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Article

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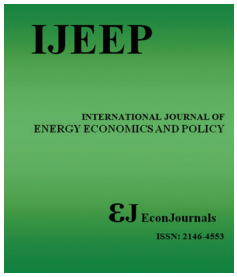

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Renewable Energy Transition: Evidence from Spillover Effects in Exchange-Traded Funds

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ABSTRACT

The article examines the spillover effect of the transition to renewable energy on different financial markets: specifically, the stock market. The research paper analyzes the prices and dynamics of oil-related assets and renewable funds, as well as reviews literature on the topic in order to evaluate the most important factors of development in these industries. The article utilizes methods of correlation analysis, analysis of variance, regression analysis and standards of deviation and error with the intention to test null hypotheses from previous research. The study uses empirical data spanning the majority of the last decade, in which a decline in the oil market can be observed. This is juxtaposed by the rapid and intense development of renewable energy – solar energy in particular. As concluded in the article, there is a strong spillover effect of this growth onto other markets, emphasizing the investments flowing into renewable energy. Moreover, the ambitious prospects of renewable energy development and it being a strong competitor to fossil fuels and, specifically, oil is drawn as a result of the conducted research.

Keywords: Spillover Effect, Solar Energy, Oil Energy, Transition, Energy Investments
JEL Classifications: C12, C52, E23, Q41

1. INTRODUCTION

Oil is an incredibly important and valuable asset, which has given many countries and companies power and wealth. Many states became influential subjects of world politics and economic relations through their rich oil supply. It can be said that society today operates on oil or, more specifically, the energy that it provides. However, in recent years the effects of oil and petroleum-powered machines on the environment have been an object of many discussions and confrontations, which have started the conversation about alternative sources of energy. Not only are some energy sources "greener" than petroleum, but they are also not finite – renewable energy is a real concept that must be taken advantage of Solar energy as a renewable source involves using panels to harness energy from the sun. This energy is converted into electricity. Electricity can replace oil when powering machines – for example cars (Nyangarika et al., 2018). It is known that electric vehicles (EVs) are becoming popular among producers, in part due to the success of Tesla. The company's success goes so far, in fact, that its market capitalization is currently about three times larger than Exxon Mobil's capitalization. This is also considering that Exxon Mobil was, for a long time, the largest company in the world when the global market was dominated by oil and gas businesses.

Global investments into solar power in 2019 were equal to USD 141 billion, which cannot be compared to over USD 700 billion invested in up-, down- and midstream and refining of the oil and gas supply. Considering this, it is noteworthy that the value of large participants in the solar market has more than doubled since the beginning of 2020. This growth on the stock market has attracted many investors, especially in the current reality of the COVID-19 pandemic, which has had significant effects on the demand for oil and, subsequently, its price. Moreover, even though solar energy currently does not contribute a large share into the GDP of an

economic powerhouse such as the United States, the influx of cash moving into the market of renewable energy may be a sign of prospective active development. The movement on the stock market, whilst not a reflection of the economy, can be considered to be a good indicator of investor sentiments and the projects they consider to be ambitious and promising.

The research paper examines the surge on the stock market of green companies of renewable energy and evaluates the prospects of further development. It draws data on prominent exchange-traded funds (ETFs) of the oil market – the United States Oil Fund (USO) – and the Invesco Solar ETF (TAN). The reason oil future contracts were not used is explained by the choice to research homogenous financial instruments. USO, of course, is consisted for a larger part of WTI crude oil futures, so this asset is still indirectly used. TAN and USO are the largest ETFs in their respective segments, with the first having an average daily volume of USD 110.87 million and the latter USD 136.33 million. In order to understand the profitability and investment attractiveness of these assets, numerous analysis methods were used to conduct research. A t-test of the variables USO and TAN was executed in order to compare the means of profitability of these funds/products and to conduct hypothesis testing of whether the growth of solar assets has caused significant damage to oil's market share in the energy sector as a whole. Furthermore, the correlation between these ETFs and related companies' stock prices was examined. Sampling includes weekly price closes for the period from January 3rd 2012 until November 2nd 2020 and daily price closes from January 2nd 2020 until November 6th 2020. The first period was chosen to start after the world financial crisis of 2008 and the latter to highlight the recent growth of solar assets on the stock market.

2. LITERATURE REVIEW

The prominence and value of oil has been evident for over a century now. Businesses and enterprises were able to achieve incredible levels of wealth as early as the second half of the 20th century. This dominance of the commodity as a high-demand asset has carried through to modern days, with the stock market valuing companies of this sector as the most expensive. One of the largest producers of energy in general and crude oil in particular is the United States. When assessing its activities on the market these past 100 years, it would be evident that the production of oil surged in the new century after decades of gradual decline (Mikhaylov, 2018).

Several oil crises in the 2010s lead to the sharp decline of the commodity's price near the latter half of the decade. In a very recent study, Su et al. (2020) researched the many factors responsible for price changes of oil from the perspective of the United States. They found that U.S. oil production has the weakest effect on the international price of oil, which allows us to determine that the surge in production in the 21st century does not contribute to the price drop. Moreover, their study determined that the States' political relations can have both negative and positive influence on the commodity's price. Considering this, there is a factor more objective and more influential than politics – the price of USD. The dollar, perhaps, affects the price of crude oil the most. This is important and can be used for future research, which would analyze indicators such as DXY and its correlation to WTI prices.

Chen et al. (2016) researched the spillover effect between the USD exchange rates specifically. The article found that the spillover effect between these exchange rates and oil prices are not nonlinear. Moreover, it was discovered that oil shocks and the supply of oil has a heterogeneous effect on exchange rates. It was concluded that shocks on the oil market can be the reason of up to 20% of exchange variations.

Continuing the discussion about the crash of oil prices in 2014, Baumeister and Kilian (2016) focused on the effect of this event on the commodity market's stock returns. They found that whilst, obviously, petroleum and natural gas sector companies suffered the biggest losses, many other consumer goods producers, such as those in the retail sales business, food products and tobacco, had their stock returns appreciated. This information will be used to examine whether there is a correlation between declining oil prices and solar energy price fluctuations.

Herrera et al. (2019) highlighted that fluctuations in oil prices is responsible for disruptions in its consumption and investments. The paper states that the decline in oil price in 2014 in particular had adverse effects on subsequent investments in the oil sector.

Considering this, it was concluded in the study of Smyth and Narayan (2018) the oil prices have been, in fact, beneficial for the economy of the United States. Furthermore, the oil prices' decline has had a positive real output effect on the world economy. Thus, it can be concluded that whilst, the price fluctuations of oil this decade have been good for the US economy as a whole, the same cannot be said for stock market returns and the performance of oil-related stocks and ETFs.

Henriques and Sadorsky (2007) researched the spillover effect between oil prices and alternative energy companies' stock prices. This topic is similar to the research object of this paper, but the article was written before the 2008 financial crisis and the oil price shocks of the last ten years. Moreover, the paper uses oil prices and the Wilder Hill Clean Energy Index (ECO), unlike ETFs, such as in our case. The PSE index is also used, which measures technology firms' stock market performance. The VAR model and its variations was utilized in the research. The paper concluded that alternative energy companies' stock prices can be impacted by the prices of technology stocks. However, different price shocks on the oil market have little impact on the price of companies of alternative energy. Instead of technology stocks, the paper will resort to examining the correlation between the chosen solar ETF and Tesla, the electric car company, which is also considered to be high-tech company due to their innovative projects and ideas.

The idea of correlation of solar energy companies and systems in general with technology is reinforced in a later study by Kabir et al. (2017). The paper concluded that further development and growth of the solar energy market requires the industry to focus more on the quality of its technology and further research, including innovative projects. This also confirms that at least since 2007, technology stocks should have a correlation with solar energy-related market assets' prices. It also reinforces the idea that the

prospects of solar energy depend on innovative technological stocks (Nyangarika et al., 2019a).

Creutzig et al. (2017) concluded that photovoltaics (PV) costs have been quickly decreasing and these systems are being deployed at a rate much higher than what was forecasted by corresponding models. PV has potential to contribute to the decarbonization of other sectors, such as transportation and manufacturing.

Regarding PV systems, by the results of 2019 the United States was ranked second in solar PV capacity. Moreover, the country was also second in investments in renewable energy and renewable power capacity. The demand for PV grew in Europe and the USA, making up for the decline observed in China, which ranked first in all the categories, where the United States came in second. Compared with 2018 the US increased investments in renewable fuel and power 25,2%, which is the biggest leap since 2011. However, on a global scales, investments into this industry increased only by 1% (Arouri et al., 2011; Elder et al., 2014).

Guangul and Chala (2019) conducted a SWOT-analysis of solar energy specifically. As strengths they highlight their limitlessness; environmental friendliness; ease of usage and harvesting; cheaper costs and versatility of utilization. That being said, there is also a series of weaknesses, such as solar energy harvesting being available only during daytime and the general dependance of energy on sunlight in the area, the relatively low compared to other energy systems efficiency, the physical space that is required to install PV systems and the high initial cost of investments. The latter weakness also correlates with the research conducted by Strantzali and Aravossis (2016), which determined investment costs to be the most important Economic criteria when investors evaluate energy planning projects. In fact, its share is over half among other criteria, greatly overcoming those, such as operation and maintenance costs, the cost of energy and the payback period of the investment. It is important to note that the lack of CO_2 emissions is the most important Environmental criteria, which reinforces the importance of renewable energy in the present in future to combat changes occurring in the climate.

Renewable energy has also been concluded to be the fastest growing source of energy. As the demand for energy rises, 40% of this increase will be met by renewable energy sources. One of the many factors contributing to this statistic involves understanding the following facts about oil: over 25% of the world's demand for oil is from the demand of passenger cars. The transportation sector as a whole is responsible for over 50% of global oil demand. As has been examined, renewable energy has many prospects to develop the EV market, thus obtaining a larger share in demand (Pickl, 2019; Dooyum et al., 2020).

As studied by Cohen et al. (2020), solar investments may be attracted and incentivized to and by large corporations. Among these are specific financing programs, tax breaks for companies and even solar carve-outs in renewable portfolio standards. Along with new adopting ESG reports, businesses become keener to adopt a green marketing and development strategy. Apart from benefits to the world's ecological state, the company also improves its social responsibility image (Awartani and Maghyereh, 2013; An and Mikhaylov, 2020).

Renewable energy includes ambitious and promising prospects of development, including the proposed hydrogen and electricity production with the utilization of renewable resources contributing to a transition of a total of 100% renewable energy (Diebold and Yilmaz, 2012; An et al., 2020).

3. DATA AND METHODS

The data used in the study includes the prices of USO and TAN ETFs, as well as the stock prices of TSLA on a weekly basis starting from January 2012. This date was chosen with regard to the aftermath of the financial crisis of 2008. Furthermore, 2012 also sees a decrease in investments in renewable energy compared to 2011, after which in a few years a steady increase can be observed (Figure 1). Data for the year 2020 was gathered in accordance to daily prices to allow for more detailed analysis. The Tesla stock was included in the research in order to examine a specific example of the correlation between solar companies' market performance and that of a technological green-energy company which is also in the automobile industry – an industry with a strong spillover effect with oil and other fossil fuels. A correlation analysis is conducted in order to test the aforementioned proposition.

The stock market prices are converted into log-returns (Chang and Ke, 2014). The following equation was used in order to achieve this:

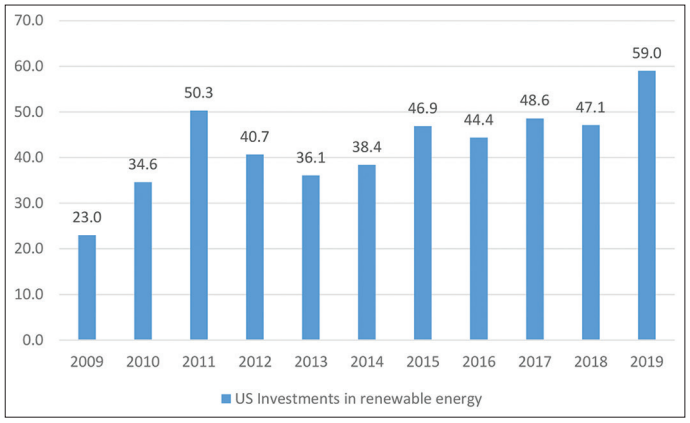
$$r = \ln\left(\frac{p_t}{p_{t-1}}\right) \quad (1)$$

Where r is the return over the designated amount of time;
p_t is the price close at the end of the trading week;
p_{t-1} is the price close at the end of the previous trading week.

Figure 2 presents the data for log-returns of USO and TAN from January 2012 until November 2020, where the data was collected for weekly prices This Figure illustrates the sharp decline in oil prices in 2014 and 2020, as well as the surge in TAN's price in 2020.

Figure 3 illustrates the log-returns of both ETFs from January 2, 2020 until November 6, 2020 on daily prices. The figure below is evidence of the strong recovery of solar energy after the stock market crash in March of the same year, as well as the lack of demand for oil, leading to its sharp decline in price.

Figure 1: US investments in renewable energy (billion USD)



The next step of the analysis includes researching a t-test for USO and TAN ETFs (Enders, 2004). The n sample of price closes amounts to 461 trading weeks. The article also uses the following formula in order to examine the standard deviation of both ETFs:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \quad (2)$$

Where σ is the standard deviation;
n=461 is the amount of sample log-returns;
x_i is the log-returns of each corresponding week;
$\bar{x}$ is the mean of log-returns for USO and TAN.

The standard error is also calculated in the research utilizing the following formula, based on the calculated standard deviation:

$$(\sigma_{\bar{x}}) = \frac{\sigma}{\sqrt{n}} \quad (3)$$

This data will be used in order to calculate the standard error of the difference with the use of the formula:

$$SE_d = \sqrt{\sigma_{TAN}^2 + \sigma_{USO}^2} \quad (4)$$

Figure 2: Log scale of USO and TAN prices from January 2012 until November 2020

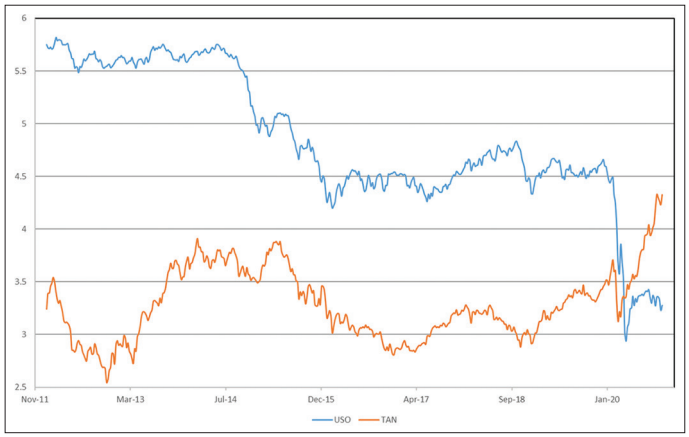
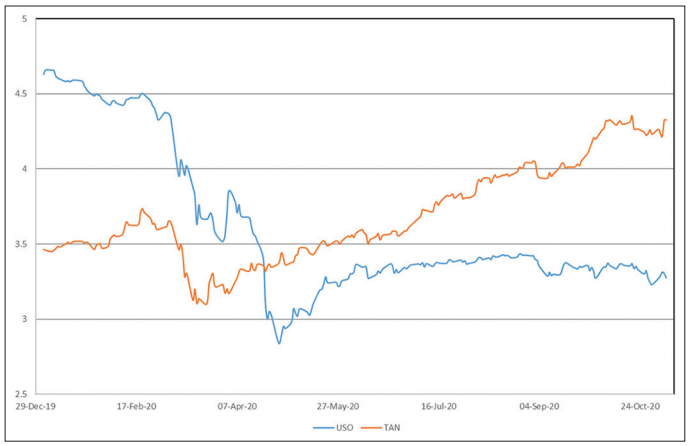


Figure 3: Log scale of USO and TAN prices from January 2020 until November 2020



Where SE_d is the standard error of the difference;
σ_{TAN}^2 is the square of the standard deviation of TAN;
$\sigma_U SO^2$ is the square of the standard deviation of USO.

Moreover, in order to research the hypothesis that the increase in production of oil did not have an effect on oil prices, a regression analysis is conducted between USO ETF's prices and USA oil production from January 2012 until November 2020. Figure 4 presents data on USA oil production from January 1, 1920 until August 2020 in order to demonstrate the sharp increase in oil production (Choi et al., 2015; Mikhaylov, 2020).

4. RESULTS

The research paper begins with the results of the correlation analysis between TSLA, TAN and also USO, which are presented in Table 1. The main focus of the correlation is that between TAN and TSLA, however the inclusion of USO may yield interesting results.

The correlation between TAN and TSLA is in fact the strongest between the researched objects. It is almost equal to 0.6 and positive, which is relatively high considering these assets. Interestingly, the study observes a medium negative correlation between TSLA and USO in contrast to the obsolete spillover effect

Table 1: Correlation analysis of log-returns of USO, TAN and TSLA from January 2012 until November 2020

	USO	TAN	TSLA
USO	1		
TAN	0.038476	1	
TSLA	-0.51368	0.595774	1

Table 2: Regression statistics for US oil production (Y range) and USO price (X range) monthly from January 2012 to August 2020

Regression statistics	
Multiple R	0.730907534
R Square	0.534225824
Adjusted R square	0.52965941
Standard Error	1240.58109
Observations	104

Figure 4: Field production of crude oil in the United States, thousand barrels per day from January 1920 to August 2020

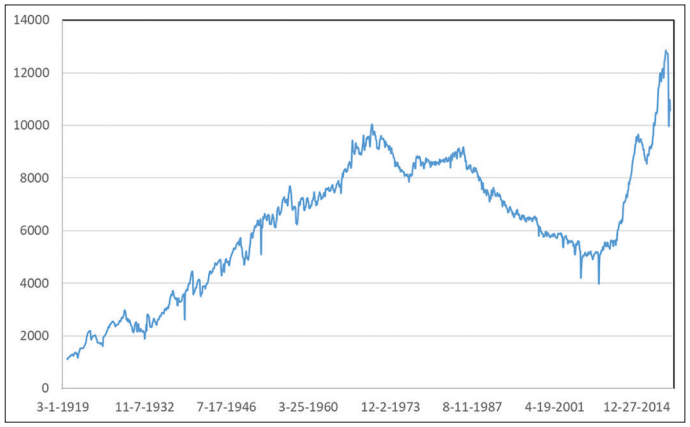


Table 3: ANOVA results for US oil production (Y range) and USO price (X range) monthly from January 2012 to August 2020

Indicator	df	SS	MS	F	Significance F
Regression	1	180052831.9	180052831.9	116.9902429	1.2767E-18
Residual	102	156982226.9	1539041.441		
Total	103	337035058.9			

Table 4: t-Test: Paired two sample of means of USO and TAN

	USO	TAN
Mean	−0.005363593	0.00234751
Variance	0.002954962	0.002873288
Observations	461	461
Pearson correlation	0.297974111	
Hypothesized mean difference	0	
df	460	
t Stat.	−2.588286204	
P(T≤t) one-tail	0.004975366	
t Critical one-tail	1.64817289	
P(T≤t) two-tail	0.009950733	
t Critical two-tail	1.965134461	

between USO and TAN. This data indicates that although the two researched ETFs do not have any correlation with each other, the Tesla stock serves as a "middleman" or "bridge" between a possible negative spillover effect of these two assets (Nyangarika et al., 2019b). These data findings can be the subject of further researches in order to learn about the specifics of the link of these three assets. Figure 5 presents the prices of TSLA and TAN for the period from January 2012 until November 2020.

The figure also emphasizes the surge in 2020, which may significantly contribute to the correlation between the assets. The opposite may be observed for the year 2020 when researching TSLA and USO prices, in which the growth of Tesla's stock prices was accommodated with a crash of the ETF's prices (Figure 6).

Furthermore, the article analyzed the correlation between the increase in oil production in the United States in the 2010s and the declining prices for the commodity during the same period of time. The results of the aforementioned regression analysis are presented in Table 2. At the same time, Table 3 includes the data on the Analysis of Variance for the same subject.

The null hypothesis of the effects of US oil production on USO price can be confirmed based on the value of Significance F, which is near-zero. This means that there is in fact little correlation between the surge in production of the commodity and its price, which is significant to the current study when evaluating the pricing of oil and its subsequent spillover effect with stock market-returns and solar energy competition.

The results of the conducted t-test between USO and TAN ETFs are presented in Table 4.

Furthermore, the calculations of standard deviation, standard error and the standard error of the difference are also presented in Table 5. As it should be, the standard error of the difference is

Figure 5: TSLA and TAN prices from January 2012 until November 2020

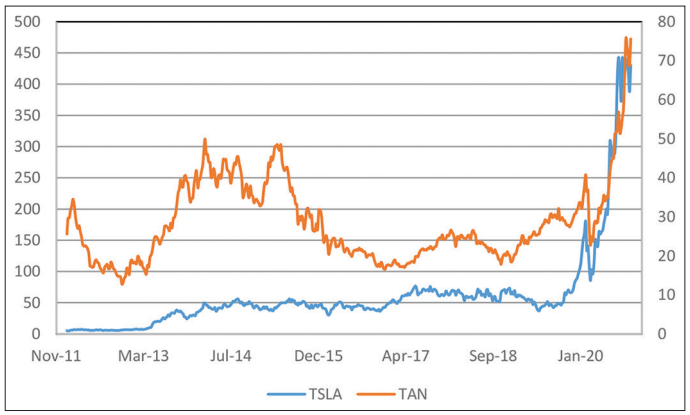
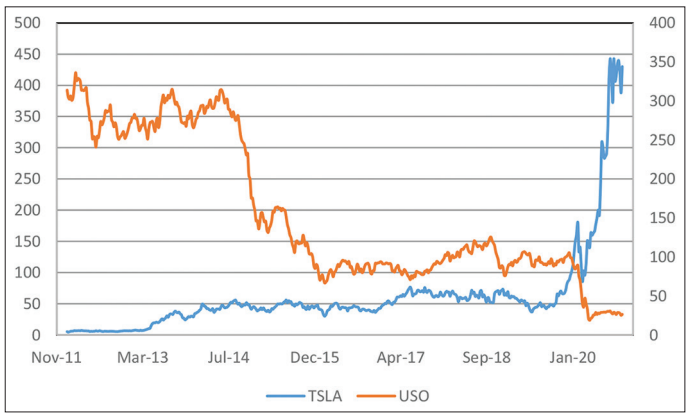


Figure 6: TSLA and USO prices from January 2012 until November 2020



in fact larger than both individual standard error values for USO and TAN ETFs.

5. DISCUSSION

Regarding the correlation analysis between USO, TAN and TSLA, it can be concluded that log-returns of oil and solar ETFs have had absolutely no correlation with each other for most of the past nine years. That being said, it is hard to overlook the interesting results obtained by adding to the analysis a technological EV-producing company, which has seen great growth in the past months. Data shows that TSLA and TAN have a decently-strong positive spillover effect, confirming the idea presented in the second chapter of the correlation between renewable energy and tech-stocks. Moreover, another hypothesis is confirmed about the oil price drops observed in the last decade leading to increase of price of different commodities. This idea can be expanded to include EVs, as seen by the negative spillover effect between TSLA and USO – the decline in oil's prices has been accommodated

Table 5: Deviation and error of USO and TAN values

Standard dev.		Standard error		Standard error of the difference
USO	TAN	USO	TAN	
0.0543596	0.053603	0.002531777	0.002496543	0.003555647

by growth of the car company's stock. As has been mentioned, despite a lack of correlation between the studied ETFs, TSLA possess a considerable spillover effect with both of the assets (An et al., 2019).

The crises in the oil-market this past decade have serious impacts on the entirety of the market. As noted by the Finance, Bonterra Energy Corp. (2017), the decrease in prices has not led to a corresponding decline in oil supply from the US – in fact the opposite has happened. This was a catalyst for the study examining the effects of increased oil production and the price drops. The results indicate that there is no connection between the two phenomena, leading to the belief that other important and global factors, such as political relations and the market for Foreign Exchange, are more significant in affecting the price of the commodity, as has been proposed by Su et al. (2020). Further research on this topic may examine the factors responsible for the decreasing costs of renewable energy production – whilst it is obvious that technological development in this industry leads to more accessible production mechanisms, enabling cheaper operational costs, there may be political factors affecting the price of renewable energy production, drawing a parallel between oil and solar energy.

Moreover, the value of the standard error of the difference between the means of log-returns of TAN and USO is equal to 0.003. With investments in the US increasing significantly in 2019 in comparison to the prior year and, despite the crisis caused by the global pandemic, the growth of renewable energy stocks in 2020, it can be said that the industry is beginning to see incentives not just for sustainable growth, but intense development simultaneously with many technological stocks.

6. CONCLUSION

The article researched the log-returns of the solar ETF (TAN) and oil-based ETF (USO) and the spillover effect between these assets, along with the stock performance of a company related to green energy. The paper concludes that while there is no correlation between the performance of the two examined ETFs, TAN and USO show a positive and negative spillover effect with the included car-company respectively. The oil price decline observed this decade has, perhaps, lead to the growth in value of the EV firm, which also corresponds with the conclusions of Baumeister and Kilian (2016).

Furthermore, the study examined the standard error of the difference between the means of log-returns of TAN and USO since January 2012. The mean of TAN returns is positive, whilst that of USO is negative, indicating a significant loss in the respective market. Oil prices have seen two major crashes in the period of time that was studied, the first of which in 2014 was examined in-depth in the study, in order to retrospectively research the effects of volatility in the oil market on the market of solar energy. The second crash caused by a global pandemic, accommodated by the consequent decrease in energy demand and, specifically, oil, has led a surge in the returns of the solar ETF and a drop in the price of USO, which has yet to recover even from the 2014 crash, as well as the crash in 2020 (Mikhaylov et al., 2020).

Investments in renewable energy in the United States hit record levels in 2019, possibly being a showcase of the shifting paradigm in the valuable energy sector. Businesses see benefit in developing green energy, which is contributing to the growth seen in the industry, which will surely lead to positive effects on the climate and environment.

Green projects utilizing renewable energy and solar power have been instilled by many firms and governments (Diebold and Yilmaz, 2009). This all leads investors to believe and evaluate the industry to be worth more than it did a couple of years ago. Unlike in 2014, this crisis has not yet resulted to a decline in the price of TAN, but rather its rapid growth. This may be identified as a characteristic of sustainability and viability of renewable energy even during periods of economic uncertainty. The examined solar ETF is independent from USO, which is a significant participant in the energy market. This independence is valuable and allows for the understanding of solar energy being able to develop and grow without reference to oil. Moreover, it possesses a correlation with technological stocks that are on the forefront of innovation, which renewable energy specifically requires.

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