A Work Project, presented as part of the requirements for the Award of a Masters Degree in Finance from the NOVA – School of Business and Economics and a Professional Master in Finance from the São Paulo School of Economics.

The relationships of Alternative Energies with the Technology Sector and non-Renewable Energies

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nº 843/329308

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14/08/2015

Abstract

This work aimed to understand the investor perception on clean energy: if it is seen as part of the technology sector, awaiting new developments, or as an alternative to the existing energy production methods. To answer this question, a four variable vector autoregression model was developed so that a Granger causality test and Impulse response function could be applied. The results suggest that while both hypotheses were confirmed worldwide for the period 2002-2007, from 2009 to 2014 results suggest that investors do not recognize the field of clean energy as part of the technology sector. Moreover, during the period that ranges from 2009 to 2014, and when comparing the American investor with the European investor, only the latter identifies renewable energy as a viable source of energy production.

Key Words: Vector autoregression, Clean energy, Technology, Non-renewable energy

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1. Introduction

In recent years, an increase in energy demand has been observed which was mostly driven by demand from developing countries, mainly China and India, figure 1. While in the past, a situation as such would be overcome by a raise in the non-renewable energies supply, the same principle cannot be applied nowadays. There are concerns over the greenhouse effects of such energy sources. These issues together with three other facts: 1) both developed and developing countries avoidance in needing commodities which are sourced from areas of geopolitical tension; 2) the European “20-20-20 program” setting European Union to have 20% of the total energy produced coming from renewable energy by 2020; and 3) the U.S. commitment to invest in clean energies as stated by the President Obama; are leading to an unprecedented interest in renewable sources of energy. Nonetheless, are renewable energies already perceived as alternatives to non-renewable energies?

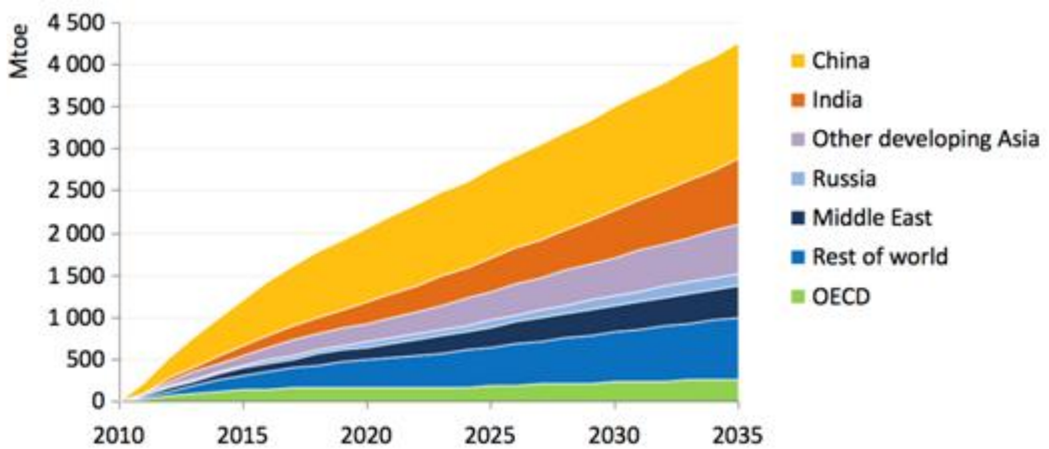

Figure 1 - Expected growth of primary energy demand worldwide by the International Energy Agency.

In the beginning of the new millennium, renewable energies were heavily dependent on new scientific and technological innovations in order to improve their efficiency, reduce their costs and to be a real contender for energy production. In a study by Sadorsky and Henriques (2008), it was demonstrated that U.S. investors looked at alternative energy companies in a similar way as to other high technology companies, in other words, renewable energy was not seen as an efficient technology yet. The aim of this work project is to extend on previous studies in this area and to understand the current perception of investors on alternative energies. Finally, an additional aim of this project is to discern differences in investor attitudes towards clean energy according to their geographical region. To this end, viewpoints from European and U.S. investors were considered and also viewpoints at a worldwide scale were studied by analysis of indexes for each region.

In order to accomplish the goals, a methodology similar to that presented by Sadorsky and Henriques (2008) is followed, where a four variable vector autoregression model is developed and estimated. Subsequently, a Granger causality test and an Impulse response function are applied to study the relationship among the variables. The variables used are: 1) an index composed by renewable energies companies; 2) an index made of technology companies which produce some of the components used by clean energy companies; 3) oil price, to understand the link between alternative energies with non-renewable sources; and 4) an index of gas and oil companies. The hypothesis behind the inclusion of the latter is can it provide insights into the differences between renewable and non-renewable companies relationships with oil and technology.

The usage of oil price as variable instead of gas price had to do with the following reasons. Despite of energy companies, that use non-renewable commodities as raw materials, using mainly gas instead of oil to produce electricity and electricity being the main output of clean energy, the inclusion of oil price in this work is justified by a study carried out by Mohammadi (2009) where it was concluded that the gas price is regional while the price of oil is global. This characteristic is majorly important for the worldwide analysis as well as to the comparison between regions. Additionally, Mohammadi (2009) proved that even though oil is scarcely used for electricity produce, fluctuations in its price have an impact on the price of electricity.

Figure 2 shows a time series from plot of the four variables with data ranging from 16th November 2001 to 26th May 2015 global data: the Ardour Global Alternative Index (Renewable), the i-shares Global Energy ETF (Energy), the i-shares Global Technology ETF (Technology) and oil prices at WTI (Oil). In order to ease the comparison among the variables, they were normalized to 100 on the first time-point (16th November 2001).

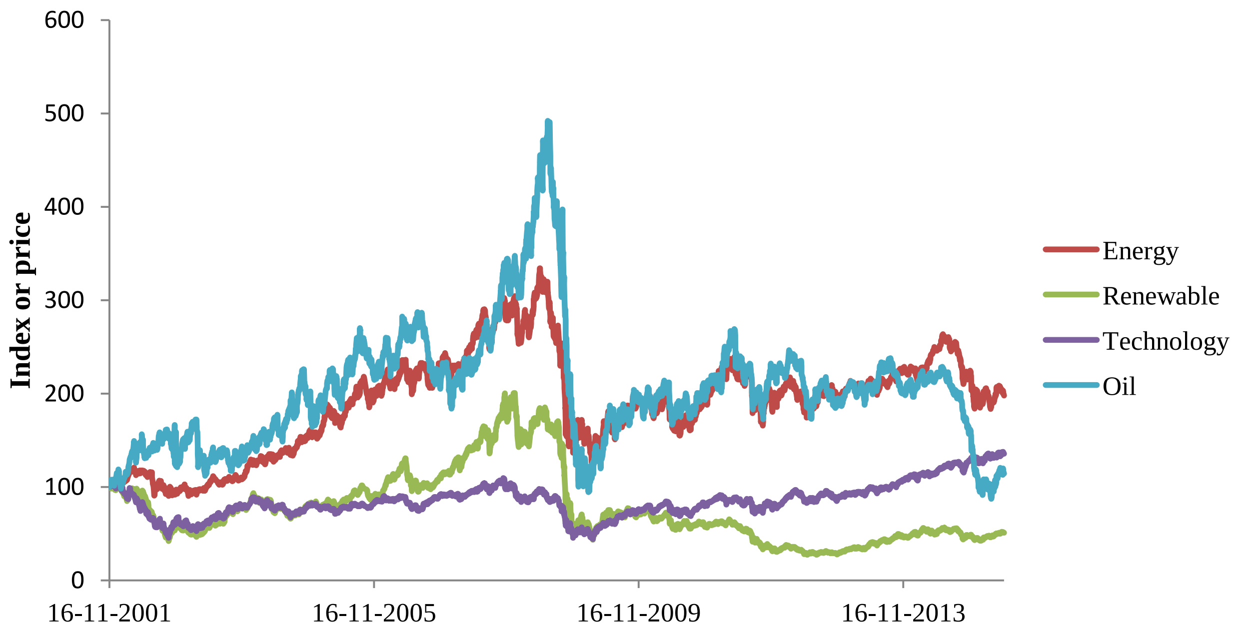

Figure 2 - Indexes: Oil and Gas (Energy), Renewable Energy (Renewable) and Technology (Technology); and oil price (Oil). Base year as value of 100.

Due to the significant impact of the subprime crisis in all the variables considered and to better understand eventual changes in the investors viewpoint before and after the crisis, the data was split in two time periods, leaving the financial crisis period (from October 2007 until December of 2009) out of the analysis. The period from the 1st October 2014 onwards is also not taken into account due to the plunge in the oil price and in the Euro/USD exchange rate. The first event has had major implications in the relationship between the variables related to energy, while the latter has mainly affected the European indexes.

2. Literature Review

Significant emission levels of greenhouse gases, such as carbon dioxide (CO_2), have resulted in a serious global-warming problem, which is having a tremendous impact in the world's climate (Cox *et al.*, 2000). Oil consumption leads to the release of CO_2, which is understood as one of the most important contributors to climate change. Moreover, the oil price has a huge impact in the economy of OECD members since a 10% increase in its price leads to a decrease of 0.5% in the GDP, due to a raise in inflation and unemployment therefore affecting macroeconomic growth (Awerbuch and Sauter, 2006). Oil price fluctuations are so impactful that numerous studies have been conducted in the last years to further understand their effect on the stock market returns. In particular, a study employing a Granger temporal causality model has analyzed fluctuations in demand, supply and idiosyncratic demand shocks of oil and concluded that only the latter has a significant impact on stock market returns (Apergis and Miller, 2009). Additionally, since oil is a traded commodity, its price should be governed by oil's global demand and supply but in reality this is not the case. As stated by several studies in the literature, it is claimed that an "OPEC Cartel" exists and it faces the dilemma of having to choose between macroeconomic stability and oil industry profitability, the latter being responsible for increases in OPEC's wealth. Ultimately, the existence of the aforementioned dilemma creates conflict of interests and geopolitical tension, which are in turn linked to oil prices (Kesicki, 2010).

In contrast to oil, renewable energies (e.g. wind power, solar, biomass, etc.) do not play a part in greenhouse gases emission and contribute to the GDP, making clean energy more environmentally and economically friendly (Awerbuch and Sauter, 2006). A look at global investment on sustainable energies, shows that these grew at a compound rate of 29% between 2004 and 2009. In fact, investments on these energies hit a record high in 2008, even though it was the year of the worst economic downturn since the Great Depression (New Energy Finance, 2010). The International Energy Agency (IEA) predicts that renewable energy will be the fastest growing component of global energy demand, growing at a compound average annual growth rate of 7.3% between 2007 and 2030. Several circumstances might help in meeting these predictions.

To begin with, the European Commission has put forward the "Renewables Directive" which mandates that 20% of energy consumption within the European Union should be produced from renewable energies. Besides this directive that all E.U. members must follow, the overall E.U. population is aware of the environmental issues which might help the adoption of such alternative energies (Szabó *et al.*, 2014).

Secondly, in 2012 the U.S. president Barack Obama made the pledge to "not walk away from the promise of clean energy". In contrast to the E.U. directive which is centralized, in the U.S. its organization is made at a state level. This results in some states passing legislation that obliges electricity providers to source a certain percentage of the energy from clean sources, imposes limits to CO_2 emissions and gives public benefit funds for clean energy projects. Other states do not possess legislation to enforce or funds for clean energy projects to encourage the use of renewable energy, and therefore the U.S. as a whole is not all heading in the same direction (United States Environmental Protection Agency).

Finally, the major oil and gas companies around the world have themselves begun to make large investments in the renewable energies sector, a trend that started in 2000 (Pinkse and Buuse, 2012).

Chang *et al.* (2009) have demonstrated that between 1997 and 2006 a certain GDP growth threshold had to be achieved before the OECD member countries started policies to promote clean energy use. It was found that the value of this threshold was 4.13% with one period lag. In other words, countries with high economic growth can respond to high energy prices with increases in clean energy use, but in countries with low economic growth energy price changes are not accompanied by a change in clean energy use.

"In the long run, households and businesses respond to higher fuel prices by cutting consumption, purchasing products that are more efficient, and switching to alternative energy sources. Higher energy prices also encourage entrepreneurs to invest in the research and development of new energy-conserving technologies and alternative fuels, further expanding the opportunities available to households and businesses to reduce energy use and switch to low-cost sources" (United States Government Printing Office, 2006).

Sadorsky and Henriques (2008) published a study concerning the period from 2001 to 2007 on the relationship of clean energy response to shocks in oil price and technology. The authors concluded that shocks to technology had a larger impact on the stock prices of alternative energy companies than do shocks in oil prices. While this conclusion may seem unexpected at first, the reason behind this is that, during that time period, the clean energy sector was heavily dependent on new technological innovations in order to improve its efficiency and lower its costs. This also means that, during those years, investors saw alternative energies as a technology and not yet as a substitute to the oil.

3. Data

In this work project, a daily four-variable vector autoregression model (VAR) was used to study the relationship among the indexes of clean energy, technology and non-renewable energies, and Oil prices. The variables considered for the model are the following: the index of clean energy is hereinafter represented as Renew X; the technology index as Tech X; the non-renewable energy index as Energy X and oil prices as Oil. The X stands for the region of the index, that is US for the United States, EU for Europe and G if it is global.

As aforementioned, two data samples will be used in this study: the first contains daily data from 21^{st} November 2002 until 28^{th} September 2007; and the second has daily data from 18^{th} December 2009 until 29^{th} August 2014. The 18^{th} December 2009 was purposely selected to exclude data from the sub-prime crisis while choosing a starting point where the markets were relatively stable, whereas the last data point was selected to exclude from the analysis any "noise" that could arise from the plunge in oil's price that occurred on that period. An analysis of the period after the 29^{th} of August of 2014 until the present would be interesting to understand if there were changes among the relations of the variables. However this period is too short, not having enough data to draw significant conclusions and consequently being out of the study. Regarding the first period the ending day selected, like the starting point of the second period, is to avoid the sub-prime crisis. Since both data samples need to have the same number of observations, so comparisons between the VAR models can be made, the 21^{st} November 2002 was chosen to begin the first data sample. Moreover, only an analysis to the global indexes will be made regarding the first data sample, since the introduction of the European and U.S. indexes were only made after the beginning of this period.

The stock market performance of clean energy, technology, and oil and gas companies were measured through the following indexes with data obtained from Bloomberg, using the closing prices in USD.

Renew G

To measure the global performance of the stock market regarding clean energy companies the Ardour Global Alternative Energy Index was used, whose ticker symbol is AGIGL and it is a market capitalization-weighted index. The index is composed of companies in several alternative energy areas: alternative energy resources, distributed generation technologies, environmental technologies, energy efficiency and enabling technologies. Tesla Motors Inc., Vestas Wind System A/S and China Longyuan Power Group Corp. Ltd., are an example of the companies presented in the index. Further details regarding this index can be found at http://ardour.snetglobalindexes.com.

Renew US

The Wilder Hill Clean Energy Index is a modified equal-dollar-weight index, with the ECO ticker symbol. This index was the first of its kind for tracking companies of this sector and has therefore become the benchmark. The ECO encompasses companies of several alternative energy areas (renewable energy harvesting, power delivery & conservation, energy conservation, energy storage, cleaner fuels and greener utilities). Some constituent companies of the index are: SunPower Corp., FuelCell Energy Inc. and Hydrogenics. Additional information about this index can be found at www.wilderhill.com

Renew EU

The Ardour Global Alternative Energy Index Europe, with the ticker symbol AGIEM, was used to evaluate the performance of the clean energy sector in Europe. This index was created in the end of 2005, it includes 23 companies related to the clean energy sector and it is a market capitalization-weighted index. Gamesa Corp. Tecnologica SA, Nordex SE and EDP Renovaveis SA, are some of the companies that make part of the index. Further details regarding this index can be found at http://ardour.snetglobalindexes.com.

. **Tech G**

The performance analysis of the technology sector at a worldwide level in the stock market was made through the i-shares Global Technology ETF, with the ticker symbol IXN, which tracks the S&P Global 1200 Information Technology Sector index. This index is a market capitalization-weighted index. The index is composed by one of the Global Industry Classification Standard (GICS) which is in turn composed by companies which develop semiconductors as one of their main activities. The semiconductors are key components for controlling the generation and connection to the network of renewable energy sources. Intel Corporation Corp., Tawian Semiconductor Manufacturing and ASML Holding NV, are an example of the companies presented in the index. Further information on the ETF is available at http://www.ishares.com/global/.

Tech US

ARCA Tech 100 Index, with the ticker symbol PSE, was formally known as The Pacific Stock Exchange Technology Index and kept the sticker symbol from that period. This index is exclusively focused on technology and it is a price-weighted index. The index is composed of 100 companies in 15 different industries. Example of companies that make part of the index are: Texas Instruments Inc., KLA Tencor Corp. and Applied Materials Inc. Additional details on the index are available at https://www.nyse.com/.

Tech EU

Euro TMI Technology Index, with the ticker symbol BTHE, was selected to examine the performance of the technology sector in Europe. This index, just as the index selected for the Global technology, is composed only of companies of one GICS sector, which is linked to semiconductors, and it is a market capitalization-weighted index. Dialog Semiconductor PLC, STMicroelectronics and Aixtron SE, are an example of the constituents of the index. For additional information visit http://www.stoxx.com/

Energy G

To evaluate the performance of the oil and gas companies, the i-shares Global Energy ETF, with the ticker symbol IXC, was selected. This ETF tracks the S&P Global 1200 Energy Sector Index and it is composed of companies with connection to oil, gas and consumable fuels. Some constituents of the index are: Exxon Mobil Corp., Total SA and CNOOC Ltd. Further details on the ETF can be found at http://www.ishares.com/global/.

Energy US

Dow Jones US Oil & Gas index, with the ticker symbol DJUSEN, is a market capitalization-weighted index and provides a tradable and liquid exposure to 93 companies. Chesapeake Energy Corp., Halliburton Company and Weatherford International PLC, are three examples of the companies presented in the index. The index is only composed by companies linked to oil, gas and consumable fuels. Additional information on the index can be found at http://www.djindexes.com/globalfamily/.

Energy EU

The STOXX Europe 600 Oil & Gas index, with the ticker symbol SXEP, was chosen to understand the oil and gas sector in Europe. It is composed of 24 European companies linked to this sector and it is a market capitalization-weighted index. BP PLC, Royal Dutch Shell PLC and Repsol SA, are some of the constituents of the index. Further information can be found at http://www.stoxx.com/.

Oil

Oil, a conventional non-renewable energy, is the most widely traded physical commodity in the world. However, environmental and energy security concerns make a shift from oil towards clean energy a necessity. An increase in oil price should also encourage the substitution towards non-petroleum based energy sources, increasing the use of alternative energies, which in turn would be accompanied by a rise in the stock price of this sector. In this study, the oil price used was the closing price of crude oil spot contract in West Texas Intermediate in USD.

Tables 1 and 2 show the daily correlation of the compound returns across all the variables, for the two periods under study. It can be observed that the correlation among all global variables increased from one period to the other. This is true even between Oil and the other global variables; Oil correlations to the other variables were almost nil for the first period but changed in the second period with the exception of Energy G, whose correlation with Oil was already positive in the first data period. An important observation to be made from table 2 is that by excluding Market and only considering variables from the same region, the variable to which Renew presents the highest correlation is to Technology. Interestingly, there is a high correlation between the global variables of a sector with the U.S. variables counterparts, although the same does not occur between the European variables and the Global variables. An explanation for this result might be that at least 50% of the Global indexes are made of U.S. companies.

Table 1 - Correlation Matrix of the daily compound returns for the period 2002-2007.

	Renew G	**Tech G**	**Market**	**Energy G**	**Oil**
Renew G		0,67	0,69	0,46	0,03
Tech G	0,67		0,72	0,38	-0,09
Market	0,69	0,72		0,56	-0,07
Energy G	0,46	0,38	0,56		0,38
Oil	0,03	-0,09	-0,07	0,38	

Table 2 - Correlation Matrix of the daily compound returns for the period 2009-2014.

	Renew G	**Renew Us**	**Renew EU**	**Tech G**	**Tech US**	**Tech EU**	**Market**	**Energy G**	**Energy US**	**Energy EU**	**Oil**
Oil	0,46	0,42	0,37	0,47	0,45	0,47	0,49	0,60	0,60	0,53	
Energy EU	0,68	0,55	0,72	0,66	0,62	0,82	0,66	0,75	0,69		0,53
Energy US	0,76	0,76	0,52	0,82	0,82	0,60	0,90	0,97		0,69	0,60
Energy G	0,77	0,76	0,56	0,84	0,83	0,64	0,91		0,97	0,75	0,60
Market	0,83	0,84	0,55	0,93	0,94	0,64		0,91	0,90	0,66	0,49
Tech EU	0,68	0,55	0,75	0,67	0,63		0,64	0,64	0,60	0,82	0,47
Tech US	0,81	0,82	0,53	0,94		0,63	0,94	0,83	0,82	0,62	0,45
Tech G	0,81	0,80	0,56		0,94	0,67	0,93	0,84	0,82	0,66	0,47
Renew EU	0,74	0,55		0,56	0,53	0,75	0,55	0,56	0,52	0,72	0,37
Renew Us	0,91		0,55	0,80	0,82	0,55	0,84	0,76	0,76	0,55	0,42
Renew G		0,91	0,74	0,81	0,81	0,68	0,83	0,77	0,76	0,68	0,46

Tables 3 and 4 show the statistics summary of the daily compound returns, in percentage, for all the variables. It can be observed from the table that indexes from the same sector but from different geographic zones have relatively similar mean values and with the same sign, exception being the Energy EU. A comparison for the global indexes between the two periods shows the Market as the only variable with an increase in mean from the first to the second period. Regarding volatility for global variables, it has increased for Renewable G, Market and Energy G, opposing the trend shown by the other variables.

Table 3 - Descriptive statistics of the daily compound returns, for the period 2002-2007.

	Renew G	**Tech G**	**Market**	**Energy G**	**Oil**
Mean	0,10	0,05	0,05	0,10	0,10
Median	0,17	0,11	0,09	0,17	0,21
Maximum	5,20	4,75	3,41	4,05	7,37
Minimum	-5,95	-5,46	-3,43	-7,90	-11,54
Std. Dev.	1,38	1,24	0,82	1,23	2,15
Skewness	-0,31	-0,17	-0,25	-0,52	-0,27
Kurtosis	4,14	4,78	4,36	4,81	4,34
Observations	1164	1164	1164	1164	1164

Table 4 - Descriptive statistics of the daily compound returns, for the period 2009-2014.

	Renew G	Renew US	Renew Eu	Tech G	Tech US	Tech EU	Market	Energy G	Energy US	Energy EU	Oil
Mean	-0,01	-0,04	-0,04	0,05	0,07	0,04	0,07	0,04	0,05	0,00	0,02
Median	0,08	0,08	-0,02	0,10	0,13	0,03	0,11	0,08	0,06	0,06	0,04
Maximum	6,23	8,24	8,41	5,18	4,83	6,24	4,97	5,48	5,29	5,82	8,95
Minimum	-7,12	-10,21	-7,66	-6,43	-6,54	-7,46	-6,97	-8,89	-8,77	-7,19	-9,04
Std. Dev.	1,48	1,91	1,80	1,12	1,16	1,52	1,06	1,34	1,35	1,42	1,65
Skewness	-0,35	-0,25	-0,19	-0,31	-0,32	-0,28	-0,42	-0,47	-0,45	-0,23	-0,13
Kurtosis	4,82	5,05	4,39	6,37	5,94	4,97	7,49	7,19	6,87	4,93	5,73
Observations	1164	1164	1164	1164	1164	1164	1164	1164	1164	1164	1164

4. Methodology

A vector autoregression (VAR) model was used in this work to study the relationships amongst the variables: Renewable, Technology, Energy and Oil. This model was chosen because a similar methodology to the study published by Sadorsky and Henriques (2008) is being employed, where a VAR model was applied. A VAR can be written in the following way:

$$y_t = \sum_{j=1}^{p} \beta_j \, y_{t-j} + u_t$$

In the equation above, y is an n vector of endogenous variables and β_j is an $n \times n$ matrix of the regression with the value of the parameters being estimated. The u_t is the error term of the equation which is assumed to be independent and following a normal distribution with zero mean and a constant variance. In the equation shown above the degrees of freedom are equal to n^2p, where p is the number of lags. The number of lags selection is a crucial part of the model seeing that if the number of lags is too high, it will diminish the degrees of freedom which in turn lead to higher standard errors. On the other hand, if the number of lags is too low, the VAR model may not capture all relationships amongst the variables.

In order to estimate the VAR parameters, the variables need to be stationary. Most economic variables are of order of integration equal to 1. Once the variables are stationary, an Akaike Information Criteria (AIC) is conducted, using the respective stationary variables in order to discover the appropriate number of lags to use in the model. Subsequently, running a Johansen Test is necessary to understand if the variables present co-integration and, if so, the VAR model needs to be estimated using a vector of error correction model (VECM), otherwise an Unrestricted VAR model can be used.

Since the significance of the parameters estimated in the VAR are hard to understand, it is advisable to perform a Granger causality test and then apply an Impulse response function. The Granger causality test gives information about which variables have no impact in the value of a variable at the present. In the Impulse response function test a shock of one standard deviation is given to one of the variables. The output of the test is a graph which shows the response of each of the variables to the shock, through a lag period. This enables to see if a shock has a negative/positive impact on a variable, how it changes through time and how long it takes for the variable to stabilize again. However, if there is no statistical evidence from the Granger causality test from variable Y to X, then the importance of the Impulse response function result is unclear.

5. Results and Discussion

5.1 Construction of the VAR models

In order to understand the order of integration of the data an Augmented Dickey and Fuller test (ADF) and Kwiatkowski-Phillips-Schmidt-Shin test (KPSS) were computed based on the logarithm of the variables. For the levels ADF test, the null hypothesis (H_0) is: the order of integration is equal to one (I(1)); while the alternative hypothesis (H_1) is: the order of integration is 0 (I(0)). For the levels KPSS test, the H_0 is I(0), while the H_1 is I(1).

The results of the ADF and KPSS tests for both time periods are shown in tables 5 and 6. Doubts may arise concerning the order of integration of Renew G, Renew EU, Energy US and Oil, for the second period. In the Appendix are the histograms of the respective variables, figure A1 to A4, which are enlightening regarding this question. The tests and the histograms demonstrate that the level of integration of all variables is 1. In order to build the VAR model, the variables need to be stationary and therefore the VAR was constructed using the difference of the variables' logarithm values - in other words the returns were used.

Table 5 - Unit Roots are tested using (ADF) and (KPSS), for the period 2002-2007. ***, **, * denote a statistical significance of 1%, 5% and 10%, respectively.

		ADF		KPSS	
Oil	Levels	-1,42		3,99	***
	First Difference	-35,45	***	0,04	
Energy G	Levels	-0,62		4,34	***
	First Difference	-26,06	***	0,02	
Renew G	Levels	-0,09		3,85	***
	First Difference	-29,55	***	0,08	
Tech G	Levels	-1,21		3,15	***
	First Difference	-33,44	***	0,05	

Table 6 - Unit Roots are tested using (ADF) and (KPSS), for the period 2009-2014. ***, **, * denote a statistical significance of 1%, 5% and 10%, respectively.

		ADF		KPSS	
Renew G	Levels	-1,40		1,35	***
	First Difference	-30,33	***	0,56	**
Renew US	Levels	-1,57		2,25	***
	First Difference	-20,53	***	0,30	
Renew EU	Levels	-1,65		1,56	***
	First Difference	-31,92	***	0,80	***
Tech G	Levels	-0,46		3,91	***
	First Difference	-34,64	***	0,08	
Tech US	Levels	-0,64		4,09	***
	First Difference	-35,07	***	0,04	
Tech EU	Levels	-1,30		2,54	***
	First Difference	-34,37	***	0,07	
Energy G	Levels	-1,43		2,96	***
	First Difference	-34,95	***	0,04	
Energy US	Levels	-1,18		3,37	***
	First Difference	-35,15	***	0,04	
Energy EU	Levels	-2,98	**	0,40	**
	First Difference	-32,53	***	0,04	
Oil	Levels	-3,03	**	1,45	***
	First Difference	-34,33	***	0,54	**

Once all variables were stationary it was conducted an Akaike Information Criteria (AIC) in order to discover the appropriate number of lags of the VAR. Each test contained the returns of Oil and the returns of the indexes on that region, in that specific period. The AIC tests suggested that all the VAR models should be constructed with one lag period. Regarding the Johansen Cointegration tests, which were done using the same variables of the AIC, the results did not suggest the presence of cointegration for the different models. Therefore Unrestricted VAR models with one lag period were constructed for each region and each time period. Tables A1 till A4 in the Appendix show the VAR fit for the models. Tables A5 till A8 present the results of the Lagrange-multiplier test for serial correlation. The results show no evidence of serial correlation.

5.2 Granger causality test and Impulse response function

In order to understand the relationship amongst the global variables a Granger causality test was performed using an F-statistic test. For this test the null hypothesis is: Variable X does not cause the variable Y.

Table 7 shows the Granger causality test results of the global variables for the two periods, while table 8 shows the results of the Granger causality test separately for the U.S. and Europe.

Table 7 - Granger causality test for the following variables: Oil, Tech G, Energy G and Renew G. The variable shown at the top of each set is the dependent variable. The test is conducted for the two periods: 2002-2007 and 2009-2014. ***, **, * denote a statistical significance of 1%, 5% and 10%, respectively.

	Oil	
	2002-07	**2009-14**
Energy G	2,34	7,07 ***
Renew G	0,10	0,08
Tech G	0,02	0,32

	Tech G	
	2002-07	**2009-14**
Oil	1,59	2,51
Energy G	0,07	0,92
Renew G	12,50 ***	0,62

	Energy G	
	2002-07	**2009-14**
Oil	2,54	3,59 *
Renew G	0,38	0,01
Tech G	0,10	4,29 **

	Renew G	
	2002-07	**2009-14**
Oil	1,85	0,39
Energy G	15,79 ***	3,01 *
Tech G	4,10 **	0,16

Table 8 - Granger causality test. The "X" after each variable may refer to US or EU, as shown in the second row. The variable shown at the top for each set is the dependent variable. The test is conducted for the period 2009-2014. ***, **, * denote a statistical significance of 1%, 5% and 10%.

	Oil	
	US	**Europe**
Energy X	4,03 **	6,35 **
Renew X	1,84	3,55 *
Tech X	6,28 **	5,13 **

	Tech X	
	US	**Europe**
Oil	2,14	3,02 *
Energy X	0,07	2,61
Renew X	0,00	0,60

	Energy X	
	US	**Europe**
Oil	1,93	2,25
Renew X	0,49	2,46
Tech X	2,14	0,48

	Renew X	
	US	**Europe**
Oil	1,05	0,68
Energy X	0,67	7,47 ***
Tech X	1,34	1,90

Figure 3 shows the Impulse response function using as variables: Oil, Tech G, Energy G and Renew G, for the first period. The "DL" before the name of each variable denotes the use of the difference of the logarithms as variables. Figure 4 shows the same analysis as Figure 3 but for the period 2009-2014. The Impulse response functions using American and European variables are shown in Figures 5 and 6, respectively. The analysis of the Granger causality test and the Impulse response functions was made together. Firstly, the results referent to the global data for both periods were analyzed.

Regarding Oil in the first period, it does not cause any of the variables and on the second period the null hypothesis is only rejected for Energy G at a significance level of 1%. This result is in accordance with studies in the literature, where it has been shown that only idiosyncratic demand shocks lead to stock market returns. Regarding causality on Renew G as the dependent variable and for the first period, the null

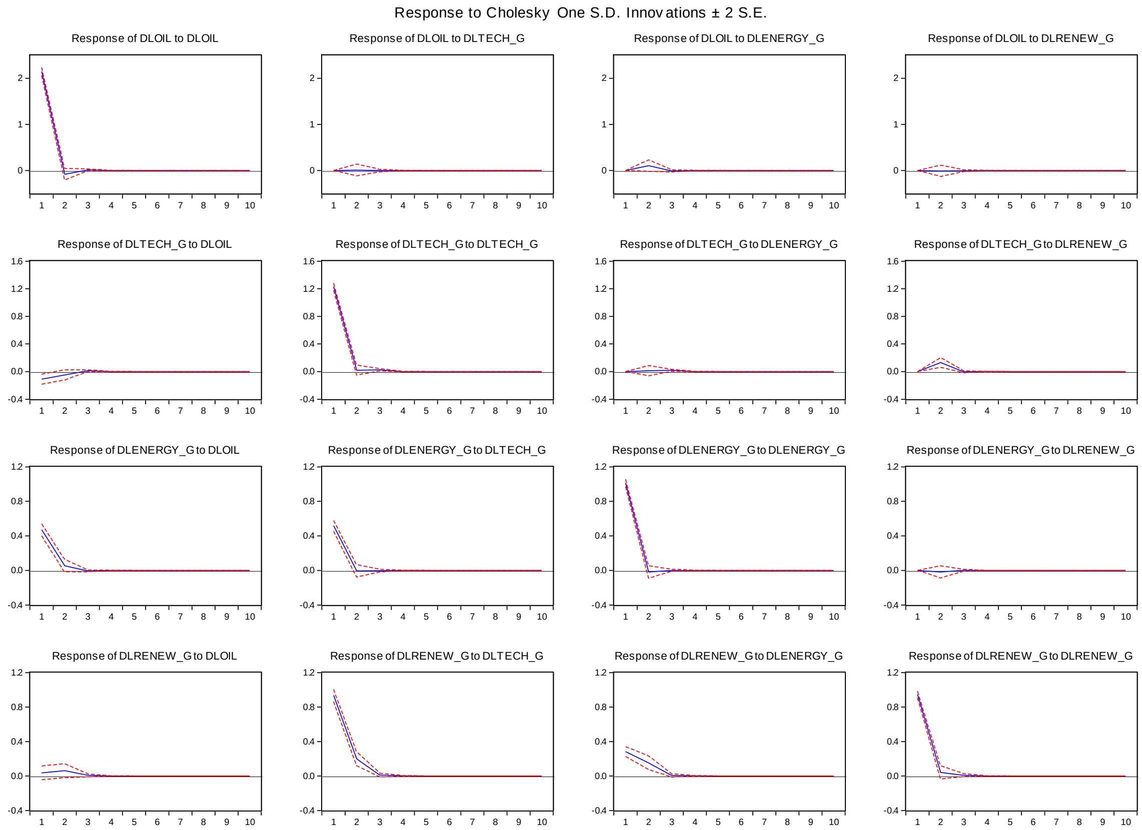

Figure 3 - Impulse response function using as variables the difference of the logarithms of the Global variables, for the period 2002-2007.

hypothesis is rejected at a significance level of 1% for Energy G and at 5% for Tech G. Looking to the results of the Impulse response function, figure 3, it can be concluded that a shock on Tech G has a higher impact than one of Energy G, on Renew G. This result confirms the prediction that, during this period, renewable energies were highly linked to technology. What is more, the fact that at a significance level of 1%, for the same period, the null hypothesis of Renew G not causing Tech G to be rejected suggests that renewable energy was perceived as a sub sector of technology from 2002 to 2007. The expansion phases of the business cycle that the world was facing on this period, coupled with high investment in clean energy as mentioned in the literature due to high GDP's, led to technology developments in this area, which may explain the double causality. Nonetheless, the fact that the null hypothesis on the second period

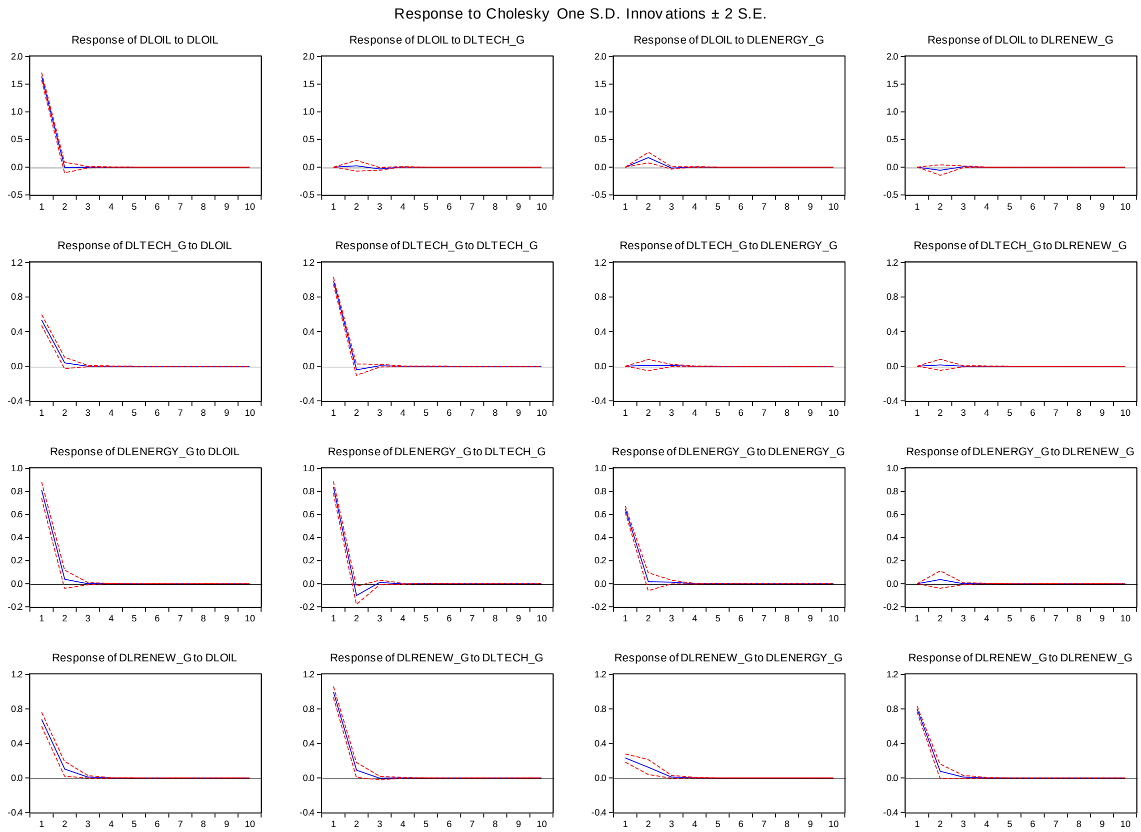

Figure 4 - Impulse response function using as variables the difference of the logarithms of the Global variables, for the period 2009-2014.

was not rejected, for both cases, indicates a change in the attitude of the investors/market. It is conceivable that investors believe renewable energies are already efficient enough to compete with non-renewable energy and not so dependent of technological breakthroughs anymore. Even though this might be true for wind power, it is not yet a reality for solar energy. It would be therefore interesting, for instance, to be able to split the renewable index into solar and wind indexes and investigate if the theory would be confirmed. Moreover, this is the period after the sub-prime crisis, where investments on the economies were low and consequently lower technology developments were expected (Campello *et al.*, 2010), which may have led investors

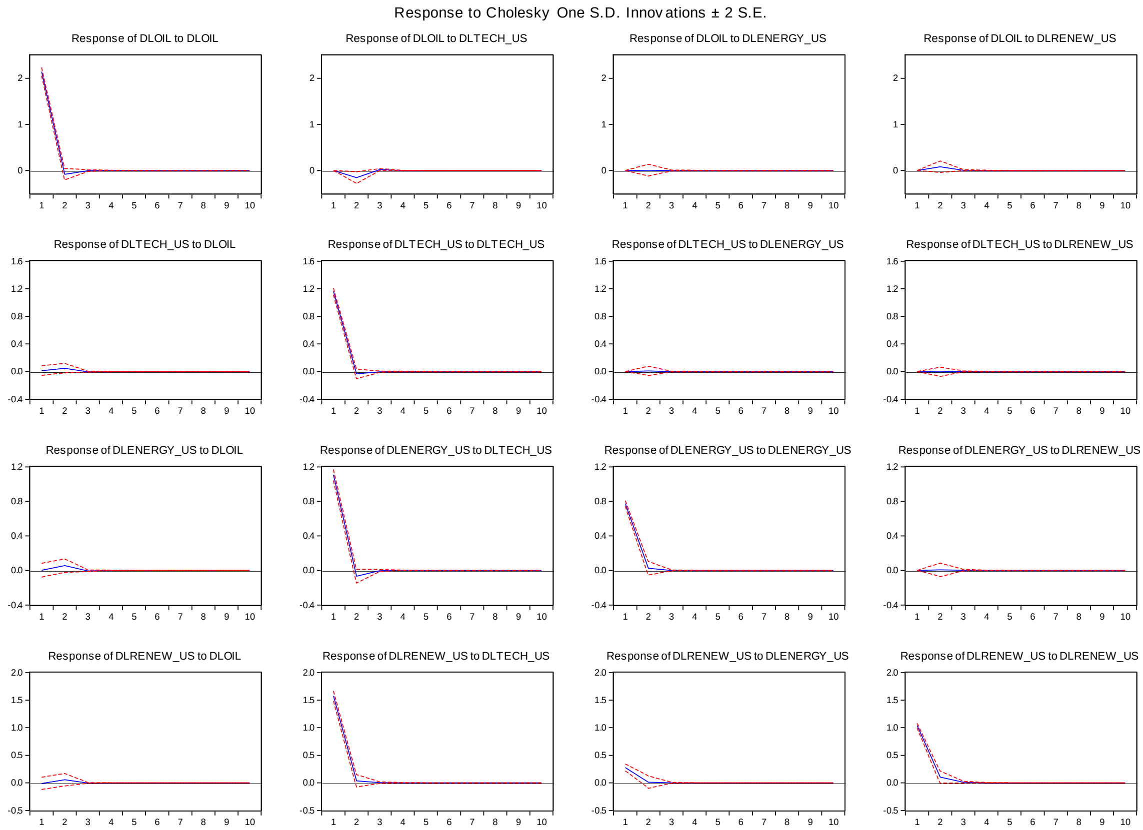

Figure 5 - Impulse response function using as variables the difference of the logarithms of the U.S. variables, for the period 2009-2014.

to see renewable energy as more dependent on governmental policies and incentives. On the other hand, there is rejection of Energy G not Granger causing Renew G for both periods, although at a 10% significance level on the second period. There is also a small positive response of Renew G to the shock of Energy G in the Impulse response function at a global level for both periods, figure 3 and 4, which suggests that investors have seen renewable energy as a sub-sector of the energy producing sector from 2002 onwards. The positive response to the shock was unexpected since investors should had seen clean energy as competitor of non-renewable energies. On the other hand, the increase in energy demand worldwide could explain this result. Since the oil and gas index is recognized as a benchmark for the energy producing sector, in times of energy

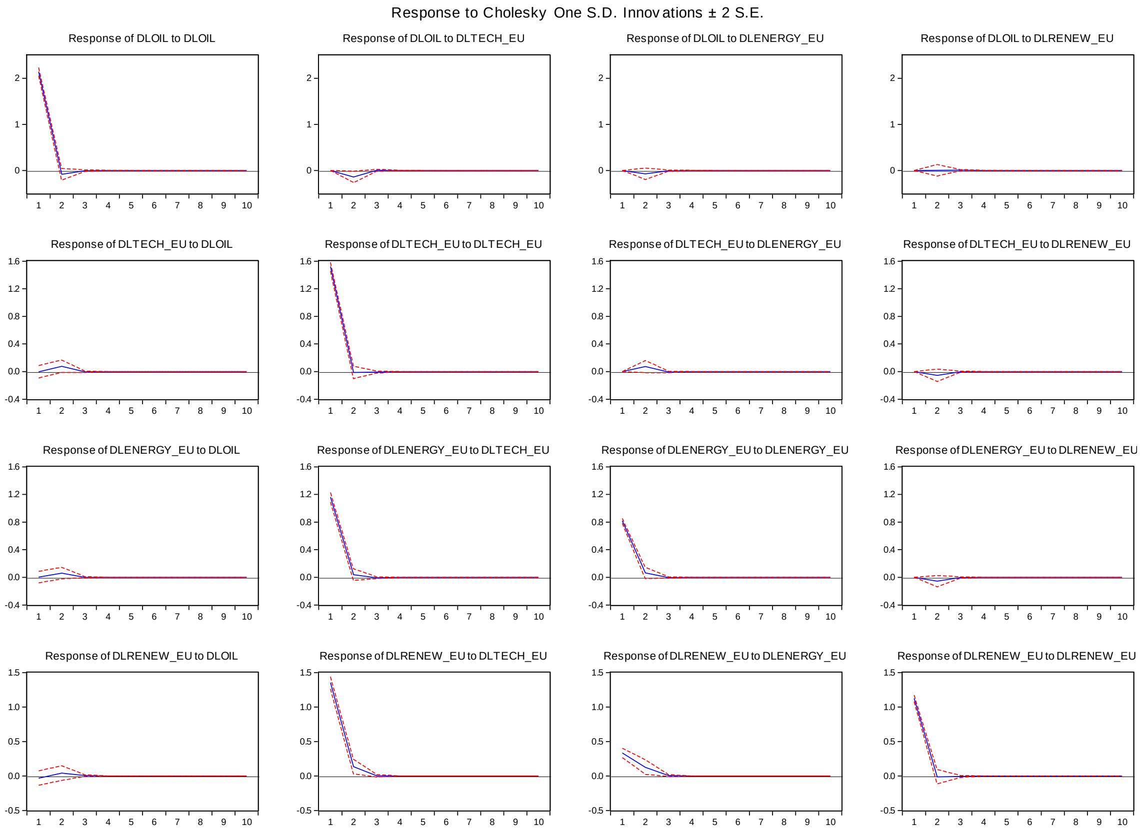

Figure 6 - Impulse response function using as variables the difference of the logarithms of the European variables, for the period 2009-2014.

demand increases, an increase in this index would lead to increases in other related indexes, since they have the common goal of being able to match the supply to cope with increases in demand. Still regarding the global analysis, not rejecting the null hypothesis in the first period from Renew G to Energy G contradicts the predictions, in which a minor causality was to be expected during this period since the major oil and gas companies were investing in this sector. One explanation for the results might lie in investments from non-renewable energy companies on clean energies being too low when compared to their companies sizes. A lack of causality was also verified during the second time period analyzed but, in this case, this was expected as studies have shown that the major oil and gas companies have withdrawn their investment on clean energies during the course of this period (Ferris and Gronewold, 2014).

An analysis of the results for the U.S. and Europe during 2009-2014 shows similarities with the global indexes for the same time period, regarding renewable energy as the dependent variable. The exception is the relationship between Renew US with Energy US, where rejection of the null hypothesis is not verified. The Granger causality test null hypothesis, being Renew EU the dependent variable, was rejected for Energy EU at a significance level of 1%. This outcome goes in hand with the result observed for the Global indexes for the same period. These results suggest a different investors attitude depending on the region they live: while European investors see clean energy as a energy production sector as global investors, American investors do not. Additionally, since the null hypothesis was not rejected for Renew X to Tech X in both cases, investors regardless of their location believe that clean energy is not dependent on new technological developments. Because European policies are strict and investments are high due to incentives, a lack of or low relationship between clean energies and technology is somewhat expected. Incentives from the European Union may be leading investors to see green energies as a sub-sector of the energy producing sector. In the U.S. the level of investment in clean energies during this period is lower when compared to Europe, the policies are still at a state level and not centralized yet. This makes renewable energy more dependent on technological advances to reduce costs and increase their efficiency so they can become a viable option. Therefore, rejection of the null hypothesis for Tech US Granger causing Renew US was to be expected. However, in a period of low investment and after a financial crisis, the technology sector was also affected and this can explain the non-existence in causality revealed by the results (Campello *et al.*, 2010). Additionally, the investment in shale oil during this period relegated investments on renewable energy to second place, which may also explain why clean energy is not seen as an alternative energy production method in the U.S..

6. Conclusion

This thesis analyses the relationships of clean energy with technology, oil and gas companies, and oil prices. This study contributes to the existing literature by updating data, including a non-renewable energy company's index and by analyzing two geographical regions.

The work here presented aimed to answer to the three following questions:

1) How does the global investor/market see renewable energy associated with the technology sector, the oil and gas companies sector, as well as with oil prices variations, from 2002-2007;

2) How has the investor's perspective on clean energy changed over time, by analyzing two distinct periods: 2002-2007 and 2009-2014;

3) How have different regions (Europe and U.S.) of the world seen these relationships during the period from 2009 to 2014.

Regarding the first question, the results suggest the global investor in this period perceived clean energy mainly as a sub-sector of the technology sector, as previously stated in the literature. The results also suggest that from 2002 to 2007 investors begun to perceive green energies as a weak sub-sector of the energy production sector. The two energy sectors, renewable and non-renewable, were not seen as competitors but rather as two sub-sectors with the same goal, where one is clearly bigger than the other and therefore the causality has only one way. The results show that the oil price has no impact on clean energy.

With respect to the second question, the results suggest a perspective shift from the investors after the global crisis as they believe renewable energy is no longer dependent on the technology sector. With the crisis, companies have cut their budget regarding investments and technology innovations, which might lead to the obtained results. During this period, as in the first, investors kept the opinion that clean energy was a sub-sector of the energy production sector.

Concerning the third question, in this period the U.S. became an exporter of oil, while Europe continued to be an importer of oil. This fact may explain the differences in policies and incentives with regards to clean energy, which in turn influences the attitudes of investors. The European Union and therefore Europe as a whole - since most of the countries of Europe belong to the E.U. - kept its policies and incentives on clean energy and even set future goals for them. These actions led European investors to see green energy as an alternative to the existing methods of energy production. Contrarily, there was a lack of policies and incentives in the U.S. in support of renewable energies, when comparing with E.U.. Shale oil investment in the 2009-2014 period further led American investors to move away from seeing renewable energy as an alternative energy production method.

7. Future Research

In order to improve on the knowledge of this field, the indexes should be constructed under the same weight model, for instance all as market capitalization-weighted indexes. Moreover, the development of the European and the American indexes for the first period, 2002-2007, would give insights into how the investors attitudes evolved in the two different regions. The addition of more geographical regions would also enable a better understanding and comparison of investors attitudes worldwide. Another interesting development would be the division of the renewable energy index into the different types of existent clean energies and the addition of nuclear and coal indexes to the model. These would allow a deeper understanding on how the different types of green energy relate to technology and to the energy production sector. Finally, the introduction of a dummy variable linked to government policies and incentives on clean energy would allow to understand the vulnerability and reliance of renewable energies on these directives.

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9. Appendix

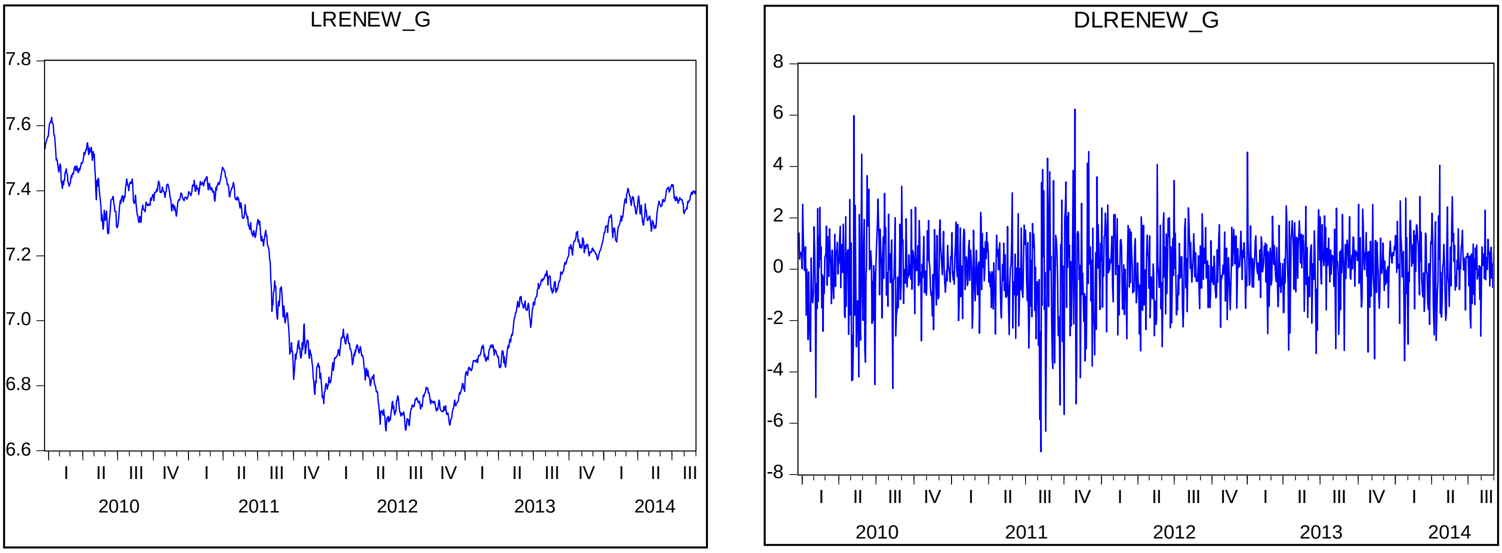


Figure A1 - Histograms of Renew G for the second period, 2007-2014. The first graph is for the logarithm of the variable while the second is for the first difference of the variable logarithm.

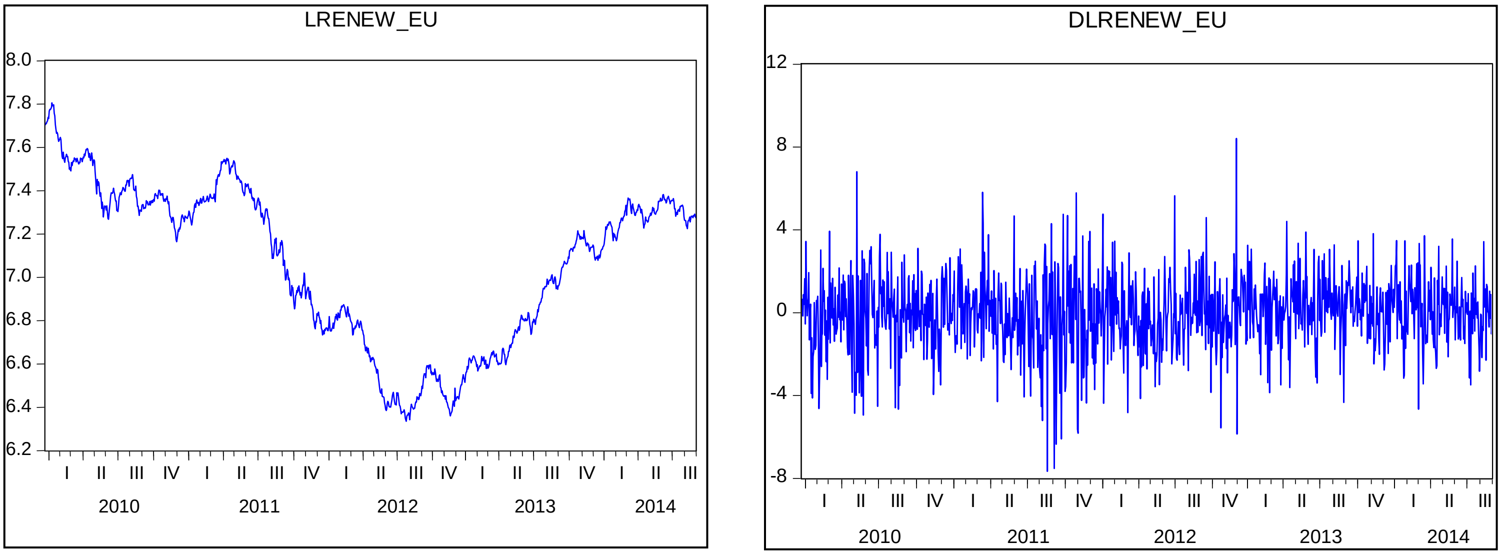
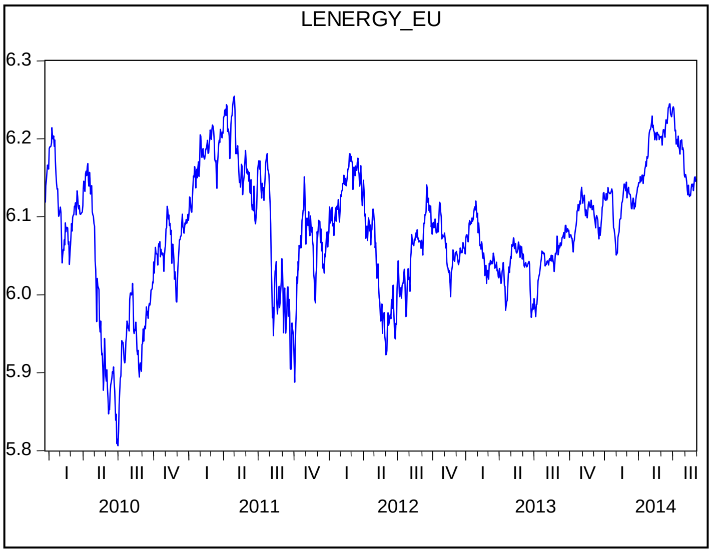


Figure A2 - Histograms of Renew EU for 2007-2014. The first graph is for the logarithm of the variable while the second is for the first difference of the variable logarithm.



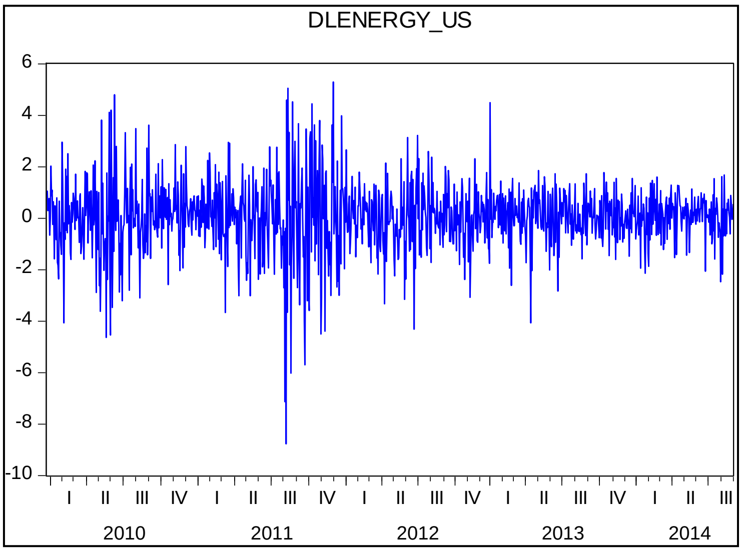
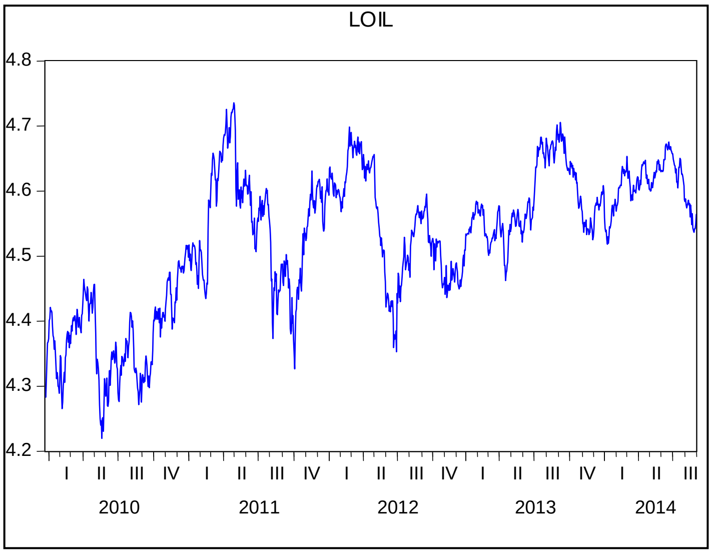


Figure A3 - Histograms of Energy EU for 2007-2014. The first graph is for the logarithm of the variable while the second is for the first difference of the variable logarithm.



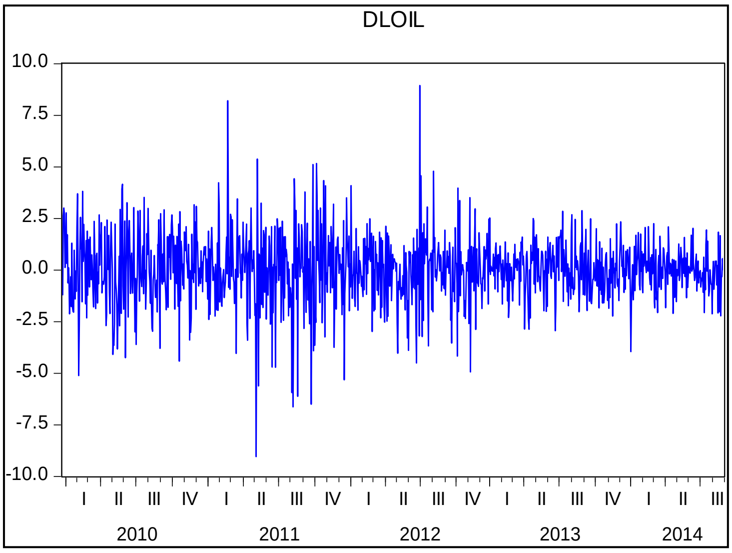


Figure A4 - Histograms of Oil for 2007-2014. The first graph is for the logarithm of the variable while the second is for the first difference of the variable logarithm.

Table A1 - Fit of Unrestricted VAR Model with 1 lag, using Global variables with data from 2002-2007.

Determinant resid. covariance (dof adj.)	6.454902
Determinant resid covariance	6.344611
Log likelihood	-7675.285
Akaike information criterion	13.23351
Schwarz criterion	13.32050

Table A2 - Fit of Unrestricted VAR Model with 1 lag, using Global variables with data from 2009-2014.

Determinant resid. covariance (dof adj.)	0.709796
Determinant resid covariance	0.697668
Log likelihood	-6391.555
Akaike information criterion	11.02589
Schwarz criterion	11.11288

Table A3 - Fit of Unrestricted VAR Model with 1 lag, using American variables with data from 2009-2014.

Determinant resid. covariance (dof adj.)	4.048477
Determinant resid covariance	3.979303
Log likelihood	-7404.016
Akaike information criterion	12.76701
Schwarz criterion	12.85400

Table A4 - Fit of Unrestricted VAR Model with 1 lag, using European variables with data from 2009-2014.

Determinant resid. covariance (dof adj.)	9.075389
Determinant resid covariance	8.920324
Log likelihood	-7873.417
Akaike information criterion	13.57423
Schwarz criterion	13.66123

Table A5 - Lagrange-multiplier test for the VAR model using Global variables, from 2002-2007.

Lags	LM-Stat	Prob
1	24.54366	0.0783

Table A6 - Lagrange-multiplier test for the VAR model using Global variables, from 2009-2014.

Lags	LM-Stat	Prob
1	14.79631	0.5396

Table A7 - Lagrange-multiplier test for the VAR model using American variables, from 2009-2014.

Lags	LM-Stat	Prob
1	8.961997	0.9150

Table A8 - Lagrange-multiplier test for the VAR model using European variables, from 2009-2014.

Lags	LM-Stat	Prob
1	11.36413	0.7865