The Impacts of the COVID-19 Pandemic on the Electric Vehicle Sector in the United States

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Abstract. This current work measures the difference in how retailers of electric vehicles, mixed vehicles, and green energy ETFs performed in the market during the COVID-19 pandemic. By aggregating the average daily returns of four U.S automotive stocks and two green energy ETFs from Feb. 2020 to March 2021 using the two-variance analysis – ANOVA test, the result shows that the average daily returns of electric vehicle retail differ significantly from that of the mixed vehicle retailers. Additionally, this paper uses a multiple linear regression model on the market return of the S&P 500 index and market volatility of the COBE index to measure how much the COVID-19 pandemic affects the performance of four representatives of U.S Automotive companies and two green energy mutual funds. The result shows that the mixed vehicle retailers suffered the most throughout the pandemic. Additionally, during the analysis period from Feb. 2020 to March 2021, the result also indicates that the electric vehicle retailers have the most positive correlation with the COVID-19 pandemic. The study implies that the COVID-19 pandemic not only affected the U.S equity market but has also accelerated the global concern on climate change and the environment from investors' perspectives.

Keywords: COVID-19 Pandemic · Green Energy Stock Performance · Electric Vehicle · Green Energy ETFs

1 Introduction

The COVID-19 outbreak has drastically impacted the world. The World Health Organization (WHO) has indicated there have been in excess of 25 million COVID-19 cases across the world. Nevertheless, the pandemic also has significant negative impacts on the world's economy, particularly the equity market. Hui et al., for example, finds that the pandemic has negatively impacted the overall index return of the eight major economies even at a 1% level.

Although the degrees to which the COVID-19 pandemic has affected the economies were unknown, the IEA has reported that the COVID-19 pandemic has caused the global energy demand to decline by an average weekly rate of 25% for countries experiencing full lockdowns in 2020. Specifically, energy demand on Earth fell 3.8% in 2020's first

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fiscal quarter. Similarly, demand for oil demand plummeted in that timeframe by about 5% among the mobility and aviation industry that make up about 60% of demand for oil around the globe. Electricity has also been reduced because of the lockdown, with demand down in the area of 20% in the context of full lockdowns in several nations. Only renewable energy, on the other hand, saw demand increase as more substantial installed capacity drove its growth.

As the market is gradually shifting toward high demand for renewable energy, the electric automobile sector's financial performance has also exceeded the market's expectations [1]. It is evident that investors are continuing to look for alternative investment attractions, such as the electric vehicle sector. Subsidized by the national government and favored by environmental activists, the electric vehicle has transformed the automobile industry by switching internal combustion engines to electric motors. According to IEA, the global net sales of electric vehicle has reached an estimated 2.3 million in 2020, and the EV market share has increased 3.1% since the last decade (IKA, 2020).

For one to comprehend the impacts of the COVID-19 pandemic on the energy sectors across different fields, the Multi-Linear Regression Model is introduced for analysis. The purpose is to evaluate the degrees to which the COVID-19 pandemic has on the financial performance of four U.S automobile retailers and two energy ETFs.

Stenšin et al. tested six representative Electric Vehicle Stock and characterizes the joint distribution of returns in time series by the Copula-Garch models. The study did this by helping to optimize portfolios by combining rewards and risks. After selecting data beginning in 2012 and ending in 2020, Stenšin et al. illustrated the application of the Copula-Garch model, specifically by considering minimum shortfall expectation portfolio and stock ratio performance that is equally rated [1]. Kozaki et al. used data related to the S&P 500 index to investigate the Beck model's application from the representative stock markets on stock relaxation time, volatility, and returns. In their analysis, Kozaki et al. determine that the time constant of volatility is the month and the return falls in line with Gaussian distribution; both of these follow assumptions of the Beck model [2]. Kang et al. found that when stakeholders collaborate on optimizing their portfolios, the investment's payoffs are significantly more effective. For example, government and EV companies' co-effort in developing charging services and manufacturing EVs is likely to enhance and widen the EV market when those products fall under consumers' reservation price [3].

Li et al. conclude that the investors' utility function is divided into two sections: the CRRA utility function for final wealth, and final wealth's S-shaped value function. They find that the optimization model of the portfolio is founded upon the decision and return of the expected utility maximization. In their research, the analysis of the improved GWO algorithm is designed to show such a model is better than the traditional PSO model and GA model [4]. When designing experimental methodology, Rodriguez et al. stress the importance of structural breaks in tail dependence in designing an asset allocation strategy. Additionally, such changes in tail dependence are not captured by correlation shifts [5]. Abraham et al. predicted the excess equity returns from the world's producers of green energy from 2010 to 2019 using fixed-effects panel data regression of quantile regressions and daily returns. They conducted empirical analysis on the portfolio's market returns, and market risks (beta) from the CAPM model. As a result, they find that

95% and 99% confidence levels regarding the Value-at-Risk model predict returns on green equity most reliably [6].

Jammazi et al. estimated and forecasted the Value-at-Risk (VaR) of a portfolio by looking at the financial data in terms of stylized facts and complex structures. They did this by employing a wavelet-based extreme value theory (W-EVT). They applied this understanding to US crude oil price and dollar exchange rates' portfolios in an approach that was empirical in nature and proved the effectiveness of the W-EVT model that improved the VaR forecasts accuracy in the profile [7]. Ibikunle et al. published the first comparative analysis of the performance of conventional, black, and green European mutual funds. From 976 conventional, 259 black, and 175 green mutual funds between 1991 and 2014, the researchers found that green mutual funds underperform substantially when compared to conventional ones, despite not adjusting for risk in the performance. The researchers also found that Electric Vehicle shows potential as a growth stock and is more exposed to small caps while black funds tend to be exposed more to value stocks. As time progresses, the green fund's risk-adjusted return portfolio improves significantly over time [8].

Haquel et al. tested correlated random effects 'mean' (CREM) coefficient heterogeneity of panel quantile regression estimator using Abrevaya and Dahl's (2008) samples of performance. They assessed the power and the size of the test across a different range of sample sizes, eventually determining that the test was undersized in terms of the extent of the sample, and it displayed lower power alongside heteroscedasticity at a higher degree. The power and the size therefore increase as samples become larger across experiments [9]. Wielechowski et al. measured stock market variations in performance between companies in the alternative energy and main stock markets sector. They did this during the first two years of the COVID-19 pandemic. Upon a foundation of one-factor variance analysis, otherwise called ANOVA, results indicated statistically significant differences between the market sectors in both years. Wielechowski et al.'s results implied that COVID-19 impacted stock price performance in a sector-specific way. Their results indicate that the most differentiation appears in the alternative energy sector, considering its average rate of return in 2020 exceeded other sectors [10].

The study's purpose is to measure the COVID-19 pandemic's impact on the Electric Vehicle Sectors in the United States using a multi-linear regression model and the ANOVA test. This paper aggregates the daily returns of the four representative U.S automobile retailers and two renewable energy ETFs and categorized the six portfolios into three categories. By comparing the means of the portfolio returns, this paper aims to measure the performance of the portfolio and to what degrees does the pandemic contribute to their performance for investors' reviews.

2 Method and Data

This current paper measures the differences in the performance of the stock market performance in the green energy sector in the United States focusing on six different representative stocks and mutual funds during the COVID-19 pandemic from February 2020 to March 2021.

To achieve the research goals, this paper has formulated the following hypothesis

H_o: Companies from the green energy sectors, especially electric vehicle retailers, outperform mixed-electric vehicle retailers and green energy ETFs

H_1: Green Energy ETFs outperform electric vehicle wholesalers and mixed electric vehicle wholesalers.

In the present study, this research categorizes the stocks in the green energy sector into three categories.

This research conducted daily returns from the six representative stocks in the green energy sector based on daily closing prices during COVID-19 from the beginning of February 2019 to the beginning of March 2021. In total, 522 daily observations were used across six stocks.

This research paper uses a parametric statistical testing tool, ANOVA, to compare the mean values of returns from the selected datasets. ANOVA test, introduced by Fisher and Mackenzie, is used to determine the statistical difference between means of multiple groups and observations. Such a technique allows us to investigate the difference across groups from a two-way variance situation in which we aim to examine the influence of two independent variables on the qualitative dependent variable.

The general form of the Two-Way ANOVA model for the variable Y is as follows:

$$Y_{ik} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk} \tag{1}$$

Where Y_{ik} is referring to the i_{th} observation from the k_{th} group, μ is the mean of the entire population, α_i is the deviation from μ cause by alpha at the i_{th} level, β_j is the deviation from μ cause by beta at the j_{th} level, $(\alpha\beta)_{ij}$ is the interaction of alpha and beta at the i_{th} and j_{th} level, respectively, and finally e_{ik} representing random deviation that is related to the $i_{th,}$ j_{th} observation for the k_{th} level of factor ε.

To run the ANOVA Test hypothesis, this paper assumes that all factors' levels equally affect the dependent variables Y, which implies that all the means in the p groups are the same. Additionally, the total variable of the dependent variable Y, or the total sum of squared SST, is the sum of the variations that is caused by randomation effects (sum of squared for errors, SSE).

$$\mathrm{SST} = \mathrm{SST_R} + \mathrm{SSE} \tag{2}$$

In ANOVA, the sums of squares for treatment, error, and total are defined as

$$SST_R = \sum_{i=1}^{I} \sum_{j=1}^{J} (\overline{x}_i - \overline{x}_{.})^2 \tag{3}$$

$$SSE = \sum_{i=1}^{I} \sum_{j=1}^{J} (\overline{x}_{ij} - \overline{x}_i)^2 \tag{4}$$

$$SST = \sum_{i=1}^{I} \sum_{j=1}^{J} (\overline{x}_{ij} - \overline{x}_{..})^2 \tag{5}$$

In the ANOVA model, the test follows a F distribution with the $p - 1$ degrees of freedom, which is i the numerator followed by n-p in the denominator, where $n = n_1 + n_2 + \ldots + n_p$ is the sample size. For the random variable Y, the p is also the number of groups.

$$F_{(p-1,n-p)} = \frac{SSTR/p - 1}{SSE/n - p} \tag{6}$$

Table 1. Portfolio Selection Overview

Stock	Business Position
Tesla Inc. (TSLA)	EV Manufacturer
Nio Inc. (NIO)	EV Manufacturer
General Motors Co. (GM)	Mixed Automobile
Ford Motor Co. (F)	Mixed Automobile
Global X Lithium (LIT)	Mutual Fund
iShare Semiconductor (SOXX)	Mutual Fund

Table 2. Portfolio Descriptive Statistics

	TSLA	*NIO*	*GM*	*F*	*LIT*	*SOXX*
Count	522.00	522.00	522.00	522.00	522.00	522.00
Mean	223.47	13.41	35.15	8.32	33.89	257.08
Std	232.85	17.24	7.55	1.69	13.02	66.80
Min	35.79	1.32	16.8	4.01	18.13	174.76
25%	52.92	3.05	30.01	6.97	25.48	204.75
50%	109.38	4.58	36.19	8.81	28.61	235.39
75%	370.28	14.50	38.95	9.34	38.19	296.57
Max	883.09	62.84	56.88	12.27	74.31	439.36

The F statistic produces higher value when one intergroup differentiation is greater than the random effect. The right side of the F-test, being the critical value, allows us to reject or fail to reject a null hypothesis.

In this research, the purpose is to measure the response and returns of stock price performance throughout the COVID-19 pandemic within the green energy sector. This study determines whether the average daily return on the shares of six representative U.S green energy stocks, characterized by three groups, differs significantly from one another.

In this analysis, this research chose the period from Feb. 2019 as the beginning of the COVID-19 Pandemic to March 2021 as the ending period of the pandemic. Taking daily closing prices of the six representative stocks, this paper hypothesizes that the daily returns of the electric vehicle retailers have the highest returns and are affected the most by COVID-19 compared to other green energy stocks, derivatives, and mutual funds (Tables 1, 2 and Fig. 1).

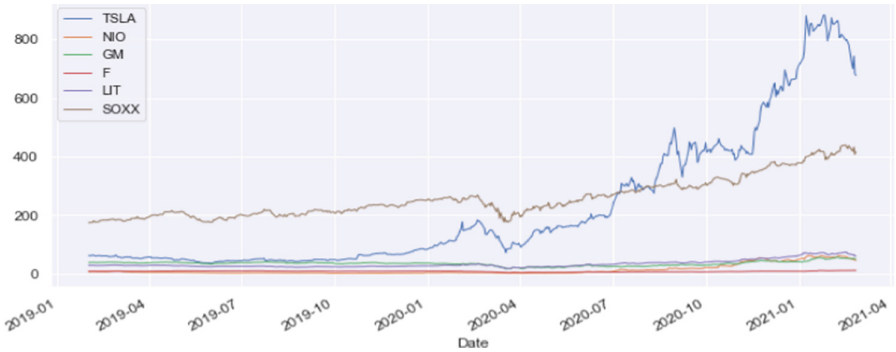

Fig. 1. Aggregated Stock Portfolio Performance Overview

3 Results

The COVID-19 Pandemic has drastically affected markets, especially in the Electric Vehicle Sector. Among the six selected representative stocks, Tesla has the highest percentage of returns from the period February 2019 to March 2021. Following Tesla, Nio has the second-highest returns, and such return is the highest during COVID-19 (Fig. 2).

Table 3 offers statistics pertaining to the daily returns of the six representative stocks from February 2019 to March 2021. Out of the six stocks and mutual funds, all green energy wholesalers and ETFs have positive daily returns, including Tesla, NIO, Lit, and SOXX. The stocks such as General Motors and Ford suffered as the average daily returns are negative.

In testing the significance of the COVID-19 Pandemic on the six selected stocks and ETFs. This research categorized out six representative stocks into three categories: Electric Vehicle Retailers, Mixed Vehicle Retailers, and Green Energy ETFs.

After aggregating the six representative stocks into three different categories, the result shows that the average daily return of electric vehicle retailer stock is significantly

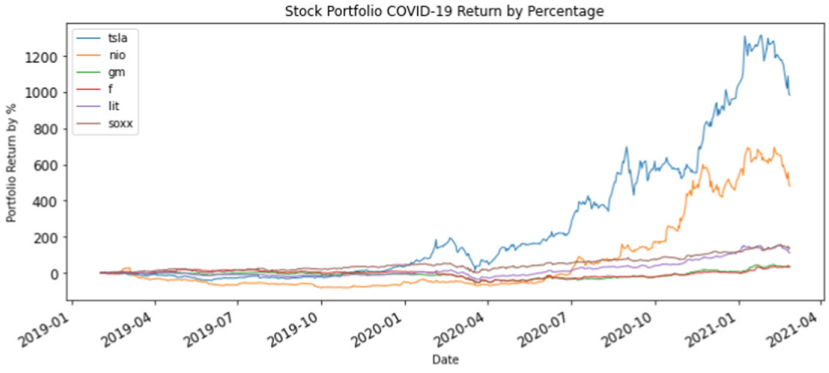

Fig. 2. COVID-19 Stock Portfolio Return Overview

Table 3. COVID-19 Stock Portfolio Return Descriptions

	TSLA	*NIO*	*GM*	*F*	*LIT*	*SOXX*
Count	522.00	522.00	522.00	522.00	522.00	522.00
Mean	257.89	69.76	−9.36	−4.59	17.47	47.10
Std	372.90	218.26	19.47	19.49	45.14	38.226
Min	−42.68	−83.29	−56.68	−54.01	−37.16	0.00
25%	−15.24	−61.39	22.605	−20.07	−11.70	17.17
50%	75.17	−42.03	−6.67	1.03	−0.85	34.69
75%	493.01	83.56	0.46	7.11	32.39	69.71
Max	1314.26	695.44	46.67	40.71	157.57	151.41

Table 4. Stock Portfolio Return Descriptions by Percentage

	Electric Vehicle Retailers	*Mixed Vehicle Retailers*	*Green Energy ETF*
Count	522.00	522.00	522.00
Mean	163.83	−6.98	32.28
Std	292.35	19.01	41.06
Min	−52.68	−54.31	−17.05
25%	−32.95	−21.69	3.566
50%	11.09	−1.86	13.11
75%	291.99	4.33	51.04
Max	998.84	40.69	154.49

higher than that of mixed vehicle retailers or ETFs (Table 4). The average return for the electric vehicle retailers is 163.82%, which is significantly higher during the COVID-19 pandemic.

To quantify the differences observed in three categories of stocks in the green energy sector during the COVID-19 pandemic, the multiple linear regression model is shown as the follows

$$R_{it} = \beta_0 + \beta_1 * marketR + \beta_2 * marketVol + \varepsilon_i \tag{7}$$

R_{it} is the return of the i_{th} stock at time t, *marketR* and *marketVol* are independent variables representing the market return and the market volatility affected by Covid-19 pandemic by percentage from Feb. 2019 to March 2022. S&P 500 index and COBE index during the COVID-19 Pandemic are aggregated to test the regression. Finally, the ε_i represents the error term on the i_{th} observation.

Table 5. Multiple Linear Regression Analysis

	(1)	*(2)*	*(3)*
Intercept	158.473***	−7.420***	31.452***
	(12.994)	(0.858)	(1.828)
marketR	4.768	0.385	0.859
	(7.885)	(0.521)	(1.110)
marketVol	−0.248	0.008	−0.067
	(1.506)	(0.099)	(0.212)
Observations	486	486	486
R2	0.001	0.001	0.001
Adjusted R2	−0.003	−0.003	−0.003
Residual Std. Error	285.840 (df = 483)	18.877(df = 483)	40.219 (df = 483)
F Statistic	0.193 (df = 2; 483)	0.279 (df = 2; 483)	0.342 (df = 2; 483)
Note:	*p < 0.1; **p < 0.05; ***p < 0.01		

Table 6. ANOVA Statistic Table

	df	*sum_sq*	*Mean_sq*	*F*	*PR (>F)*
marketR	1.0	2.98e + 04	29869.7	0.365	0.545
marketVol	1.0	2.21e + 03	2212.4	0.027	0.869
Residual	483.0	3.94e + 07	81704.5	NaN	NaN

4 Discussion

The results in Table 4 allow investors to visualize the returns of the six representative stocks from Feb. 2019–Mar. 2021. From the table, electric vehicle retailer stocks such as Tesla and Nio had leaped drastically to an average of 163.83 positive percentage change on return. In comparison, mixed vehicle retailers such as General Motors and Ford had an average of −6.98% change during COVID-19. The ANOVA test (Table 6) implies that the pandemic has a positive correlation to returns of the electric vehicle retailers since the market return and market volatility and its associated risks do not impede investors' strategy in expanding their portfolios in the EV sector ($p > 0.05$).

Using S&P 500 index and COBE index (the Chicago Options Board Exchange Index) on the multiple linear regression, this research aims to measure the degrees to which COVID-19 affects the returns of the green energy portfolio. S&P 500 characterizes the U.S market return under the influence of COVID-19. COBE includes data from the market's volatility and risks, which would help investors determine the change in return of the portfolio by the market. For example, the coefficient of the variable marketR (Table 5) is positive for stocks in the electric vehicle retailers and the green energy

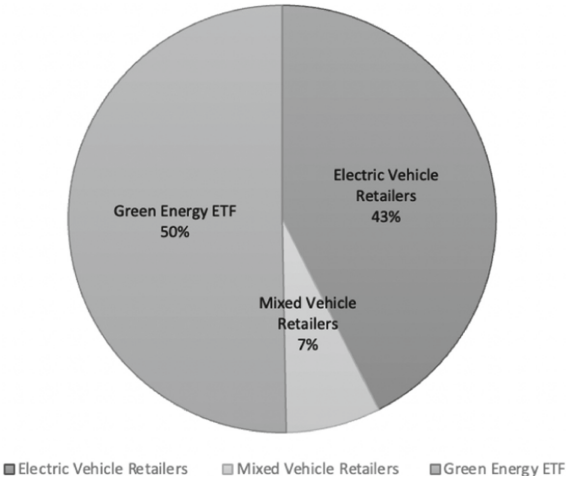

Fig. 3. U.S Energy Portfolio Allocation

ETFs, indicating that the market return under the influence of the pandemic is most significant in the electric vehicle sectors and less significant in the ETFs (163.83% > 32.28%). Though market volatility has a negative coefficient of −0.248 for the electric vehicle retailers, and −0.067 for the green energy ETFs, the impacts are minimal for the performance of the stocks and mutual fund returns.

Additionally, the F test statistics results from the ANOVA test imply that COVID-19 has contributed positively to the performance of the EV stocks. The F-test from the marketR, 0.36, is significantly less than the critical value, and therefore, this paper fails to reject the null hypothesis (Fig. 3).

From investors' perspective, the electric vehicle stocks yielded the greatest returns during the COVID-19 pandemic, and mixed retailers had the least returns and suffered the most from COVID-19. Due to market volatility and stock volatility, this paper recommends investors allocate 50% to Green Energy ETFs, 43% to electric vehicle retailers, and 7% to mixed vehicle retailers deriving from a 50% percentile daily return during the pandemic (Fig. 4). The prices of the six representative stocks started to skyrocket only during the COVID-19 outbreak. Such a phenomenon implies that the equity market endeavors to find alternative and sustainable energy funds that correspond to the government's efforts to reach its carbon-neutral goals when exogenous factors, such as COVID-19 impact the global equity market.

Nevertheless, the result of this research has limitations. For example, the aggregated data on stock returns are characterized by six representative U.S stocks and mutual funds in the green energy sector. However, the size of the research samples may lead to bias in the result when the number of public traded electric vehicle companies is very underrepresented, especially during the COVID-19 pandemic. Therefore, research going forward should measure the impacts of this pandemic on the U.S green energy stocks and mutual funds to eliminate potential bias.

5 Conclusion

This paper uses the Multi-Linear Regression Analysis to measure the COVID-19 pandemic's myriad of impacts on the financial performance of portfolios in the U.S energy sector. In conclusion, the electric vehicle retailers' return is significantly different from that of mixed-vehicle retailers and green energy mutual funds. During the pandemic, the stock returns of the electric vehicle retailers skyrocketed to an average of 163.83%, while the mixed-vehicle retailers suffered the most with an average daily return of -6.98%.

Additionally, the COVID-19 pandemic has the most positive correlation with the daily returns of the electric vehicle retailers of 4.768. Though the samples are underrepresented, it can still be implied that the investors are actively searching for alternate investment attractions as financial assets during the pandemic.

The outbreak of the COVID-19 pandemic inevitably created massive returns for investors in electric vehicle stocks. However, investors are cautious about staking high on electric vehicle retailers because the volatility in such assets is also enormous. The balanced weights of the portfolios are essential in hedging against market risks as investors should consider safer and less volatile portfolios such as the green energy ETFs.

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