CNBC, January 27, 2023, https://www.cnbc.com/2023/01/27/big-oil-earnings-preview-energy-giants-to-smash-annual-profit-records.html.

calls and a 40% increase in the duration of all calls.[33] Looking at Figure 2.3A, we can clearly see that the average profit for communications skyrockets during the COVID-19 pandemic much faster than anticipated. In Figure 2.3B, the forecast increases with it being linear regression and AR(1) model. In this case, the variance is not constant, and the amount of data points is small which does not make the data appropriate for a AR(1) time series model but is appropriate to include linear regression to the model. In terms of time series analysis, the data showed too much trend and non-constant variance which leads us to believe that we should rely on the double exponential smoothing model but both forecasted a gradual increase.

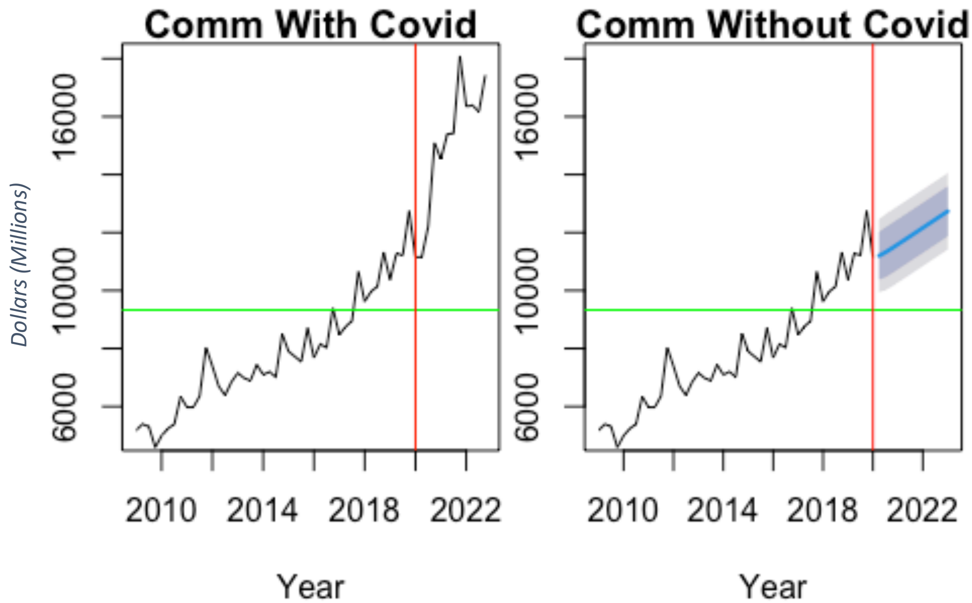


Figure 2.3B: Time series model linear regression and AR(1) on communication sector for profit with complete timeline from 2009-2022. Green line represents the mean of the communications sector and the red line represents when Covid occurred

[33] "Scoping the Impact of COVID-19: The Communications Lifeline (Part One) | North Highland," North Highland, n.d., https://www.northhighland.com/insights/blogs/scoping-the-impact-of-covid-19-the-communications-lifeline-part-one.

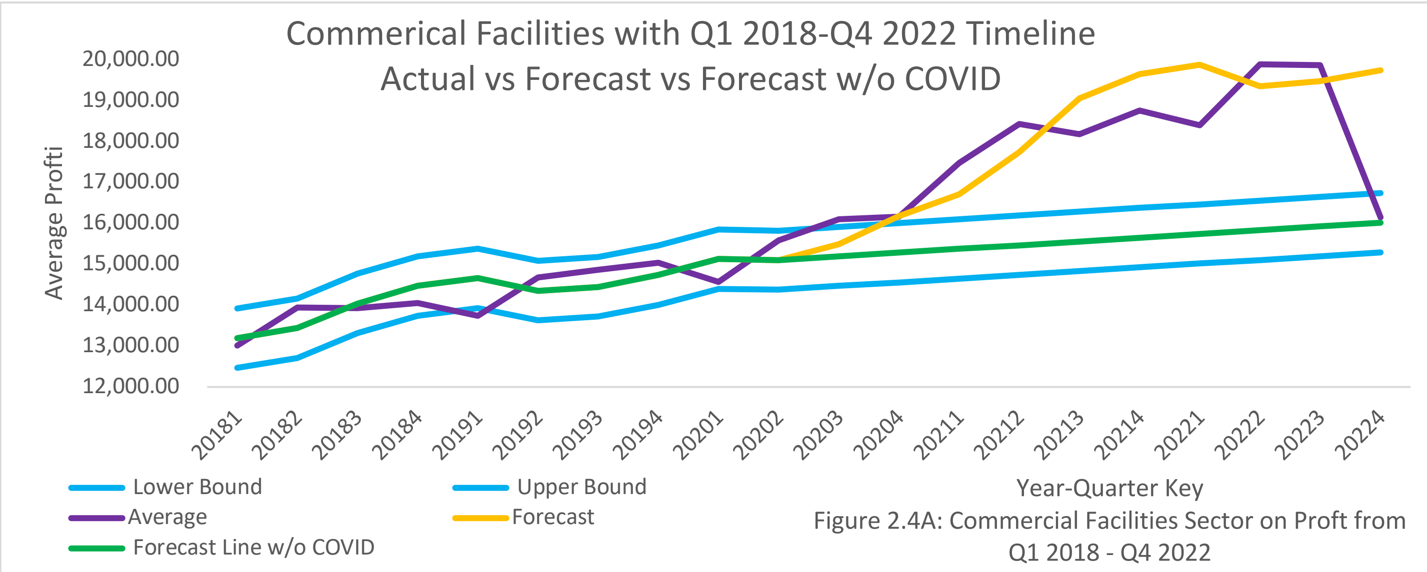


Figure 2.4A: Commercial Facilities Sector on Proft from Q1 2018 - Q4 2022

The final industry to look at is commercial facilities. Commercial facilities include companies such as Amazon, Walmart, Target, Walt Disney, etc. Commercial facilities only saw a 4% difference from the actual average versus what was forecasted without COVID-19, but the profit difference is 15%.

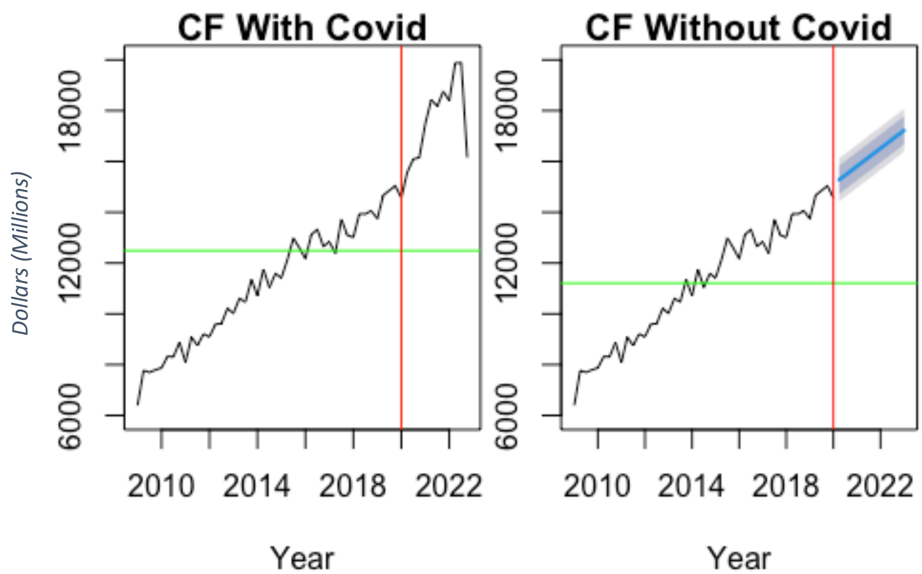


Figure 2.4B: Time series model linear regression and AR(1) on commercial facilities sector for profit with complete timeline from 2009-2022. Green line represents the mean of the commercial facilities sector and the red line represents when Covid occurred

Like the energy sector increase in profit and revenue, the commercial facilities industry was greatly profitable as seen in Figure 2.4A. Note that the fourth quarter 2022, was missing some data points but does not impact the overall forecast as it is at the end of the forecasted line. Most of the profit in this industry though is from Berkshire Hathaway. With the first half of 2021 seeing a 30% increase in the Berkshire Hathaway Automotive dealerships and a 129% increase

in real estate sold by Berkshire Hathaway.[34] Now, just because Berkshire Hathaway sold more homes and cars during 2021, does not necessarily mean that this major increase was from COVID-19 without evidence.

During COVID-19, once the market stabilized a bit, there were record low interest rates and a large increase in new houses being built. With the rise of remote work, there was a 28% increase in all single-family homes being sold in the first quarter of 2022.[35] Many homes were selling so fast and well over the asking price, even as the Federal Reserve started increasing the interest rates to help reduce inflation rates.[36]

Outlook Moving Forward

As already mentioned, COVID-19 has caused a dramatic shift in the supply chain arena for various industries. The next step though is what is next?

For consistency, we will focus on the energy industry and then discuss what we forecast to happen in the next two years as they are the most impacted industries from COVID-19. Using the same methodology in the double exponential model and time series analysis for forecasting without the COVID-19 data to acquire what should have happened, we can apply that to predict what will be based on current

Quarter Year	Revenue Forecasted (In millions)
Q1 2023	$30,539.43
Q2 2023	$32,444,93
Q3 2023	$34,350.43
Q4 2023	$36,255.93
Q1 2024	$38,161.43
Q2 2024	$40,066.93
Q3 2024	$41,972.43
Q4 2024	$43,877.93

Figure 3.1: Data table of forecasted values from Q1 2023-Q4 2024 for Energy.

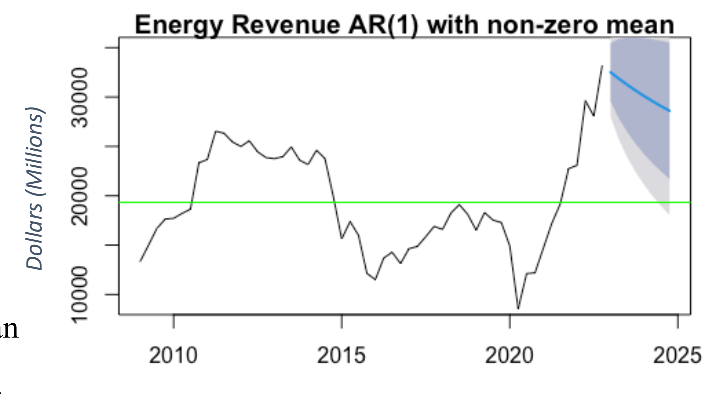


Figure 3.2B: Time series model for energy sector future outlook in revenue

[34] Jonathan Stempel, "Warren Buffett's Berkshire Hathaway Recovers from Coronavirus Slowdown," Reuters, August 8, 2021, https://www.reuters.com/business/berkshire-hathaway-operating-profit-rises-21-2021-08-07/.
[35] Rae Hartley Beck, "COVID's Long Impact on the Housing Market," Bankrate, September 14, 2022, https://www.bankrate.com/real-estate/covid-impact-on-the-housing-market/.
[36] ibid

information in the next eight quarters (Q1 2023-Q4 2024). Looking at Figure 3.1, we can see that the predicted revenue by quarter is expected to increase in a steady upward trend within the next two years. Now this is on trend as we have seen since COVID-19 began looking at Figure 3.2A. Now the further we get out from current data; we estimate that this trend line will begin to flatten or decrease in slope to show a smaller increase in revenue quarter over quarter.

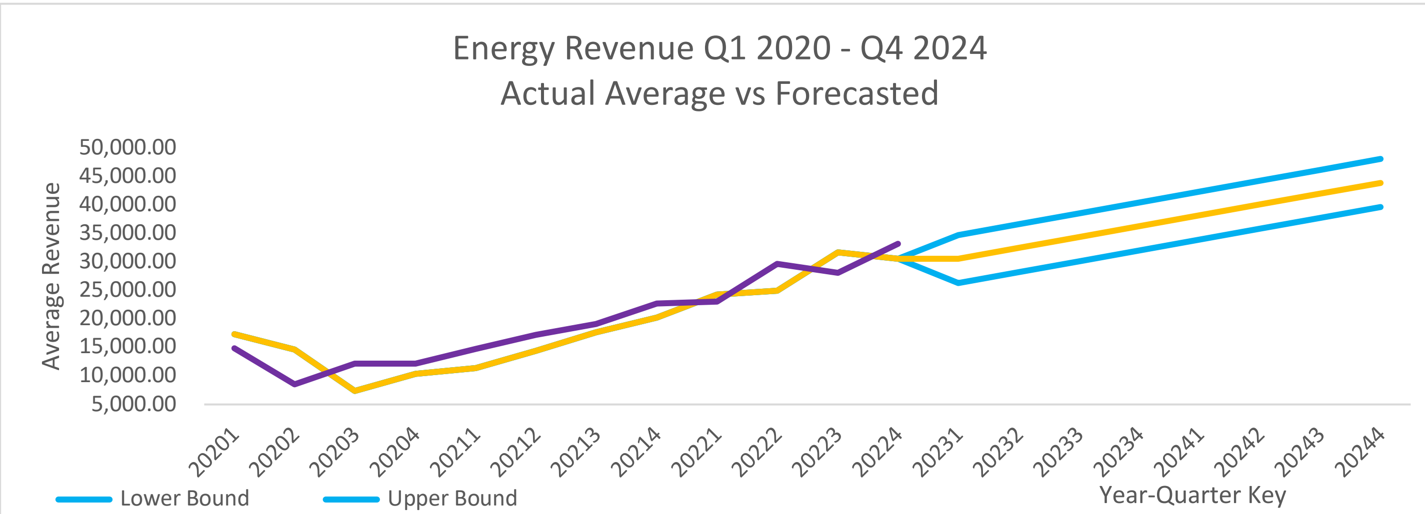


Figure 3.2A: Energy Sector on Revenue from Q1 2020 - Q4 2024

Switching over to look at the predicted profit for the energy industry, we can see in Figure 4.1 that there is another steady upward trend that can be found that increases in overall profit quarter over quarter based on the actual average profit generated using the historical data. This trend though is sloped at a much faster rate than the revenue seen above, which with the Russo-Ukrainian

Quarter Year	Profit Forecasted (In millions)
Q1 2023	$8,669.70
Q2 2023	$9,350.16
Q3 2023	$10,030.62
Q4 2023	$10,711.07
Q1 2024	$11,391.53
Q2 2024	$12,071.99
Q3 2024	$12,752.45
Q4 2024	$13,432.91

Figure 4.1: Data table of forecasted values from Q1 2023-Q4 2024 for Energy.

war occurring and the prices of oil and natural gas still rising, this is not the most outlandish idea that it would grow in profitability so quickly in the next two years.[37]

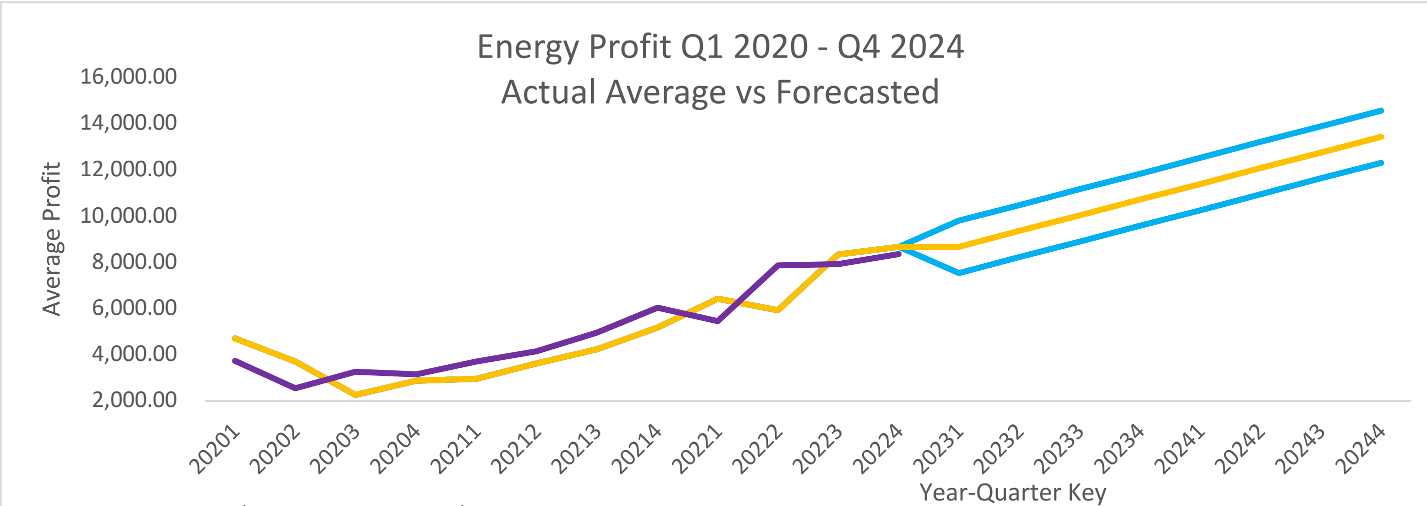


Figure 4.2A: Energy Sector on Proft from Q1 2020 - Q4 2024

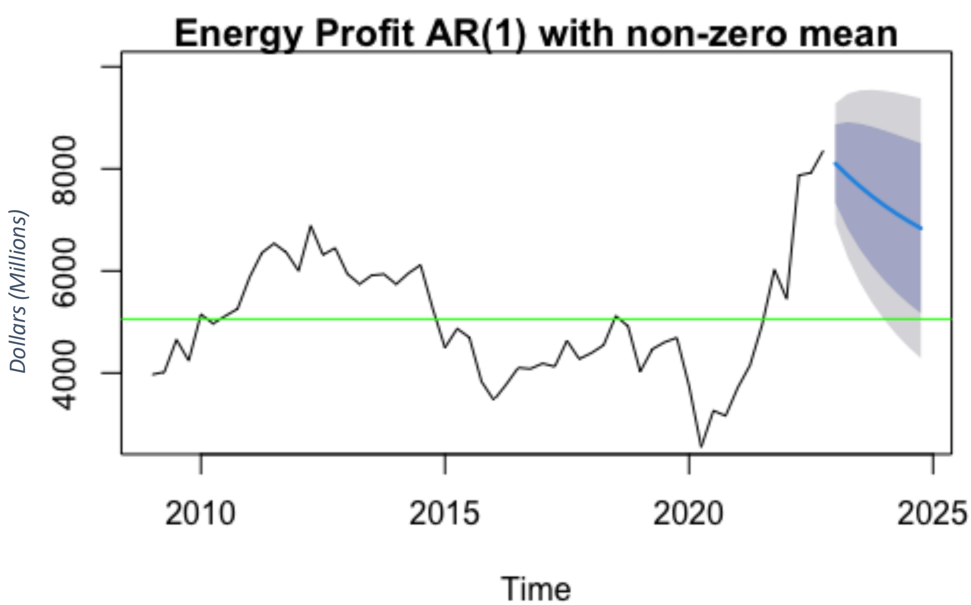


Figure 4.2B: Time series model for energy sector future outlook in profit

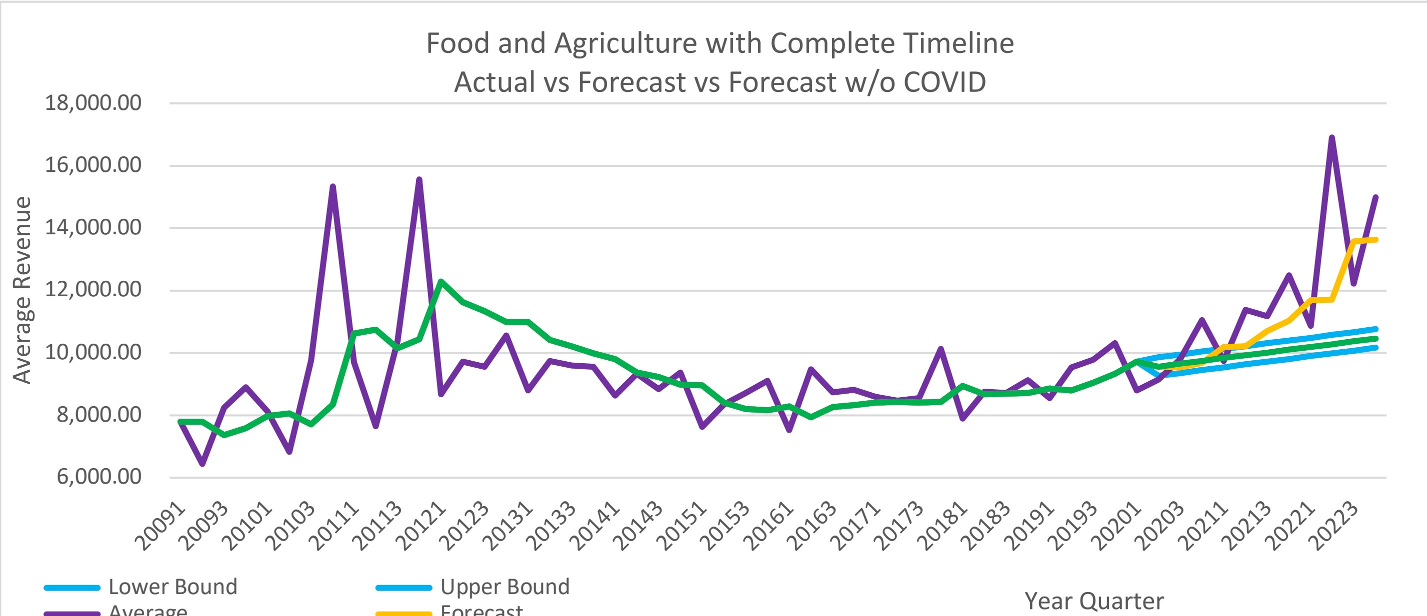
Conclusion

While we only touched on the top three biggest differences for revenue and profit, respectively, we can see that not every industry was impacted the same way during the COVID-19 pandemic. Nonetheless, out of the nine industries classified in this paper, seven in the revenue analysis and all nine in the profit analysis showed a difference on average

[37] Meredith, "Big Oil Poised to Smash Annual Profit Records — Sparking Outcry from Campaigners and Activists," January 27, 2023.

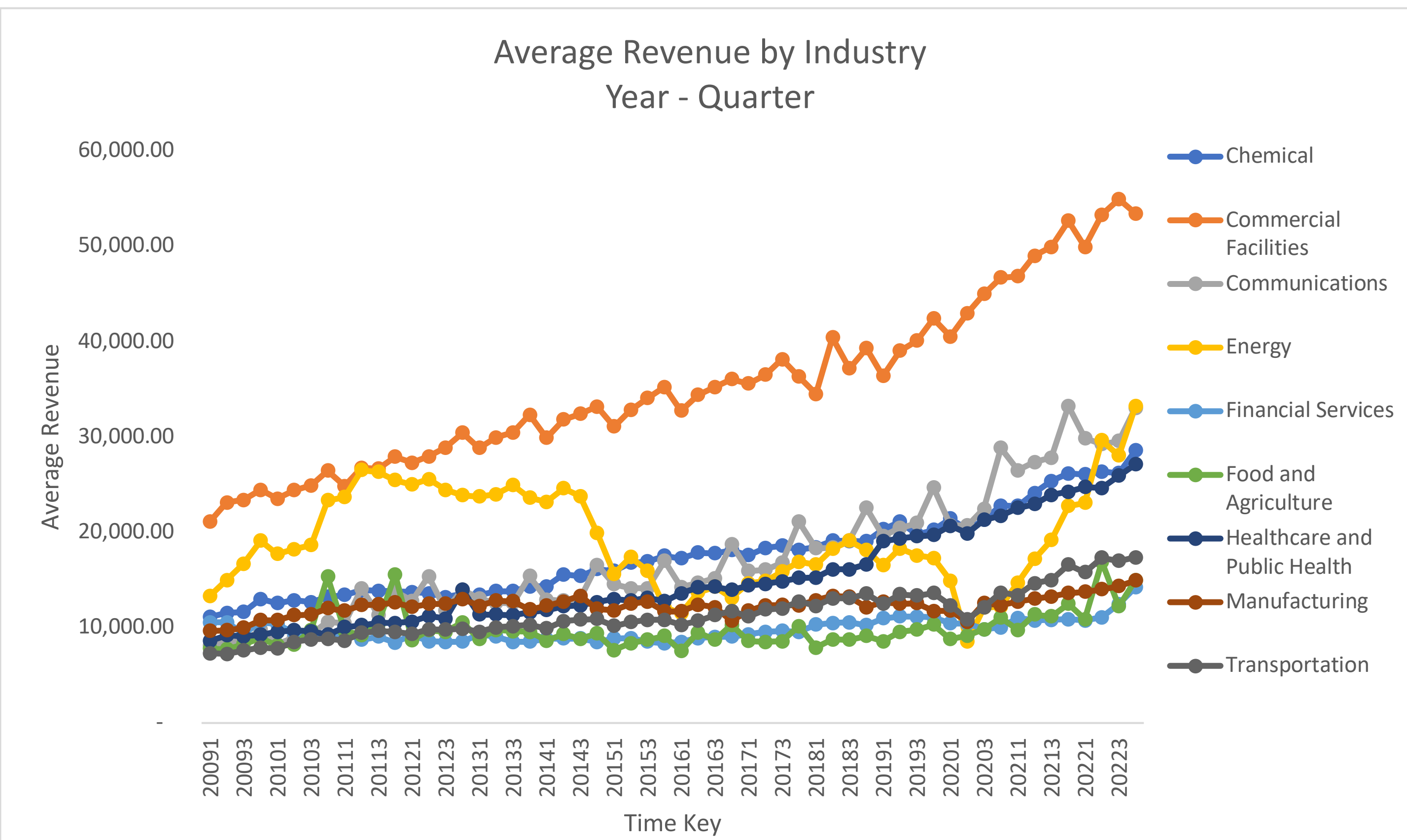
of greater than five percent of actual dollars generated in millions versus historical predictions created by our models. So, with our models being validated, tested against all assumptions necessary for accuracy, and compared against one another, we can conclude that the COVID-19 pandemic created a deviation from the historical averages.

Appendix A



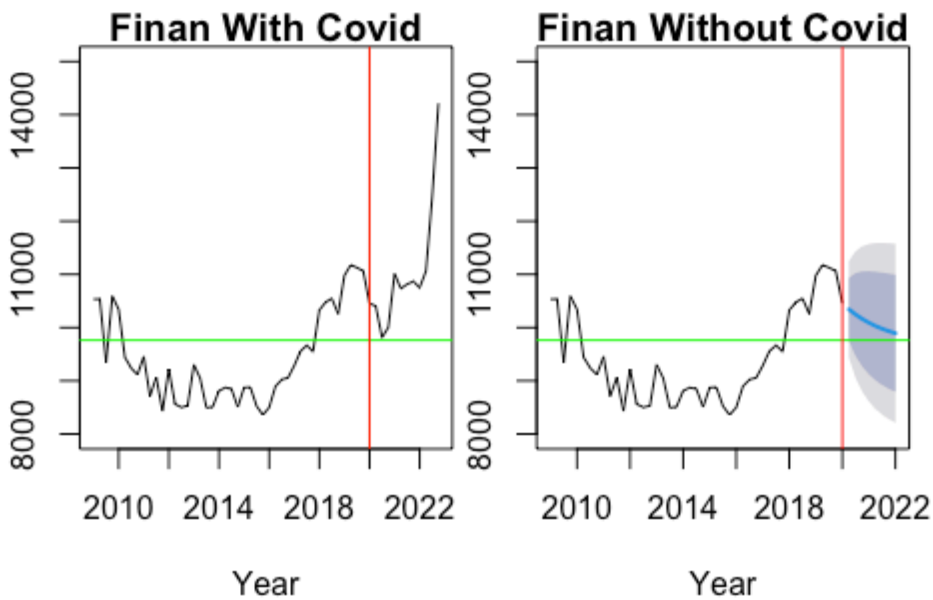
Appendix A: Food and Agriculture Revenue Complete Timeline

Appendix B



Appendix B: Average revnue for each of the nine industries classified

Appendix C



Appendix C: The time series revenue plots for financial services with and without COVID-19 including the confidence interval.

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