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Clean Energy Stock Indexes: Trends, Fluctuations, and Implications for Investors

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Abstract: *The heightened attention towards clean energy markets has been spurred by COVID-19 and geopolitical concerns in 2022. This study investigates the persistence of the Nasdaq Clean Edge Green Energy, Wilder-Hill Clean Energy, S&P Global Clean Energy, iShares Global Clear Energy ETF, and Clean Energy Fuels stock indexes for the period from May 3, 2018, to May 2, 2023. The findings are mixed since long memories were observed throughout the tranquil period; therefore, the events of 2020 and 2022 did not accentuate persistence. Based on the findings, it can be inferred that the long-term predictability of clean energy markets has potential advantages for investors with a focus on environmentally sustainable investments. However, investors must be aware of market risks and volatility, especially during periods of economic or political instability. To reduce risk and increase returns, investors should diversify their portfolios across different clean energy indexes and other asset classes.*

1. INTRODUCTION

One of the fundamental concepts of financial theory concerns the efficiency of markets, where the prices of financial assets provide the appropriate signals for the purchase of resources. The hypothesis of market efficiency starts from the premise that an investor cannot obtain an extraordinary return adjusted to risk. However, some empirical studies have proven the opposite: that an investor may have a return above the market average (Dias et al., 2021, 2022; Dias, Heliodoro, Alexandre, Santos & Vasco, 2021; Santos et al., 2021).

Despite the impressive growth of the clean energy sector, traditional, dirty energy remains the world's main source of energy. Furthermore, because clean energy sources are frequently viewed as alternatives to dirty energy, the development and sustainability of the clean energy industry cannot be separated from traditional energy markets. In addition, the concept of decarbonization is gaining strength globally, particularly following the 2015 Paris climate agreement and COP26. Regulators, businesses, financial institutions and investors have all attempted to replace dirty energy with sustainable energy. Indeed, numerous experts believe that investing in clean energy is crucial for achieving the COP26 goals (Papageorgiou et al., 2017; Ren & Lucey, 2021, 2022; Farid et al., 2023).

There is a significant gap in the current literature that makes understanding the efficiency of the clean energy stock index difficult. This is an important issue in terms of green energy consumption, dirty energy, and the growth of renewable energy technologies. This issue's significance can be observed in several ways. Firstly, the efficiency of the clean energy stock market has the potential to have a direct impact on energy consumption and economic sectors, resulting

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in the creation of new jobs. Second, because market efficiency is directly related to the accuracy of price information, the effects of clean energy stock markets can be felt in dirty energy markets like crude oil. Third, the efficiency of the clean energy stock market can have a considerable impact on technological choices and renewable energy legislation, which can influence the direction of clean energy technology. Furthermore, the extent of market inefficiency might be a useful tool for market regulators. Regulators can identify areas for improvement and seek to establish a more efficient market for clean energy by identifying market inefficiencies. Faced with a gap in the literature, this article aims to study market efficiency and predictability in the clean energy stock indexes Nasdaq Clean Edge Green Energy (CELS), WilderHill Clean Energy (ECO), S&P Global Clean Energy (SPGTCLEE), iShares Global Clean Energy ETF (ICLN), and Clean Energy Fuels (CLNE) from May 3, 2018, to May 2, 2023.

This essay is structured into five pieces. Section 2 provides a comprehensive examination of the existing literature related to publications that discuss the potential of efficient market behavior in the global financial markets. Section 3 provides an overview of the technique employed and the data used in the study. The findings are presented in Section 4. The fifth section of the document concludes.

2. LITERATURE REVIEW

There has been a recent surge in the interest of portfolio managers towards clean energy stocks, primarily driven by the increased value associated with investments in clean energy stocks. Interestingly, recent research suggests that investing in clean energy businesses might reduce the risk of investing in the aggregate US stock market index. The value of investing in clean energy stocks has recently piqued the curiosity of portfolio managers. According to recent research, investing in clean energy firms might reduce investment risks in the global US stock market index (Uddin et al., 2019).

According to other research, clean energy stock indexes can be viewed as a hedge and safe harbor for crude oil and gold markets (Elie et al., 2019). The same authors argue that clean energy assets are attractive investment routes due to government subsidies that stabilize the cash flows of green companies. Clean energy reserves have characteristics of both the general stock market and energy products and include companies involved in renewable energies and related products and services. Participants in the clean energy market now include professional investors, resulting in less room for speculation in the market. The prices of clean energy shares can be driven by the interactions of market participants with various time horizons and information interpretations.

The authors Yang et al. (2016) investigated the persistence of China's oil prices and energy market shares using the MF-DFA method to test multifractality. The authors highlight the presence of long memories in the oil market, which is an important source of multifractality in the energy stock index. In addition, Shahzad et al. (2020) examined the market efficiency, in its weakest form, in the clean energy stock indexes of the US, Europe, and the rest of the world. The asymmetrical multifractality in the US clean energy stock index is due to fat tails and far-reaching correlation. However, in the European and world shares of clean energy, multifractality is due only to the distribution of the fat tail. We see greater efficiency in the upward trend of European and global clean stock markets, whereas, in the case of the US, the market is less efficient when it shows an upward trend.

Later, the authors, Yao et al. (2021), examined the persistence of China's clean energy stock indexes, suggesting that the clean energy stock market is far from efficient and exhibits significant asymmetries in both upward and downward fluctuations. While the authors Shen and Wang (2023) analyzed the multifractality of the Chinese energy futures market (EFM), the CSI Energy Index, and the CSI Mainland New Energy Theme Index. Empirical evidence suggests that the autocorrelations and cross correlations of the markets under consideration have asymmetrical multifractality and that the multifractality of cross correlations is produced principally by the fat tail distribution of the original series. Following the outbreak of COVID-19, the risks of the traditional energy stock market and the whole new energy market increased, while the risks of the entire EFM decreased.

In conclusion, understanding the efficiency of clean energy stock indexes is important for several reasons. First, as the world moves towards green energy consumption, it is important to understand how the clean energy market operates. This knowledge can assist investors in making informed investment decisions, which can have a significant impact on the development and growth of clean energy technologies. Secondly, understanding the efficiency of clean energy stock markets can help policymakers develop more effective policies to promote the growth of clean energy markets. Finally, understanding the efficiency of clean energy stock markets can provide a more comprehensive knowledge of how markets operate and the elements that influence their efficiency.

3. METHODOLOGY

3.1. Data

Table 1 shows the price indexes of the Nasdaq Clean Edge Green Energy (CELS), WilderHill Clean Energy (ECO), S&P Global Clean Energy (SPGTCLEE), iShares Global Clean Energy ETF (ICLN), and Clean Energy Fuels (CLNE) stock indexes were studied from May 3, 2018, to May 2, 2023. To increase the robustness of the results, we divided the sample into two subperiods: the quiet period, which covers the years May 2018 to December 2019, and the stress period, which covers the years January 2020 to May 2023 and includes the events of 2020 and 2022. The prices are daily and were obtained from the Thomson Reuters platform.

Table 1. Indexes and countries used in this research

Index		Country
CELS	Nasdaq Clean Edge Green Energy	USA
ECO	WilderHill Clean Energy	USA
SPGTCLEE	S&P Global Clean Energy	USA
ICLN	S&P Global Clean Energy ETF	USA
CLNE	Clean Energy Fuels	USA

Source: Own elaboration

3.2. Methodology

The present study will be conducted in multiple phases. Firstly, we will present the return graphs to observe the dispersion in relation to the mean. To characterize the sample, we will utilize the primary measures of descriptive statistics and the Jarque and Bera (1980) adherence test. Additionally, we will be using Q-Q plots to evaluate whether the distributions are Gaussian. To assess the validity of the stationarity assumption in the time series, we will employ the panel unit root test proposed by Phillips and Perron (1988), which involves using both the Fisher Chi-square and Choi Z-statistics. The PP version, Fisher's Chi-square, also known as Pesaran and Pesaran test, evaluates the cross-independence of data in a panel based on the Fisher Chi-square statistics. The Choi Z-stat test, proposed by Choi (2001), is used to examine the existence of cross-dependence in panel data. We will use the model Detrended Fluctuation Analysis (DFA) to answer the research question. DFA is a method of examining time dependency in non-stationarity time series. This method, which assumes that the time series are non-stable, avoids spurious results when the analysis focuses on the long-term relationships of the time series. The DFA interprets it as follows: $0 < \alpha < 0.5$ anti-persistent series; $\alpha = 0.5$ random walk series; $0.5 < \alpha < 1$ persistent series. This technique investigates the relationship between x_k and x_{k+t} values at different times. The interpretation of the α_{DFA} exponent is shown in Table 2.

Table 2. Detrended Fluctuation Analysis α_{DFA}

Exponent	Type of signal
$\alpha_{DFA} < 0.5$	long-range anti-persistent
$\alpha_{DFA} \simeq 0.5$	uncorrelated, white noise
$\alpha_{DFA} > 0.5$	long-range persistent

Source: Own elaboration

4. RESULTS

Figure 1 shows the return evolution of the Nasdaq Clean Edge Green Energy (CELS), WilderHill Clean Energy (ECO), S&P Global Clean Energy (SPGTCLEE), iShares Global Clean Energy ETF (ICLN), and Clean Energy Fuels (CLNE) stock indexes from May 3, 2018, to May 2, 2023. The indexes under consideration clearly exhibit significant structural breakdowns, demonstrating the volatility to which these stock indexes were subjected, particularly in the first months of 2020, which coincides with the occurrence of the first wave of the COVID-19 pandemic and the oil price war between Russia and Saudi Arabia. Already in 2022, primarily in the first and second quarters of the year, fluctuations in the time series can be observed, indicating structural breakdowns, an event that occurs as a result of the Russian invasion of Ukraine and the resulting concerns about rising associated inflation. These findings are also validated, in part, by the authors Dias and Santos (2020a, 2020b), Pardal, Dias, Teixeira and Horta (2022), Dias, Pardal, et al. (2022), and Teixeira et al. (2022).

Table 3 shows a summary of the main descriptive statistics, in returns, of the time series regarding the Nasdaq Clean Edge Green Energy (CELS), WilderHill Clean Energy (ECO), S&P Global Clean Energy (SPGTCLEE), iShares Global Clean Energy ETF (ICLN), and Clean Energy Fuels (CLNE) stock indexes from May 3, 2018, to May 2, 2023. In terms of mean returns, the markets present positive values; in terms of standard deviation, the CLNE stock index reveals itself as the highest-risk index (0.040084). To determine whether the time series follows a normal distribution, we estimated the skewness and kurtosis and observed that they exhibit different values from 0 and 3, respectively. To corroborate those findings, we applied the Jarque and Bera (1980) adherence test and observed that H_0 is rejected at a 1% significance level.

To validate the time series stationarity assumption, we estimate the Phillips and Perron (1988) panel unit root test, Fisher Chi-square, and Choi Z-stat for the Nasdaq Clean Edge Green Energy (CELS), WilderHill Clean Energy (ECO), S&P Global Clean Energy (SPGTCLEE), iShares Global Clean Energy ETF (ICLN), and Clean Energy Fuels (CLNE) stock indexes. To achieve stationarity, the original data is transformed into first-order logarithmic differences. The stationarity is then assessed by rejecting the null hypothesis (H_0) at a significance level of 1%, as shown in Table 3.

Table 5 shows the results of the Detrended Fluctuation Analysis (DFA) exponents applied to the time series of the Nasdaq Clean Edge Green Energy (CELS), WilderHill Clean Energy (ECO), S&P Global Clean Energy (SPGTCLEE), iShares Global Clean Energy ETF (ICLN), and Clean Energy Fuels (CLNE) stock indexes. To increase the robustness of the results, the sample was separated into two subperiods: Tranquil and Stress (which include events from 2020 and 2022). We examined the presence of long memories in the stock indexes SPGTCLEE (0.58), CLNE (0.58), ECO (0.56), and ICLN (0.53), while the CELS (0.50) index shows signs of balance, i.e., the random walk hypothesis is not rejected. Already in the subperiod of Stress, which incorporates the events of 2020 and 2022 and has a time interval from January 2, 2020, to May 2, 2023, we witness the presence of persistence in the returns, namely in the SPGTCLEE index (0.57), ICLN (0.54), CELS (0.53), and ECO (0.52), while the CLNE (0.52) index is balanced, i.e., the random walk hypothesis is not rejected. Upon conducting a comparative analysis of the two subperiods, it was observed that there was no substantial increase in the persistence of clean energy indexes. Therefore, the findings of our research don't support the research question regarding the heightened persistence observed in the occurrences of 2020 and 2022. These results receive partial validation from the studies conducted by Guedes et al. (2022), Dias et al. (2022, 2023), Zebende et al. (2022), Santana et al. (2023), Dias, Chambino, et al. (2023) in the context of international financial markets.

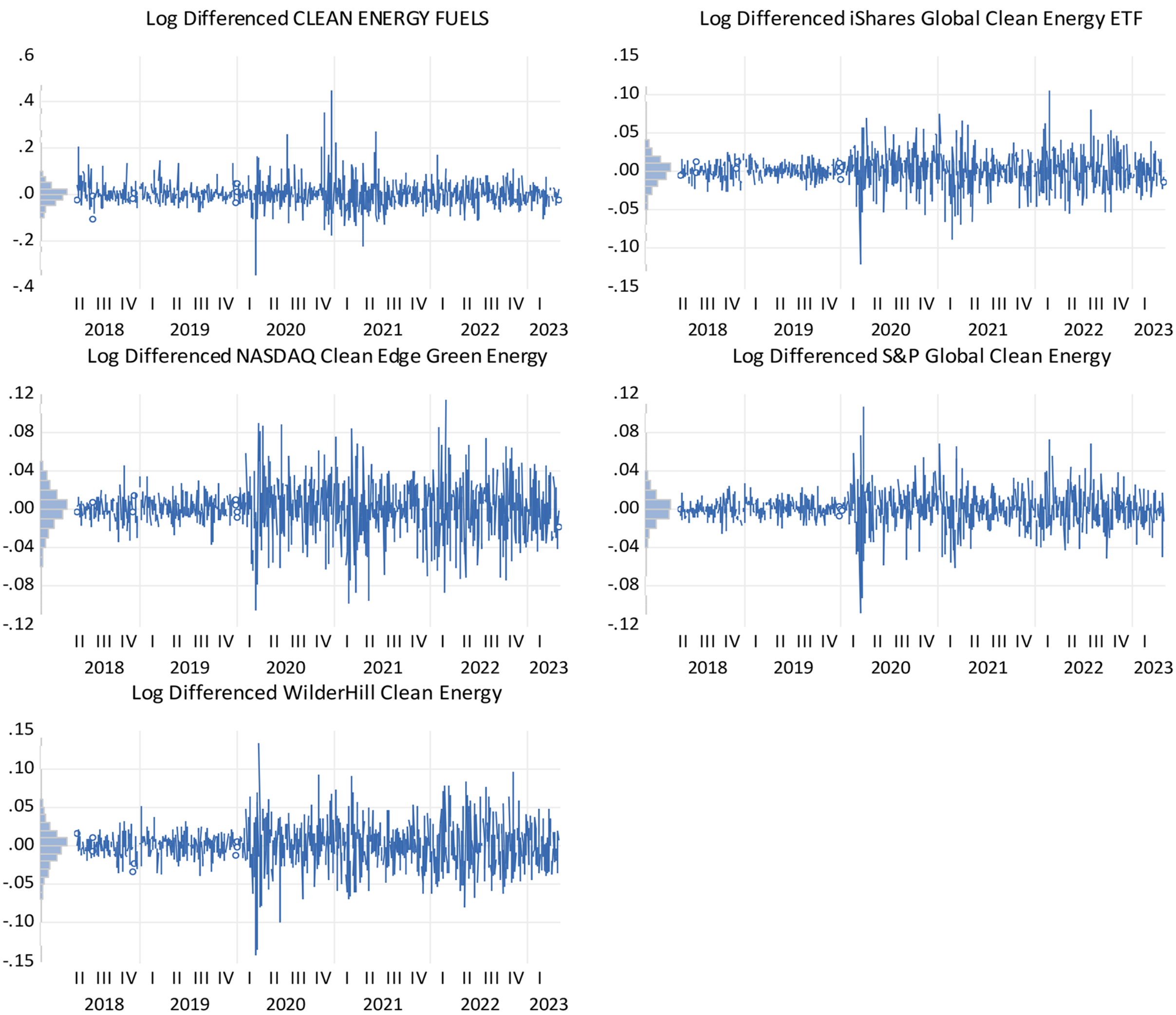

Figure 1. Evolution, and returns, of the financial markets under analysis, from May 3, 2018, to May 2, 2023

Source: Own elaboration

Table 3. Summary table of descriptive statistics, in returns, in respect of the financial markets under analysis, from May 3, 2018, to May 2, 2023

	CLNE	ICLN	CELS	SPGTCLEE	ECO
Mean	0.000482	0.000369	0.000571	0.000412	0.000125
Std. Dev.	0.040084	0.014837	0.018702	0.012749	0.019707
Skewness	1.459962	-0.088204	-0.138421	0.055932	-0.094281
Kurtosis	24.10483	11.75285	9.279764	15.16997	10.20693
Jarque-Bera	34537.25	5831.294	3006.210	11269.51	3954.463
Probability	0.000000	0.000000	0.000000	0.000000	0.000000
Observations	1826	1826	1826	1826	1826

Source: Own elaboration

Table 4. Panel unit root tests applied to the financial markets under study during the period from May 3, 2018, to May 2, 2023

Method		**Statistic**	**Prob.***
PP - Fisher Chi-square		92.1034	0.0000
PP - Choi Z-stat		-8.31597	0.0000
Series	**Prob.**	**Bandwidth**	**Obs.**
CLNE	0.0001	49.0	1824
ICLN	0.0001	50.0	1824
CELS	0.0001	50.0	1824
SPGTCLEE	0.0001	51.0	1824
ECO	0.0001	50.0	1824

Notes: * Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Source: Own elaboration

Table 5. DFA results. The hypotheses are H_0: $\alpha = 0.5$ and H_1: $\alpha \neq 0.5$

Indexes	DFA Exponent (Tranquil)	DFA Exponent (Stress)
CLNE	0.58*** ≅ 0.0192 ($R^2 = 0.98$)	0.52 ≅ 0.0229 ($R^2 = 0.99$)
ICLN	0.53*** ≅ 0.0012 ($R^2 = 0.98$)	0.54** ≅ 0.0014 ($R^2 = 0.99$)
CELS	0.50 ≅ 0.0090 ($R^2 = 0.98$)	0.53** ≅ 0.0021 ($R^2 = 0.98$)
SPGTCLEE	0.58** ≅ 0.0101 ($R^2 = 0.98$)	0.57** ≅ 0.0093 ($R^2 = 0.98$)
ECO	0.56*** ≅ 0.0015 ($R^2 = 0.99$)	0.52** ≅ 0.0074 ($R^2 = 0.98$)

Note: The hypotheses are H_0: $\alpha = 0.5$ and H_1: $\alpha \neq 0.5$

Source: Own elaboration

5. CONCLUSION

The purpose of this research was to examine the potential impact of the events occurring in 2020 and 2022 on the long-term performance of the Nasdaq Clean Edge Green Energy (CELS), Wilder-Hill Clean Energy (ECO), S&P Global Clean Energy (SPGTCLEE), iShares Global Clean Energy ETF (ICLN), and Clean Energy Fuels (CLNE) stock indexes. The study period spanned from May 3, 2018, to May 2, 2023. The findings demonstrate mixed results, as we have confirmed that the occurrences in 2020 and 2022 did not intensify the persistence since the existence of long-term memories was previously noted during the Tranquil period. The findings show that there is potential for a certain level of predictability in the clean energy markets in the long term. This predictability might be useful for investors who have an avid interest in green investing. Furthermore, policymakers can use this information to enhance their decision-making processes regarding the promotion and facilitation of clean energy markets. This study offers significant contributions to the understanding of the behavior of clean energy stock indexes and their potential as a sustainable investing option. Further research may be based on these findings, exploring other factors that may influence the persistence of these indexes, such as technological advances and government policies.

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