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Will There Be Dependencies between Oil Prices and Clean Energy Indexes?

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Abstract: *This paper analyses whether clean energy stock indexes, namely WilderHill Clean Energy, Clean Energy Fuels, and Nasdaq Clean Edge Green Energy indexes, can be considered coverage assets for the dirty energy stock indexes such as the Brent Crude Spot and Euro Stoxx Oil & Gas indexes during the events that occurred in 2020 and 2022. The results suggest low levels of integration, which shows that clean energy indexes are isolated. Based on these findings, the clean energy index may offer a better opportunity to cover oil prices. However, it is important to highlight that market conditions, transaction costs, and asset performance affect hedge strategy returns. Therefore, it is important to carefully assess the potential risks and benefits of any hedge strategy before making investment decisions. In addition, past performance does not guarantee future results, and market conditions can change quickly and unpredictably.*

1. INTRODUCTION

In recent years, the relationship between crude oil prices and renewable energy stock values has gotten more complex and dynamic. In the past, rising oil costs have increased demand for cleaner energy sources. However, this link evolved as a result of many factors. Concerns about climate change, technical advancements, and government assistance are all driving rising demand for sustainable energy. Global oil price variations, on the other hand, have become less predictable owing to geopolitical tensions, supply interruptions, and changes in demand patterns. Because of this shifting picture, the interplay between crude oil prices and clean energy stock prices has become increasingly complex (Dias et al., 2023).

In the field of the stock market, portfolio rebalancing is the process of adjusting the asset allocation in a portfolio to align it with the investor's investment objectives and risk tolerance. This approach is especially crucial during times of global economic instability since it assists investors in managing risk and maintaining the desired amount of portfolio diversification. Re-balancing can involve selling assets that have appreciated in value and reallocating revenue to underperforming assets in order to align the portfolio with its desired allocation. This reduces the risk of the portfolio becoming overly concentrated in a single asset class, sector, or geographical region (Dias et al., 2019, 2020, 2021; Silva et al., 2020; Dias & Carvalho, 2021; Pardal et al., 2021).

The present study aims to analyze whether clean energy stock indexes, specifically the WilderHill Clean Energy (ECO), Clean Energy Fuels (CLNE), and Nasdaq Clean Edge Green Energy (CELS) indexes, can be considered coverage assets for dirty energy stock indexes such as the Brent Crude Spot (BRENT) and Euro Stoxx Oil & Gas (EUSTOXX) indexes during the 2020

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and 2022 events. The results suggest low levels of integration, indicating that clean energy indexes operate in isolation. Based on these results, it can be inferred that the clean energy index may offer a more promising opportunity for covering oil prices.

Previous research argues that the linkages between clean/green and filthy energy assets change over time, but there is not much evidence on the capacity for clean energy shares to cover dirty assets such as crude oil and the portfolio implications. Furthermore, the determinants of the fluctuations in the returns of hedge portfolios remain uncertain. An important question that has received a lot of attention in recent years is whether clean energy stock indexes can be regarded as hedge assets in dirty energy stock indexes.

The main purpose of this study is to offer valuable insights into the relationship between clean energy and dirty energy stock indexes and their potential as hedge assets. Clean energy stock indexes such as the ECO, CLNE, and CELS indexes might potentially protect dirty energy stock indexes such as the BRENT and EUSTOXX indexes. The COVID-19 pandemic issue, for example, showed the potential risks of investing in dirty energy stocks while proving resilience through clean energy actions. Overall, this research examines the potential use of clean energy stock indexes, as covering assets for dirty energy stock indexes has significant implications for investors and policymakers attempting to mitigate the risks associated with investing in energy stocks.

This paper is structured into 5 distinct sections, with each section serving a specific purpose. Section 2 provides a comprehensive analysis of the existing literature on the integration of international financial markets. Section 3 provides an account of the methodology and the data used in the study. The findings are presented in Section 4. Lastly, Section 5 of the document outlines the conclusions.

2. LITERATURE REVIEW

International financial market linkages are crucial for investors, fund managers, and academics. Understanding the interrelationships between financial markets across the globe during times of stress can help investors recognize the synchronizations between markets and enable them to make knowledgeable decisions regarding portfolio diversification. For academics, examining these connections can provide effective insights into how the global financial system operates. It may also provide opportunities for research in fields such as international finance, macroeconomics, and econometrics. Understanding the global linkages among financial markets holds significant relevance for all players involved in the financial system. By recognizing the interconnections of different markets, investors are able to engage in risk management practices that improve the optimization of their investment portfolios. Furthermore, academic research may be useful as an explanation for the complex dynamics of the global financial system and to inform policymakers on financial stability and regulation issues (Dias, Pardal, et al., 2022; Dias, Pereira, et al., 2022; Pardal, Dias, Teixeira & Horta, 2022; Teixeira, Dias & Pardal, 2022; Teixeira, Dias, Pardal & Horta, 2022).

The authors Kumar et al. (2012), Managi and Okimoto (2013), and Saeed et al. (2020) explored whether clean energies could provide a safe haven for dirty energies. According to Kumar et al. (2012), increasing traditional energy prices and/or applying a price on carbon emissions would encourage investments in clean energy companies. The authors highlight that oil prices and technology stock prices separately affect the share prices of clean energy companies, showing that coverage and safe haven effects could be challenged. Similarly, Managi and Okimoto (2013) analyzed the relationships between oil prices, clean energy stock prices, and technology stock prices. The results show that there was a structural change at the end of 2007, a period in which there was a significant rise in oil prices. The author´s findings diverge from prior research as they reveal a positive relation between oil prices and clean energy prices after structural market recessions. This result challenges the concept of coverage effect in the context of portfolio diversification. Furthermore, Saeed et al. (2020) used daily data from January 3, 2012, to November 29, 2019, to analyze the covering capacity of clean and green assets in relation to 2 dirty energy assets (oil prices and energy ETFs). The authors suggest that investors should use a dynamic hedging strategy and that clean energy stocks are a more effective hedge than green bonds, in particular for crude oil.

Later, the authors Ren and Lucey (2022) and Arfaoui et al. (2023), show the negative environmental effects of cryptocurrencies' high-power energy consumption and link these assets to assess if clean energies will have the attributes required to be coverage assets or act as a safe haven. Ren and Lucey (2022) evaluated the hedges and safe haven ownership of a wide range of clean energy indexes against two separate types of cryptocurrencies named "dirty" and "clean" based on their energy consumption levels. The results indicate that clean energy does not provide immediate protection of any type. However, it acts as a poor safe haven for both markets. Furthermore, it is apparent that during times of increased uncertainty, the clean energy market may act as a safe haven for cryptocurrencies with high energy consumption rather than for clean ones. Arfaoui et al. (2023) examined the dependence between clean energy, green markets, and cryptocurrencies during the period from January 2018 to November 2021. The results show that sustainable investments, such as DJSI and ESGL, played an important role in the network system during the COVID-19 pandemic, and green bonds were the least integrated with other financial markets, implying their importance in delivering diversification advantages to investors.

In recent studies, the authors Sharif et al. (2023) and Farid et al. (2023) studied the coverage and safe haven characteristics of clean energy stock indexes in relation to various asset classes. The study conducted by Sharif et al. (2023) aimed to investigate the correlations and relationships between green economic indexes, 5 dirty cryptocurrencies, and 5 clean cryptocurrencies in the markets of the US, EU, and Asia. The research period spanned from November 9, 2017, to April 4, 2022. The empirical findings reveal that the overall correlation between green economic indexes and clean cryptocurrencies is stronger than the linkage between dirty crypto and green economic indexes. Furthermore, 2020 is a historical year for clean cryptocurrency since it signals the beginning of the COVID-19 pandemic. The total overload effect is very strong for all 3 markets, particularly in Asia, thereby raising concerns regarding the efficacy of coverage and safe haven strategies. Additionally, Farid et al. (2023) investigated co-movements between clean and dirty energy stock indexes before and during the 2020 global pandemic. The results reveal weak linkages between clean energy stocks and dirty energy stocks in both the short and long term, with an evident disassociation effect between dirty and clean energy stock markets. Also, the findings illustrate that the clean energy market was relatively detached from the dirty energy market during the recent pandemic crisis, emphasizing the benefits of portfolio diversification in both the clean and dirty energy markets.

3. METHODOLOGY AND DATA

3.1. Data

The data used in the paper is daily, and the sample includes 3 clean energy stock indexes: WilderHill Clean Energy (ECO), Clean Energy Fuels (CLNE), and Nasdaq Clean Edge Green Energy (CELS), as well as 2 dirty energy stock indexes: Brent Crude Spot (BRENT) and Euro Stoxx Oil & Gas (EUSTOXX). The period under study is the period from March 1, 2018, to March 1, 2023, and includes events with significant complexity for the global economy, such as the global pandemic COVID-19, followed by the oil price war between Russia and Saudi Arabia, and the Russian invasion of Ukraine in 2022. The data has been obtained through the Thomson Reuters Eikon platform and is expressed in US dollars.

3.2. Methodology

The paper is developed in phases. In the first phase, the main measures of descriptive statistics and the Jarque and Bera (1980) adherence test, which postulate data normality, are used to characterize the sample. The panel unit root tests from Hadri (2000) are used to validate the assumption of stationarity of the time series, and the tests of Dickey and Fuller (1981), incorporating Fisher's Chi-square and Choi's (2001) transformation, are used to validate the results. The panel tests ADF (Augmented Dickey-Fuller), Fisher Chi-square, and ADF-Choi Z-stat are econometric statistical tests commonly used to determine the presence of a unit root in a time series data set. Fisher's qui-square ADF test calculates a test statistic based on the difference between the estimated and hypothetical values of a regression model coefficient. This test statistic follows a qui-square distribution, and its level of significance is used to determine the presence of a unit root.

The Choi Z-stat version of the ADF test, on the other hand, is an alternate approach that calculates test statistics based on the autoregressive model estimate of maximum likelihood. This test statistic follows a standard normal distribution, and its level of significance is used to evaluate the research question, i.e., whether clean energy stock indexes may be considered coverage assets for dirty energy stock indexes during the events of 2020 and 2022. The rhoDCCA of Zebende (2011) is estimated, which allows it to determine the level of cross-correlation between different energy indexes. This coefficient is based on Peng et al. (1994) Detrended Fluctuation Analysis (DFA) methods and Podobnik and Stanley (2008) Detrended Cross-correlation Analysis (DCCA).

The cross-correlation coefficient depends on the length of the s box (temporal scale). The main advantage associated with this cross-correlation coefficient is the ability to measure the correlations between two non-stationarity time series on different time scales. The DCCA coefficient varies within the range $-1 \leq \rho\text{DCCA} \leq 1$. In this sense, 1 means that the series shows perfect cross-correlation between the two signs, -1 means perfect anti-cross-correlation, and 0 means no correlation between the time series. For a better understanding of this econophysical model, see the articles published by the authors Zebende et al. (2022), Guedes et al. (2022), and Santana et al. (2023).

4. RESULTS

The visual representation shown in Figure 1 demonstrates the evolution of the 5 energy stock indexes analyzed in this study. These indexes include 3 clean energy stock indexes, namely WilderHill Clean Energy (ECO), Clean Energy Fuels (CLNE), and Nasdaq Clean Edge Green

Energy (CELS), as well as 2 dirty energy stock indexes, namely Brent Crude Spot (BRENT) and Euro Stoxx Oil Gas (EUSTOXX). The time frame for this analysis spans from February 28, 2018, to March 1, 2023.

The initial wave of the global COVID-19 pandemic, as well as the oil price war between OPEP members, are known to have taken place in the early months of 2020 and, consequently, had a significant influence on the energy stock indexes under study. The behavior of the clean energy stock indexes, particularly ECO, CLNE, and CELS, has changed. With Russia's invasion of Ukraine in 2022, the supply of natural gas was reduced, and its price increased abruptly. Regarding the future scarcity of energy resources, global economies are increasingly interested in diversifying their investments through clean energy alternatives. The authors Dias, Horta, and Chambino (2023) suggested the existence of such evidence in their study of the behavior and efficiency of the international financial markets.

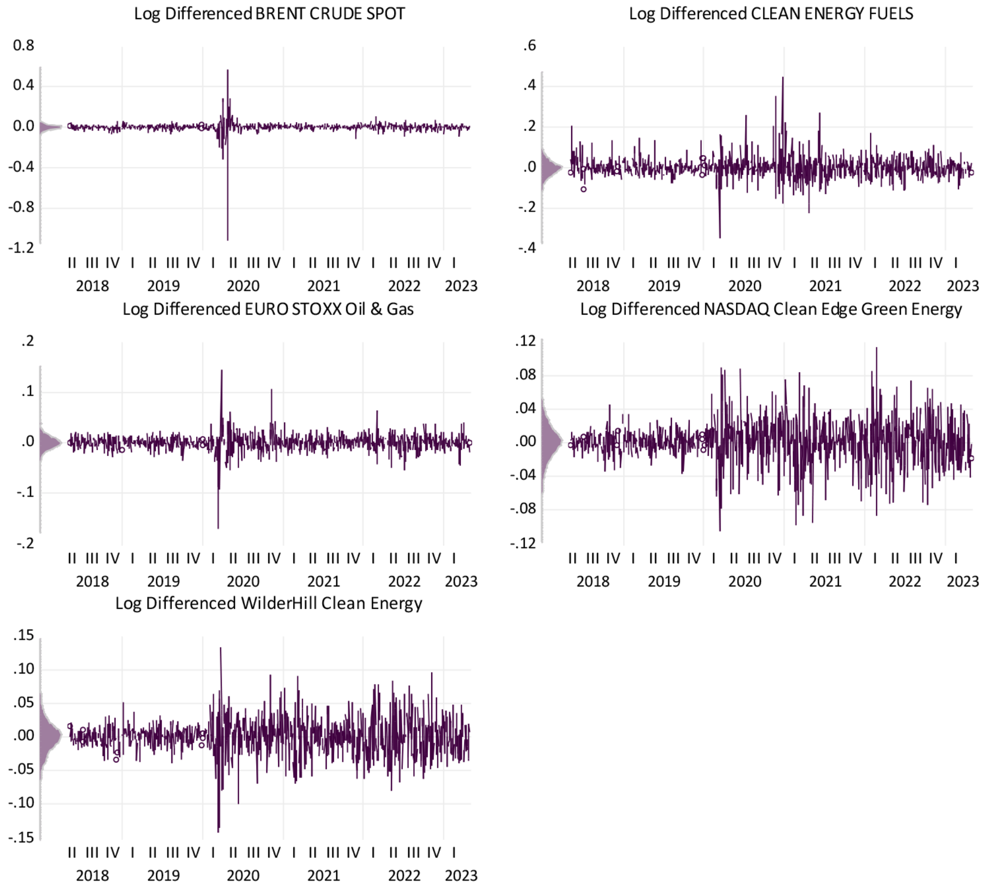

Figure 1. Evolution, in levels, of the financial markets under analysis, from March 1, 2018, to March 1, 2023

Source: Own elaboration

Table 1 shows the main descriptive statistical measures for the 5 energy stock indexes under consideration, as well as the results of the Jarque and Bera (1980) adherence test for the whole period. In terms of mean returns, all stock indexes presented positive values. Regarding standard deviation, the CLNE stock index (0.040084) has the most significant degree of dispersion. To determine if the energy stock indexes follow a Gaussian distribution, the metrics of skewness and kurtosis were estimated. The findings indicate that the indexes exhibit distinct values of 0 and 3 for asymmetry and kurtosis, respectively. Furthermore, to corroborate the previous evidence, i.e., whether the time series returns present values corresponding to a normal distribution or not, the Jarque and Bera (1980) adherence test was performed and the results indicate that H_0 is rejected at a level of significance of 1%. In other words, the time series returns on the energy stock indexes under research fail to follow a normal distribution.

Table 1. Summary table of descriptive statistics, in returns, in respect of the financial markets under analysis, from March 1, 2018, to March 1, 2023

	BRENT	CLNE	EUSTOXX	CELS	ECO
Mean	0.000431	0.000482	0.000104	0.000571	0.000125
Std. Dev.	0.038992	0.040084	0.012673	0.018702	0.019707
Skewness	-11.31994	1.459962	-0.602354	-0.138421	-0.094281
Kurtosis	418.9986	24.10483	37.57033	9.279764	10.20693
Jarque-Bera	13205589	34537.25	91038.18	3006.210	3954.463
Probability	0.000000	0.000000	0.000000	0.000000	0.000000
Observations	1826	1826	1826	1826	1826

Source: Own elaboration

The panel unit root test of Hadri (2000), which has stationarity as a null hypothesis, was used to test the assumption that the time series of the clean and dirty energy stock indexes were stationary. According to the results in Table 2, the null hypothesis is not rejected at a level of significance of 1%, implying that the time series on the panel are constant in the first differences.

Table 2. Unit root panel test, in respect of the financial markets under analysis, from March 1, 2018, to March 1, 2023

Null Hypothesis: Stationarity				
Method			**Statistic**	**Prob.***
Hadri Z-stat			-2.91247	0.9982
Heteroscedastic Consistent Z-stat			-2.76113	0.9971
Series	**LM**	**Variance HAC**	**Bandwidth**	**Obs.**
BRENT	0.0118	64.78658	50.0	1825
CLNE	0.0243	0.242504	49.0	1825
EUSTOXX	0.0109	1038.036	50.0	1825
CELS	0.0123	5445.474	50.0	1825
ECO	0.0160	219.1902	50.0	1825

Notes: High autocorrelation leads to severe size distortion in Hadri's test, leading to over-rejection of the null. * Probabilities are computed assuming asymptotic normality.

Source: Own elaboration

Additionally, the tests by Dickey and Fuller (1981) with the Fisher Chi-square transformation and Choi (2001) that postulate the same null hypothesis, i.e., the presence of a unit root or non-constant variance, were used to validate the preceding results. According to the findings presented in Table 3, the null hypothesis is rejected at a level of significance of 1%, corroborating previous evidence regarding the stationarity of the time series at the period under analysis. It should be highlighted that stationarity can only be achieved using the logarithmic transformation in first differences, which is used to calculate the return of each stock index.

In Table 4, the Detrend Cross-Correlation Coefficient (*rhoDCCA*) for the clean and dirty energy stock indexes can be observed for the period from March 1, 2018, to March 1, 2023. To increase the robustness of the findings, the sample was partitioned into two distinct subperiods.

The first subperiod, denoted as Tranquil, corresponds to a period of apparent stability in financial markets. The second subperiod, referred to as Stress, covers the events that occurred in 2020 and 2022.

Table 3. Unit root panel tests, in respect of the financial markets under analysis, from March 1, 2018, to March 1, 2023

Null Hypothesis: Unit root (individual unit root process)				
Method			Statistic	Prob.*
ADF – Fisher Chi-square			1018.04	0.0000
ADF – Choi Z-stat			-31.1896	0.0000
Series	**Prob.**	**Lag**	**Max Lag**	**Obs.**
BRENT	0.0000	19	24	1805
CLNE	0.0000	20	24	1804
EUSTOXX	0.0000	19	24	1805
CELS	0.0000	19	24	1805
ECO	0.0000	19	24	1805

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

Source: Own elaboration

Table 4. Summary of the *rhoDCCA* coefficients, applied to the 5 stock indexes, referring to the Tranquil and Stress subperiods

	Tranquil Sub-Period			**Stress Sub-Period**		
Indexes	*rhoDCCA*	**Period (days)**	**Trend**	*rhoDCCA*	**Period (days)**	**Trend**
BRENT / CELS	0.22	n > 6	weak	0.15	n > 6	weak
BRENT / ECO	0.19	n > 6	weak	0.17	n > 6	weak
BRENT / EUSTOXX	0.38	n > 52	medium	0.39	n > 6	medium
BRENT / CLNE	0.23	n > 20	weak	0.13	n > 6	weak
CELS / ECO	0.67	n > 43	strong	0.04	n > 6	weak
CELS / EUSTOXX	0.38	n > 20	medium	0.30	n > 6	weak
CELS / CLNE	0.34	n > 16	medium	0.68	n > 165	strong
ECO / EUSTOXX	0.37	n >52	medium	0.24	n > 16	weak
ECO / CLNE	0.22	n > 16	weak	0.47	n > 43	medium
EUSTOXX / CLNE	0.34	n > 112	medium	0.37	n > 52	medium

Note: Data collected by the author.

Source: Own elaboration

The *rhoDCCA* coefficients for the Tranquil period reveal 5 medium correlation coefficients ≅ 0.333 → ≅ 0.666, 4 weak correlations coefficients ≅ 0.000 → ≅ 0.333, and 1 strong cross-correlation without trend ≅ 0.666 → ≅ 1.000. In the Stress subperiod, which includes the period from January 1, 2020, to March 1, 2023, there are 6 weak correlation coefficients ≅ 0.000 → ≅ 0.333 , 3 medium correlation coefficients ≅ 0.333 → ≅ 0.666 , and 1 strong cross-correlation without trend ≅ 0.666 → ≅ 1.000.

When comparing the two subperiods, it is visible that the majority of *rhoDCCA* go through a transition from medium to weak non-trend correlation coefficients. The findings show that in 2020 and 2022, most of the stock markets studied were not integrated. This confirms that clean energy stock indexes may serve as hedge assets in relation to dirty energy stock indexes. Consequently, for investors involved in these energy markets, clean energy assets may present a viable risk diversification strategy.

5. CONCLUSION

This research aimed to assess the potential of clean energy stock indexes, specifically the WilderHill Clean Energy (ECO), Clean Energy Fuels (CLNE), and Nasdaq Clean Edge Green Energy (CELS) indexes, as hedge assets against dirty energy stock indexes such as the Brent Crude Spot (BRENT) and Euro Stoxx Oil & Gas (EUSTOXX) indexes, during the periods of 2020 and 2022. The findings indicate a limited degree of integration among these measures. This suggests that the clean energy indexes exhibit relative isolation from the dirty energy indexes. Based on these facts, it can be deduced that clean energy indexes might provide a more favorable prospect for hedging against fluctuations in oil prices. This further suggests that allocating investments towards renewable energy stocks might function as a hedging strategy against the volatility of oil prices since they seem to be less susceptible to external factors impacting the fossil fuel industry. Nevertheless, it is crucial to acknowledge that these results are limited in their applicability to the particular study conducted and the period under examination. Additional examination and the inclusion of additional variables may be required in order to substantiate and extrapolate these results.

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