All Sciences Proceedings

1st International Conference on Scientific and Innovative Studies

April 18-20, 2023 : Konya, Turkey

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Modeling the Variation between Green Energy Stock Prices and Oil Prices Using Fourier Analysis

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Abstract **–** Green energy production is crucial to protecting the environment and meeting future energy demand. Therefore, the study aims to investigate the relationship between oil price indices and green energy stock prices. In this study, the data of Nasdaq OMX Wind and Nasdaq OMX Solar indices and crude oil index (Oil) for the period of January 2015-March 2023 are collected and investigated using Fourier analysis method. Therefore, in this study, the correlation between Oil and other (Solar and Wind) data values is examined. Fourier power spectrum analysis method is used and according to the results of this power spectrum analysis; The fact that there is a correlation between the Oil data values and both the Solar and Wind data values is demonstrated by the average, maximum and standard deviation values obtained as a result of the Fourier power spectrum and power spectrum. In conclusion, the findings of this study also provide important recommendations for investors, managers and policy makers.

Keywords – Green Energy, Fourier Analysis, Solar Energy, Wind Energy, Oil Prices

I. INTRODUCTION

In recent years, energy consumption has been increasing significantly, and the world's reliance on the fossil oil industry to provide power, transport fuel, and operate industries has led to increased energy-related CO2 emissions, which threatens ecosystems and increases global warming. These global threats underscore the importance of switching to alternative energy sources such as renewable clean/green energy to maintain the sustainability of the universe [1]. At the same time, consensus is being promoted worldwide to align global development and the protection of environmental characteristics with each other due to worsening environmental quality and aggravating climate change adversities. In the past, the concept of "growing the economy now and cleaning up the environment later" was taken as a basis, while contemporary development policies focus on the greening of production processes in order to reduce greenhouse gas emissions, especially from the burning of fossil fuels. Therefore, the transition towards green/clean energy sources is accelerating [2]. Eco threats, large energy demand, and large capital formation requirements to meet energy needs emphasize the importance of clean energy production for investors, governments, and the economy, and many countries are adopting energy strategies that promote the use and production of clean energy [1].

The dynamics of energy prices, such as oil, is one of the main energy-related risk factors affecting the financial performance of green/clean energy investment projects. Therefore, identifying how different energy prices affect the value of green/clean energy companies that are renewable energy is of interest to investors who want to assess the sensitivity of renewable energy investments to energy prices, especially when energy prices are low or high [3]. At the same time, energy prices, including the price of oil, are expected to increase

investment returns in the green/clean energy sectors [1]. Therefore, there is an information link between the oil market and green energy companies, and oil prices can apply different information dissemination mechanisms for different green energy companies. The degree to which green energy companies respond to the oil price shock may also vary. The degree to which green energy companies respond to the oil price shock may also vary. In addition, the shock to clean energy companies from rising and falling crude oil prices may be inconsistent. Clean energy companies make completely different decisions about rising and falling oil prices, and therefore, it is necessary to separate the oil price yield series into positive and negative returns in each specific analysis. As economic environments change, dependence on oil prices to stocks of clean energy companies can have time-varying characteristics [4].

On the other hand, the high costs of building and installing green/clean energy systems, which are renewable energy, are obstacles to alternative energy. Therefore, any significant drop in oil prices severely limits the attractiveness and economic viability of clean energy projects and leads to an abrupt halt in the development of sustainable energy, which has a detrimental effect on the stock prices of green/clean energy companies, which are new energy companies [5].

There are few studies investigating how changes in the price of oil affect renewables or clean/green energy stock returns, but there is no consensus on the nature of the relationship between the two variables. Previous studies have also discussed the importance of investigating the relationship between oil and green/clean energy exchanges ([6], [7], [8]). Therefore, in the study, the relationship between the oil price and the green energy stock prices in the period of January 2015-March 2023 is investigated using the Fourier analysis method.

The rest of the work is organized as follows. The second part examines studies that address the relationship between oil markets and clean/green energy stock market. The third section describes the working method and data. In the third section, the study findings are summarized. The last section describes the study results.

II. LITERATURE REVIEW

Green energy production is crucial to protecting the environment and meeting future energy demand [1]. There are only a few articles in the literature on the relationship between green/clean energy stocks, which are oil and renewable energy. The findings of these papers suggest that there seems to be complete disagreement about how green energy relates to the oil market. For example, [6] examine the long-term relationship between the stock prices of alternative energy companies and oil prices over the period from January 3, 2003 to June 5, 2015. The results show that while the long-term relationship between the variables is determined, it is determined that there is a one-way causality extending from oil prices to the stock prices of alternative energy companies. [7] investigates whether oil price shocks had an impact on clean energy stock returns between May 10, 2007 and June 30, 2016 using volatility methods. The researcher finds that there is volatility from oil to the alternative energy market, and that clean energy share returns are associated with oil volatility shocks. It is also being achieved that oil price shocks are a positive cause to clean energy stocks. Similarly, [9] reveal both nonlinear causality from renewable energy indices to oil prices and mixed causality from oil to renewable energy prices over the 2008-2015 period.

[3], which investigates whether oil, gas, coal, and electricity price movements affect clean energy stock returns, note that oil and electricity prices in the U.S. and the EU over the period 2009-2016 made significant contributions to clean energy stock returns. The researchers also found that other energy prices play a small role in influencing clean energy stock returns. However, [5] finds that crude oil prices, in the short term or long term covering the period from January 2, 2003 to September 29, 2017, do not appear to be the main driver of the stock market performance of renewable energy companies. This therefore signals the departure of the alternative energy industry of clean-green energy from the traditional energy market.

[1] examined the relationship between crude oil, clean energy, and the clean energy technology market between January 1, 2001 and February 23, 2018 using the multivariate GARCH method, and the findings reveal causality from oil and the technology market to the green/clean energy market. [8] apply wavelet-based quantile-on-quantile and Granger causality-in-quantile methods to empirically address the effects of oil price structural shocks on the clean energy stock market during the period January 2006-December 2018.

The results show that the effects of the oil supply shock on clean energy are strong in the short and long term, but not relatively strong in the medium term. Similar to these findings, [10] found that during the period July 10, 2012-December 2, 2019, the impact of the oil supply shock on clean energy appears to be strong in the short and long term but positive in the medium term. Granger causality findings also provide evidence of causality from clean energy stocks to oil price shocks over the long term.

At the same time, [4] examines the dynamic impact of oil price changes on the equity returns of clean energy firms using the DCC-GARCH model for Europe from 1 September 2009 to 7 June 2019. The findings show that changes in crude oil prices and clean energy inventories move in the same direction, while oil yields move according to the information in the crude oil-clean energy relationship. Using a multi-scale time-dependent analysis method on daily closing data for the period 3 January 2006 to 31 December 2018, [11] finds that the dependence of clean energy companies' stocks on crude oil has declined in recent years, and especially after the European debt crisis.

The findings obtained as a result of the evaluation of the above studies show how the interaction between the green/clean energy price index, which is renewable energy, and crude oil prices, which is one of the important determinants of this, changes over time and according to green/clean energy types and what the effects are. Therefore, the evidence emerging from the literature becomes an important source in determining the purpose of this study, and the findings obtained as a result of this study offer important recommendations for investors, managers and policy makers.

III. Materials and Method

This study examines the relationship between the oil price and the green energy stock prices by using the monthly closing prices of the Nasdaq OMX Wind (Wind) and Nasdaq OMX Solar (Solar) indices and the crude oil index (Oil) from the green energy indices. Using the base dates of January 2015 and March 2023, respectively, the relationship is determined using the Fourier analysis method. It shows the Wind index of the US Nasdaq Stock Exchange, which is designed to track companies that produce energy with wind energy and is a sub-sector index of the green economy index [12]. It shows the index of the US Nasdaq Stock Exchange (Solar), which is designed to track companies that produce energy with solar energy and is a sub-sector index of the green economy index [12]. Oil also refers to the crude oil price index [13].

In the study, Fourier analysis is used to examine the relationship between oil price and green energy stock market prices. Fourier and his colleagues claim that the techniques they have developed can model every plausible behavior that can be observed in nature. Physical phenomena, which they define as "reasonable behavior", still find application in modern scientific developments. Classical Fourier analysis techniques are used in many fields. It lays the foundation for the interdisciplinary field called "time-frequency analysis" or "modern Fourier analysis", which is the local form of Fourier analysis. Fourier analysis, applications of time-frequency analysis today, enables the customization of these analysis applications. While taking the "picture of the black hole", which has recently come to the agenda of the whole world, these time-frequency analysis techniques are applied to classify and clean the signals coming from space. The application areas of time-frequency analysis are not limited to the application areas of classical Fourier analysis [14]. The Fourier function is the expansion of the periodic function *yt* as the sum form of cosines and sines. In conclusion, Fourier analysis is a mathematical technique used to determine the component frequencies of a signal. This technique is used in many different fields and is especially important for the analysis of digital signals ([15], [16]). There are many studies in the literature using this method of analysis. For example, [17], who investigated market elasticity as one of the stock market liquidity dimensions using the Discrete Fourier method for high-frequency intraday data, found that there are strong correlations between stock elasticity values. In addition, [18], who examined whether 22 indices were active in poor form in Borsa Istanbul using Fourier unit root tests, obtained that 13 indices were active and 9 indices were inactive. [19] predict the power spectrum by analyzing daily and minute-sample financial stock market data using Dynamic Fourier and Wavelet techniques and prevent spectral leakage or discontinuity in the data.

In conclusion, it shows that it helps to characterize some fundamental variables of stationary time series, which are very useful for making informed

decisions in the stock market, such as the assessment of financial risk in the market. In line with the studies examined in the literature, it is revealed that the Fourier method is rarely used. In this context, the use of the Fourier method in this study is the most important element that distinguishes it from previous studies.

IV. RESULTS

Results In this study, the relationship between Oil price and green energy stock pricesNasdaq OMX Wind (WIND) and Nasdaq OMX Solar (SOLAR) indices is explained by Fourier analysis method.

The trends of the power spectrum functions of the Oil, Solar and Wind data values are given in graph 1 and graph 2. It is seen in Chart 1 that the increase and decrease in the data values of the solar power spectrum move in parallel with the data values of the Oil power spectrum. It is seen that the Solar data values also increase in the frequency range where the Oil data values increase, and the Solar data values decrease in the frequency range where the Oil data values decrease. The result of this power spectrum analysis shows that there is a correlation between the Oil data values and the Solar data values.

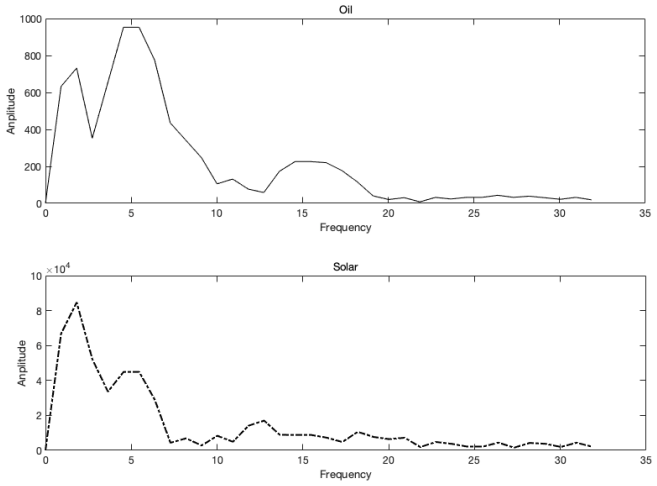

Chart 1. Fourier power spectrum plots of Oil and Solar data values The trends of the power spectrum functions of the Oil and Wind data are that the Wind power spectrum moves parallel to the Oil power spectrum, as seen in Chart 2 below. It has been shown that Wind data values also increase in the frequency range where Oil data values increase, and wind data values decrease in frequency range where Oil data values decrease. According to the power spectrum analysis result, it is shown in Chart 2 that there is a correlation between Oil data values and Wind data values. When the average, maximum and standard deviation values of the data values obtained as a result of Fourier power spectrum analysis are examined, it is shown in Table 1 that the Wind data values search and decrease in parallel with the Oil data values. These values also confirm the correlation between the Wind data values and the Solar data values.

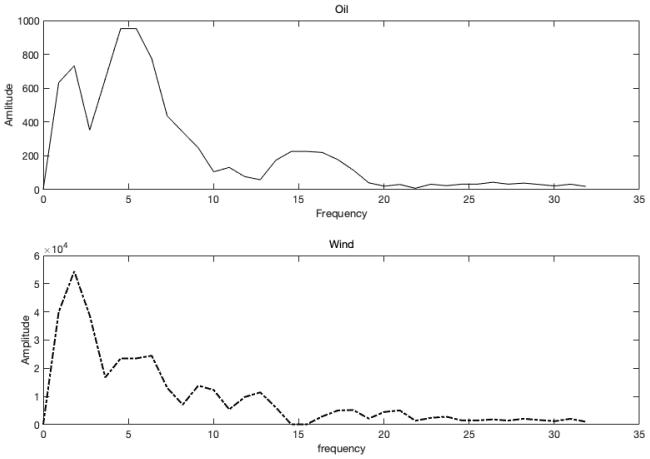

Chart 2. Fourier power spectrum plots of Oil and Wind data values.

Table 1 provides descriptive statistics for variables. The average value of the crude oil price index is 222.93, while the maximum value is 652.79 and the deviation coefficient is 280.71. The average value of the solar index is 14497.83. Its maximum and standard deviation is 84685.22 and 20100.64, respectively. Finally, the mean, maximum and standard deviation of the wind index are 9625.22, 54362.82 and 12773.26, respectively. When the average, maximum and standard deviation values of the data values obtained as a result of Fourier power spectrum analysis are examined, it is given in Table 1 that the Solar data values search and decrease in parallel with the Oil data values. These values confirm the correlation between Oil data values and Solar data values.

Table 1. Mean, maximum and standard deviation values of the data after Fourier analysis

Variables	Mean	Max	Std
Oil	222.93	952.79	280.71
Solar	14497.83	84685.22	20100.64
Wind	9625.22	54362.82	12773.26

V. CONCLUSION

In recent years, the green/clean energy industry, which is renewable energy, has been developing

rapidly due to its environmental friendliness and meeting future energy demand. The financial behavior of green/clean energy companies is confirmed by the evidence from many studies that they are influenced by oil prices. The aim of this study is to investigate the relationship between oil price and green energy stock market prices. The study period is analyzed by applying the Fourier method to the monthly data collected based on the period between January 2015 and March 2023 and the findings are interpreted.

In this study, the correlation between Oil and other (Solar and Wind) data values was investigated. In this research, Fourier power spectrum analysis method was used and according to the results of this power spectrum analysis; The fact that there is a correlation between the Oil data values and both the Solar and Wind data values was demonstrated by the mean, maximum and standard deviation values obtained as a result of the Fourier power spectrum and power spectrum. Based on the study findings, [19] examines the relationship between oil prices and clean energy sub-sector stock indices in the period October 2010-August 2018 through the GARCH model. The findings show that the relationship between oil prices and clean/green energy stocks varies between green energy stock sub-sectors. It is also found that wind is the least linked to oil with geothermal shares.

These findings offer some advice. First, to best manage public investment efforts, policymakers should also be interested in how fluctuations in energy prices shape renewable energy stock prices, and secondly, provide market-based incentives for market forces driving energy prices to invest in green energies.

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