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The effect of weather on the European stock market

The case of Dow Jones Sustainability Europe Index

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Abstract

Purpose – The purpose of this paper is to ascertain whether weather variables can explain the stock return reaction on the Dow Jones Sustainability Europe Index by employing a number of macroeconomic indicators as control variables.

Design/methodology/approach – The authors incorporate the generalized autogressive conditional heteroskeasticity model in methodology for the period August 26, 2009 to May 30, 2014 using daily data.

Findings – The empirical results indicate that not only do changes in humidity and wind levels seem to affect positively the European stock market but changes in returns oil and gold prices as well. However, the results show that the volatility of the US dollar/Yen exchange rate and ten-year bond value exerts significant negative impact on companies' stock returns.

Originality/value – This study adds to the international literature by documenting the impact of weather variables on socially responsible companies.

Keywords Environmental economics, Stock returns, Welfare economics, Wind, Investment, Sustainability Index, GJR-GARCH model, Humidity, Dow Jones

Paper type Research paper

1. Introduction

It is true that weather conditions have a significant impact on human behavior, mood, thinking and judgment (Pardo and Valor, 2003; Loughran and Schultz, 2004; Watson, 2000; Shu, 2010). In the field of behavioral finance, Shu (2010) pointed out that investors' preferences, risk assessments, rational cogitations and financial decisions can be affected by their mood or psychological state. Thus, the question that arises is whether weather conditions can affect the behavior of stock market investors. In other words, there are several empirical studies that investigate the role of weather effect on stock returns. A number of different weather variables have been introduced, such as temperature (Cao and Wei, 2005; Floros, 2008, 2011; Chang *et al.*, 2006; Keef and Roush, 2002), number of sunshine hours (Shu and Hung, 2009; Pardo and Valor, 2003) and air humidity levels (Pardo and Valor, 2003; Chang *et al.*, 2006), cloud cover (Chang *et al.*, 2006; Keef and Roush,

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2002; Saunders, 1993) and wind (Keef and Roush, 2002; Shu and Hung, 2009) in order to examine the impact on the stock market. The relationship between weather variables, stock market returns and volatility is controversial (Floros, 2011).

Unlike prior empirical studies, this study takes into consideration companies that integrate socially responsible investments (SRI).

Investors have the capability to acquire information via Dow Jones Sustainability Index (DJSI), FTSE4Good, Jantzi Social Index, Calvert Social Index and KLD indexes for firms that employ sustainability initiatives and manage effectively economic, environmental and social risks (López *et al.*, 2007) leading to a rise in SRI. Unlike the conventional mutual funds, SRI integrates non-financial considerations, such as social and environmental ones into the investment decision procedure (Schwartz and Carroll 2003; Haigh and Hazelton, 2004). SRI receives greater attention and awareness over the last years (Eurosif, 2014).

The present study intends to examine the impact of weather conditions on European stock market by exploring whether there is a relationship between the European stock returns and two environmental proxy variables, namely, humidity and wind levels. Humidity and wind are among the most significant weather variables of human comfort (Toros *et al.*, 2005). Also, a number of economic variables are used as control variables, namely, crude oil, gold, ten-year US bond value and the US dollar/Yen exchange rate. As a proxy for socially responsible companies the DJSI Europe is used as it concerns companies that operate in Europe and implement socially responsible initiatives. This is the first empirical study that investigates the impact of weather conditions on stock returns of socially responsible companies using generalized autogressive conditional heteroskeasticity (GARCH) methodology. An effort is made to record the reaction of socially responsible stock indices refining investment theories and making the investors' decision more effective. Thus, the findings can be recommended to both conventional and socially responsible investors dealing with European stock indices.

The remainder of the paper is organized as follows. Section 2 illustrates the linkage between weather and human behavior and mood along with the effects of environmental variables on stock returns focussing on humidity and wind variables. Section 3 describes the data along with the methodological steps that are incorporated in the study, while Section 4 reports the results of the analysis. In the last part, Section 5, the conclusion is presented.

2. Literature review

In the field of behavioral finance, there is a systematic approach to investigate the fact whether weather conditions can affect the investors' psychology or not. In the first part, the weather impact on human behavior and mood is recorded, while in the second part weather variables that affect the stock returns focussed on humidity and wind speed variables are presented.

2.1 Weather effect on human behavior and mood

In general, changes in weather condition can lead to complex psychological and physical responses and they are responsible for different human behavioral aspects, such as interpersonal interactions, violent behavior and performance (Lu and Chou, 2012; Shu and Hung, 2009). Kals (1982) pointed out that one-third of people, approximately, are weather sensitive so their mood mental and physical health are affected. For instance, humans seem to be more satisfied with their lives in sunny days than in overcast and rainy ones (Lucey and Dowling, 2005). Howarth and Hoffman (1984) found that weather variables are significant predictors of changes in the majority of ten mood dimensions. Particularly, humidity was the most significant predictor, while optimism is significantly affected by the number of hours of sunshine. Finally, aggressive feelings seem to be increased when temperature dropped into the very cold range. Similarly, Schneider *et al.* (1980) have showed that discomfort and, thus, aggressive behavior can be affected by cold temperatures. Cao and Wei (2005) pointed out that very high or very low temperatures tend to increase the aggression level leading to hysteria and apathy. At this point, it is crucial to indicate the effect of wind and humidity on pollution. On the one hand, high wind speed can cause low pollutant concentration diluting and dispersing pollutants to other areas. On the other hand, humidity can affect negatively both the environment and the human bodies in different ways (Viswanathan and Krishnamurti, 1989; Ahrens, 2011).

Psychologists found that weather has unexpected impacts on the psychological aspects of human beings, one of these is seasonal affective disorder (Lee and Wang, 2011) which can explicitly explain the seasonal variations in stock returns (Kamstra *et al.*, 2003). Shu (2010) indicated that pleasant weather triggers good mood inciting investors to price stocks optimistically, and vice versa. For instance, Symeonidis *et al.* (2010) stated that sunny weather is thought to affect the investors' mood making them more optimistic and willing to enter long positions, leading in turn to higher returns. Affected by optimistic or pessimistic psychological status, investors overestimate or underestimate their prospects regarding the economy's future, so they purchase or sell more stocks. As weather conditions can affect the human behavior and mood, investors in a good mood tend to be more optimistic about future prospects and seem more willing to invest. This, in turn, causes investors to overestimate the probability of success and underestimate the risk of their decision (Wright and Bower, 1992; Nofsinger, 2005). Finally, Hirshleifer and Shumway (2003) recommended that investors can benefit by being aware of their moods, not only caused by weather but other types of conditions as well, in order to avoid mood-based errors in their judgments and financial trades.

2.2 Humidity and wind effect on stock returns

This section presents selective and recent empirical studies regarding weather variables, namely, humidity and wind on stock returns.

Lu and Chou (2012) investigated the relationship between weather-related mood and stock index returns of order-driven market in Shanghai Stock Exchange of China. The study focusses on the period 2003-2008 and found that the impacts of temperature, humidity and wind speed on returns are generally found to be insignificant. In an order-driven market, investors submitted immediately their orders to different geographical regions; thus, the impact of weather on stock returns is likely to be weak.

Kang *et al.* (2010) incorporated different weather variables in order to examine if weather conditions affected the stock returns in Shanghai stock market for the period January 1996 to December 2007. Regarding the domestic stock market investors, extremely high humidity and extremely low sunshine along with extremely low temperature and extremely low humidity were negatively significant on the stock returns. Regarding the foreign investors, extremely high humidity, extremely low humidity and extremely high sunshine, extremely high temperature and extremely high humidity and, finally, extremely low humidity and extremely high sunshine affected positively the volatility of stock returns. The results infer that investors are influenced by different types of weather variables, which may affect the stock returns and volatility.

In addition, Shu and Hung (2009) examined the relationship between wind speed and daily stock market returns across 18 European countries from 1994 to 2004, namely: Belgium, Czech Republic, Finland, France, Greece, Hungary, Ireland, Italy,

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Luxemburg, Norway, Poland, Portugal, Russia, Spain, Sweden, Switzerland, Turkey and the UK. Results illustrated that wind speed has a negative impact on stock returns as well as temperature and sunlight variables.

Yoon and Kang (2009) intended to ascertain whether a relationship between three weather variables and Korean stock returns exist during the pre-financial crisis and after 1997 crisis using simple regression with the GJR-GARCH process. During the pre-crisis period, the results showed that humidity was significantly negative to stock returns. In the post-crisis period there was no weather effect on stock market due to market liberalization and the full abolition of foreigner investment restrictions in May 1998 making the market more efficient. As far as the whole period was concerned, extremely high temperature and humidity have a negative impact on stock returns, while extremely low humidity and extremely high cloudiness influence positively the stock returns.

Furthermore, Keef and Roush (2007) focussed on the effects of weather variable on the Australian stock returns. Daily returns of two stock indices, namely, S&P/ASX 20 and S&P/ASX 300 were adopted. The results revealed that stock returns were not influenced by wind speed and cloud cover, while the temperature in Sydney is a crucial determinant for both stock indices. Regarding the wind variable, an obvious explanation for the insignificant role of wind on stock returns is that the ravages of the wind are comparatively meek in Sydney.

Chang *et al.* (2006) took into account three weather factors, namely, temperature, humidity, and cloud cover in order to investigate their impact on Taiwan stock return for the period 1997-2003. It was illustrated that temperature and cloud cover have the greatest effect on stock market returns. The results showed that humidity does not have strong threshold effects on stock returns.

Dowling and Lucey (2005) attempted to investigate whether mood proxy variables incorporating humidity levels affect the Irish equity returns. It was hypothesized that greater levels of humidity are associated with lower returns. However, the results found a positive relationship with stock returns contrary to psychological literature, probably, because of the non-extreme nature of the Irish weather.

Keef and Roush (2002) examined how the stock returns in New Zealand are influenced by different weather conditions in Wellington. It was revealed that wind is a significant determinant of stock returns, temperature has a small influence on stock returns while cloud cover has no influence on stock market.

Finally, Pardo and Valor (2003) wanted to determine whether sunshine hours and humidity levels affect the stock prices of Madrid Stock Exchange. Taking into account two different periods: the first period extents from January 1981 to April 1989 whereas the second one from April 1989 until May 2000. It was found that the two weather variables do not affect the stock prices indicating a rational behavior of the Spanish stock market. Table I illustrates the most recent empirical studies incorporating, only, humidity and wind as weather variables in order to explain the stock market reaction.

There are a few remarks that should be emphasized regarding the above discussed studies. The majority of the studies are based on the assumption that investors in a good mood tend to be more optimistic about the future which increases their willingness to buy stocks. The effect of humidity on stock returns is controversial, probably, because the majority of studies take into account-specific stock market indices, while the investors come from different geographical regions. In addition, the wind variable has not been documented sufficiently in empirical studies; even if the wind is considered the most practical weather variable. Finally, none of the above studies pay attention to socially responsible stock indices.

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Authors	Period	Stock market	Variable	Result
Lu and Chou (2012)	2003-2008, hours from 08:00 to 15:00	Shanghai Stock Exchange (China)	Wind Humidity	No impact of humidity and wind on index returns Humidity and wind exert positive impact on volatility of stock index
Kang *et al.* (2010)	1996-2007	Shanghai Stock Exchange (China)	Humidity	Domestic investors-stock returns Extremely high humidity and extremely low sunshine along with extremely low temperature and extremely low humidity are negatively significant on the stock returns Foreign investors-volatility Extremely high humidity, extremely low humidity and extremely high sunshine, and, finally, extremely high temperature and extremely high humidity affect positively the volatility of stock index
Shu and Hung (2009)	1994-2004	18 European countries	Wind	Wind speed has a negative impact on stock returns
Yoon and Kang (2009)	1990-2006	Korea Composite Stock Price Index 200	Humidity	Pre-crisis period, 1990-1997: Humidity was significantly negative to stock returns.
Keef and Roush (2007)	1192-2003	Australian Stock Exchange -S&P/ ASX 20 and 300.	Wind	There is no relation between wind and index returns
Chang *et al.* (2006)	1997-2003	Taiwan stock market	Humidity	No strong threshold effects on stock market returns
Dowling and Lucey (2005)	1988-2001	Irish Stock Exchange Official Price Index	Humidity	Positive relationship between humidity and returns
Keef and Roush (2002)	1986-2002	New Zealand Stock Exchange	Wind	Wind has a significant influence on returns
Pardo and Valor (2003)	1981-2000	Madrid Stock Exchange	Humidity	No influence of humidity levels on stock prices

Table I. Summary of literature review

3. Methodological considerations

3.1 Data

For this study, two types of data have been collected, namely, market indices and environmental data. The daily market indices of DJSI Europe, Gold Bullion LBM US $/Troy Ounce (Gold), Crude oil BRNP$/B expressed in US dollars per barrel (oil), US Benchmark 10 Year DS Government Index – Clean Price Index (Bond) and the US dollar/ Yen exchange rate D/Y were collected from datastream for the period August 26, 2009 to May 30, 2014. Our analysis focusses on returns as all price series were non-stationary in levels (we were unable to reject the hypothesis that the level of each series were non-stationary in levels). To obtain a stationary series, we use the continuously compounded returns of the above market indices, which are calculated as the difference in natural logarithm of the index value for the two consecutive days $R_t = logP_t - logP_{t-1}$

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where R_t is daily return of used indexes for day t, P_t current day closing price, P_{t-1} closing price of the previous day, and log natural logarithm. Concerning the environmental data, they were retrieved by Bloomberg database concerning Europe relative humidity actual and Europe wind speed actual.

In the analysis, the first differences of these series are adopted for two reasons, first to stationarize the time series and second to obtain more meaningful statistics since the human body responds substantially to the total differences of the humidity and wind variable, while the percentage changes of the aforementioned variables do not reflect quantities to which the human senses respond accordingly. The first difference of a time series is the series of changes from one period to the next. If $Y(t)$ denotes the value of the time series Y at period t, then the first difference of Y at period t is equal to $Y(t)-Y(t-1)$.

A variety of papers have investigated the role of macroeconomic variables on stock returns (Barrows and Naka, 1994; Gjerde and Sættem, 1999; Flannery and Protopapadakis, 2002; Chang, 2009; Hondroyiannis and Papapetrou, 2001; Rapach *et al.*, 2005; Gupta and Modise, 2013). In the present study a number of macroeconomic variables are integrated in the proposed model as control variables in order to isolate the effect of weather variables on the sustainability stock index. In total, seven control variables are taken into account in this study, namely, gold, crude oil, volatility of US dollar/Yen exchange rate and ten-year bond value.

Daskalaki and Skiadopoulos (2011) pointed out that a great number of studies investigated whether commodities on asset option can improve the investors' portfolio. It was illustrated that investors can decrease the portfolio's risk by substituting the stock portfolio to a portfolio with stocks and commodities.

Regarding the oil variable, it is among the most fundamental macroeconomic factors of the world economy (Maghyereh and Al-Kandar, 2007), while volatility of oil price can cause significant consequences both on financial markets and overall economy (Ewing and Malik, 2013). In general, the literature on the relationship between oil shocks and stock market activities revealed that changes of crude oil prices are associated with stock prices fluctuation (Kang and Ratti, 2013). In this study, oil is considered as a proxy for the performance of overall economy (Ewing and Malik, 2013).

As far as the gold variable is concerned, it is a substitute that can reduce similar types of risks in portfolios (Ciner, 2001) and it can be used as an investment hedge against the US dollar (Joy, 2011). In addition, Kumar (2014) implied that gold can be used as a safe asset for investment during the period of recession and crisis as it holds its values in adverse market conditions (Baur and McDermott, 2010). However, there is no theoretical model so as to interpret why gold is considered as a safe haven. Two explanations are given to define this perception. First, gold was the first form of currency and, second, it was used as an inflation hedge. Another component that increases the role of gold is that it is uncorrelated with other types of assets (Baur and Lucey, 2010). Companies that are engaged in international transactions are affected by currency movements (Bradley and Moles, 2002). A number of studies investigate the relationship between exchange rate and stock return (e.g. Bartov and Bondnar, 1994; Griffin and Stulz, 2001; Kasman *et al.*, 2011; Chkili *et al.* 2012). This study suggests the use of US dollar/Yen exchange rate as a proxy for the effects of exchange rate on European stock returns for informative and measurable results. On the one hand, the US dollar is considered as a predominant currency which can affect the economic environment (McKinnon, 2002) and, on the other hand, Yen currency is one of the major funding currencies to carry trades (Cheung *et al.*, 2012).

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It is well known that interest rates are one of the most vital components in macroeconomics and finance (Gürkaynaka *et al.*, 2007). Thus, in this study, the 10-Year Treasury Note is used as a proxy of US interest rate. The US economy is considered a leading economy affecting all economies.

As far as DJSI concerns, it tracks the performance of the world's leading companies in terms of sustainability, allowing investors to take into account sustainability concerns in their investment portfolios. In particular, the DJSI Europe takes into account the top 20 percent of the 600 largest European companies in the S&P Global Broad Market Index[SM] that lead the field in terms of sustainability. Each company is assessed by three aspects, namely, economic, environmental and social. The main motive of DJSI in relation to other sustainable indices is that it recommends both general and industry-specific criteria. However, the weighting of general and industry-specific criteria depends on the type of industry (RobecoSAM, 2014). Finally, DJSI's transparency limitations regarding the criteria scoring, the weighting of each criterion, and general issues that concern its methodology could be explained as it can be easily imitated by their competitors and could eliminate the competitive edge of organizations that assess CSR performance (Delmas and Blass, 2010).

3.2 Econometric model

Regarding the econometric model, the GARCH model has been employed extensively in prior studies in order to examine if the weather variables affect the stock returns. For instance, Chang *et al.* (2006), Symeonidis *et al.* (2010) and Yoon and Kang (2009) used the GJR-GARCH model, Floros (2011) selected the AR(1)-TGARCH (1, 1) model while Kang *et al.* (2010) considered a simple GARCH (1, 1) model. In this study, the GJR-GARCH (1, 1) model is used in order to examine if the humidity and wind affect the European stock market returns.

The GJR (p, q) model has p GARCH coefficients associated with lagged variances, q ARCH coefficients associated with lagged squared innovations, and q leverage coefficients associated with the square of negative lagged innovations. The general form of the GJR (p, q) model is:

$$Y_t = X_t'\theta + u_t$$

where X_t is a vector of exogenous variables and u_t is the error term:

$$\sigma_t^2 = k + \sum_{i=1}^{p} \gamma_i \sigma_{t-1}^2 + \sum_{i=1}^{q} a_i u_{t-1}^2 + \sum_{i=1}^{q} \xi_i I\left(u_{t-j} < 0\right) u_{t-1}^2$$

The indicator function $I(u_{t-j} < 0)$ equals 1 if $u_{t-j} < 0$, and 0 otherwise. Thus, the leverage coefficients are applied to negative innovations, giving to negative changes additional weight.

For stationarity and positivity, the GJR model has the following constraints:

- $k > 0$;
- $\gamma_i \geqslant 0,\ \alpha_j \geqslant 0$;
- $\alpha_j + \xi_j \geqslant 0$; and
- $\sum_{i=1}^{p} \gamma_i + \sum_{j=1}^{q} a_i + \frac{1}{2} \sum_{j=1}^{q} \xi_j < 1$.

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The GARCH model is nested in the GJR model. If all leverage coefficients are zero, then the GJR model reduces to the GARCH model. This means you can test a GARCH model against a GJR model using the likelihood ratio test.

The GJR-GARCH (1, 1) model, which is used for our research, is stated as follows:

The mean equation is:

$$Y_t = X_t'\theta + u_t$$

The conditional variance equation is:

$$\sigma_t^2 = k + \gamma\sigma_{t-1}^2 + \alpha u_{t-1}^2 + \xi I\left(u_{t-j} < 0\right)u_{t-1}^2$$

where u_t GED $\left(0, \sigma_t^2\right)$is assumed to follow the generalized error distribution (GED). We employ the GED because of its ability to accommodate leptokurtosis.

The leverage effect occurs when $\xi > 0$. The condition for a non-negative variance requires that $k \geqslant 0$, $\gamma \geqslant 0$, $\alpha \geqslant 0$, $\alpha + \xi > 0$.

When $R_t - \hat{R}_t < 0$, then $u_t < 0$, which means that the observed return R_t is less than the estimated return (in other words, the mean return). Consequently, when $I(u_{t-j} < 0)$ equals 1, the negative change u_{t-1}^2 at time $t-1$ correlates with the volatility at time t.

In this model, the good news $(u_{t-1} > 0)$ related to the bad news $(u_{t-1} < 0)$ has a different effect on the conditional variance. If $u_{t-1} > 0$, this implies that at time $t-1$ we had good news, which had a positive effect on the return (over the mean return), and this is why the residual is positive. Good news reflects on the coefficient α (ξ absorbs the effect of the bad news). However, bad news has an effect on $\alpha + \xi$, because if $I(u_{t-j} < 0)$ equals 1, then the equation becomes:

$$\sigma_t^2 = k + \gamma\sigma_{t-1}^2 + \alpha u_{t-1}^2 + \xi u_{t-1}^2 * 1 = k + \gamma\sigma_{t-1}^2 + (\alpha + \xi)u_{t-1}^2$$

When $\xi > 0$, we have the leverage effect, which means that bad news has a greater effect on conditional volatility.

4. Empirical findings

Descriptive statistics of daily returns of DJSI Europe, Gold, Oil, Bond and D/Y series are presented in Table II to aid our understanding of the nature and special characteristics of each distribution. In particular, descriptive statistics provide useful information about the location and variability of the data. The sample mean returns of these series are close to zero thus, we cannot reject the null hypothesis that the mean returns are not statistically different from zero (t statistics). Also, all of the series exhibited negative skewness which means that these indexes have a downside risk, or there is substantial probability of big negative returns. Furthermore, the samples kurtosis are greater than 3, meaning that return distributions have excess kurtosis indicating leptokurtic distributions with higher densities of values at the extreme ends of the probability curves. The Jarque-Bera (JB) statistics indicate essential departures from normality for all series confirming results for asymmetry and kurtosis. Moreover, the augmented Dickey-Fuller (ADF) test, allowing for both an intercept and a time trend, showed that the sample series had been produced by stationary series.

	DJSI Europe	Gold	Oil	Bond	D/Y
Mean	0.00040	0.00022	0.00036	9.89E−05	−6.18E−05
Median	0.00057	0.00037	0.00026	1.59E−04	0.000122
Maximum	0.0737	0.05432	0.04925	0.018598	0.0361
Minimum	−0.0487	−0.1016	−0.0588	−0.019299	−0.0342
SD	0.0107	0.01144	0.0150	0.004711	0.0061
Skewness	−0.084	−1.055	−0.1329	−0.145732	−0.0844
Kurtosis	6.558	10.35	3.818	3.959	7.324
Jarque-Bera	656.5	3027.7	38.25	52.020	968.85
Observations	1,242	1,242.0	1,242	1,242	1,242
t statistics of hypothesis: mean = 0	1.302	0.6837	0.8431	0.7399	−0.1455
Augmented Dickey-Fuller (ADF)	−34.115	−35.75	−34.78	−35.734	−34.91

Table II.
Simple returns

Also, in Table III, descriptive statistics of the squared returns of D/Y and of the first differences of ERHA and EWSA are presented. According to the statistics of D/Y squared returns, the hypothesis that the mean is equal to 0, is not rejected, which implies that the squared returns reflect a measure of the daily volatility of this series. Also, the distribution of squared returns of D/Y is non-normal according to the JB test and characterized by a high excess kurtosis and positive skewness. Moreover, the descriptive statistics of ERHA and EWSA reveal that the mean of these series is statistically different from zero. Furthermore, the significant kurtosis and negative skewness mostly for the ERHA series indicate the non-normality of these series. Concerning the EWSA series, the skewness coefficient is close to zero and thus the non-normality, indicated also by JB statistic, is mostly due to the excess kurtosis rather than the skewness. Finally, the ADF test shows that all these data series are stationary.

Table IV shows the sample autocorrelation function (ACF) and partial autocorrelation function for daily returns and squared daily returns of DJSI Europe time series. It can be observed that the Ljung-Box statistics show an autocorrelation on daily returns and strong autocorrelations on the squared daily returns, indicating conditional heteroskedasticity (Bollerslev, 1986).

	$(D/Y)^2$	ERHA	EWSA
Mean	3.77E-05	0.0018	0.00077
Median	1.05E-05	−0.02	0
Maximum	0.0013	6.9	5.46
Minimum	0	−11.75	−7.47
SD	9.49E-05	1.885	1.4562
Skewness	7.5433	−0.445	0.0044
Kurtosis	77.570	6.725	4.508
Jarque-Bera	299,542.8	759.69	117.72
Observations	1,242	1,243	1,243
t statistics of hypothesis: mean = 0	14.0	0.0337	0.0187
Augmented Dickey-Fuller (ADF)	−21.701	−18.535	−15.78

Source: Sariannidis *et al.* (2015)

Table III.
Squared returns of D/Y and the first differences of ERHA and EWSA

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Table IV.
Test for serial dependence in first and second moments of DJSI Europe

	Returns				Squared Returns		
Lags	Autocorrelation	Partial correlation	LB(n)	Lags	Autocorrelation	Partial correlation	LB(n)
1	0.031	0.031	1.23	1	0.15	0.15	28.122
2	−0.038	−0.039	3.01	2	0.165	0.145	61.852
3	−0.055	−0.053	6.80	3	0.147	0.109	88.793
4	−0.055	−0.054	10.63	4	0.224	0.18	151.64
5	−0.039	−0.04	12.53	5	0.127	0.053	171.68
6	−0.012	−0.017	12.70	6	0.14	0.063	196.23
12	0.013	0.005	17.31	12	0.123	0.031	332.34
24	0.02	0.008	25.43	24	0.075	−0.016	497.95
36	−0.025	−0.04	36.48	36	0.125	0.064	604.88
70	0.021	0.005	73.32	70	−0.016	−0.024	713

Notes: LB(n) are the n-lag Ljung-Box statistics for DJSI Europe$_t$ and DJSI Europe$_t^2$, respectively; LB(n) follows χ^2 distribution with n degree of freedom; the sample period contains 1,242 daily returns

The descriptive statistical results, the model selection criteria (the Akaike Information Criterion or the Schwartz Bayesian Criterion) and the LR test on the GJR-GARCH (p, q) model support the application of the following specification:

Mean equation:

$$\mathrm{DJSI}_t = b_0 + b_1\mathrm{Gold}_t + b_2\mathrm{Oil}_t + b_3\mathrm{Bond}_t + b_4\left(D/Y\right)_t^2 + b_5\mathrm{ERHA}_t + u_t$$

Variance equation:

$$\sigma_t^2 = a_0 + a_1\sigma_{t-1}^2 + \alpha_2 u_{t-1}^2 + a_3 I\left(u_{t-j} < 0\right)u_{t-1}^2 + a_4\mathrm{EWSA}_t$$

$$u_t \sim \mathrm{GED}\left(0,\ \sigma_t^2\right),$$

Diagnostic tests were performed to establish how well the model fitted and its appropriateness.

We proceed with the ACF analysis of the standardized residuals and squared standardized residuals of the estimated specification. From Table V, LB(n) statistics provide strong evidence to accept the null hypothesis of absence of autocorrelation and ARCH formation in the residuals series. Furthermore, the ARCH LM test concerning five lags in the residuals ($N \times R^2 = 0.7567$) verifies that we do not need to encompass a higher order ARCH process. Finally, the leptokurtosis of standardized residuals distribution (kurtosis 4.5) and the coefficient estimation $v = 1.56$ for tail thickness regulator with 0.0849 standard error, confirms the pertinence of the GED assumption. An LR test of the restriction $v = 2$ (for $v = 2$ the GED is essentially the normal distribution) against the unrestricted models clearly supports the assumption of non-normal distribution and thick tails in financial returns. Finally, it must be noted that the adjusted coefficient of determination R^2 is 31.78 percent implying that a significant proportionate amount of variation in the response variable DJSI Europe is explained by the estimated model.

In Table VI, the results for the mean equations are presented. The gold coefficient (0.08) is positive, a fact that suggests that probably the gold and equities prices are interconnected in a cause and effect relationship through their link to strategic

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Lags	Residuals Autocorrelation	Partial correlation	LB(n)	Lags	Squared residuals Autocorrelation	Partial correlation	LB(n)
1	0.006	0.006	0.0412	1	−0.012	−0.012	0.1744
2	−0.034	−0.034	1.505	2	−0.013	−0.014	0.3983
3	−0.034	−0.034	2.9583	3	0	0	0.3984
4	−0.004	−0.005	2.9828	4	0.019	0.018	0.8326
5	−0.031	−0.034	4.2218	5	−0.003	−0.003	0.8471
6	−0.011	−0.012	4.3643	6	−0.006	−0.006	0.8952
12	0.023	0.025	8.395	12	−0.012	−0.013	3.8307
24	0.022	0.016	14.739	24	0.02	0.018	14.215
36	−0.001	−0.016	25.122	36	−0.007	−0.006	20.342
70	0.009	−0.006	65.88	70	−0.022	−0.025	40.563

Notes: LB(n) are the n-lag Ljung-Box statistics for the residual series; LB(n) follows χ^2 variable with n degree of freedom; the series of residual contains 1,242 elements

Table V. Diagnostics on standardized and squared standardized residuals

$$\mathrm{DJSI}_t = b_0 + b_1\mathrm{Gold}_t + b_2\mathrm{Oil}_t + b_3\mathrm{Bond}_t + b_4\left(D/Y\right)_t^2 + b_5\mathrm{ERHA}_t + u_t$$

b_0	b_1	b_2	b_3	b_4	b_5
0.000525**	0.08019*	0.20*	−0.606*	−6.4826*	0.000217**
(0.000224)	(0.01778)	(0.148)	(0.04643)	(2.29457)	(0.000109)

Notes: Standard errors are shown in parentheses. *,**,***Statistically significant at 1, 5 and 10 percent levels, respectively

Table VI. Mean equations

portfolio management. Gold functions traditionally as a hedge for stocks and responds with higher prices during equity market crashes, but nowadays fund managers and investors when they invest in stocks they put money into stocks and gold not only for hedge but also for diversification and assets allocation and as a result the prices of both rises simultaneously. Also, the coefficient of oil is positive (0.2) as it was expected, as oil constitutes a basic cost coefficient in most sectors of economies and thus its fluctuations affect stock market accordingly.

On the other hand, the coefficient of ten-year bonds is presented as negative, a fact, that is consistent with the international bibliography while the decrease of low interest rates attracts the investors' interest for more investments as stocks[1]. Also, the magnitude and the sign of the squared dollar/Yen coefficient (−6.48) indicates that the shock of Dollar/Yen exchange rate returns exerts a negative effect on DJSI Europe returns probably because of the uncertainty and the danger that they present at the stock market. Finally, the statistically significant of the humidity coefficient implies that the increase of humidity causes impulsive and irrational spending among other things including stocks.

The GJR-GARCH model parameters are presented in Table VII. The drift term of variance process is 0.000525 and it is statistically significant at the 5 percent level. The magnitude and the statistical significance of the parameter α_1 (0.86477) indicates a time varying volatility having long memory for DJSI Europe returns. The parameter α_2, which reflects information about volatility observed in the previous period (the ARCH term), is not statistically significant implying that the old information (GARCH term α_1)

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is more important than recent information and the information decays very slowly. Furthermore, the α_2 coefficient is positive (0.194) which implies that the conditional variances persist more strongly after a large negative shock than after a large positive shock of the same magnitude. Finally, the α_2 parameter is negative and statistically significant at the 10 percent level implying that the wind increase decreases volatility. This negative effect is interpreted probably by the fact that the wind increase cleans the big cities from the dangerous airborne particles which creates clarity and better feeling and as a result the investors feel less risk and consequently this is reflected as smaller variance.

5. Summary and conclusions

This study has significant implications both to socially responsible and conventional investors dealing with European stock market or similar weather condition stock markets. The results showed that weather variables induce mood and behavioral changes affecting the investment decisions.

On one side, it was revealed that humidity affects the stock market returns positively which is consistent with Dowling and Lucey (2005). This implies that a high level of humidity affects the human comfort negatively leading to aggressive behavior and, in turn, it increases the stock returns consistent with Cao and Wei (2005). Thus, humidity can overestimate the probability of success and underestimate the risk of their decision consistent with Wright and Bower (1992) and Nofsinger (2005).

On the other side, the wind affects the volatility of stock market returns negatively. The increased wind speed plays a crucial role in diluting pollution and preventing the accumulation of air pollutants, thus, socially responsible investors feel safe and optimistic for the stability of economy, thus, leading to lower stock returns volatility.

As socially responsible investors are more sensitive to social and environmental issues than conventional ones, this study illustrates that investors are sensitive to weather fluctuations in their investment decisions. In particular, humidity impels investors to be more aggressive, leading to increase the stock returns, while wind seems to be an important variable that makes investors to feel safe for the stability of economy leading to lower stock returns volatility. The results are consistent with psychologists who found that weather may have an impact on the psychological aspects of human beings, and, thus investors and their decisions.

Finally, the findings of this study imply that there might be a chain linking wind and humidity levels, human's mood and behavior, investors' decision and stock returns. Regarding control variables, gold and oil affect positively the stock returns. Traditionally, gold can be used as an investment hedge tool against other assets, such as the US dollar. According to the results, it can be implied that investors, first, tend to hedge their position and then buy stock equities increasing the stock returns. As oil can

$$\sigma_t^2 = a_0 + a_1\sigma_{t-1}^2 + \alpha_2 u_{t-1}^2 + a_3 I(u_{t-j} < 0)u_{t-1}^2 + a_4\text{EWSA}_t$$

a_0	a_1	α_2	a_3	a_4
3.94E−06*	0.86477*	−0.01672*	0.194063*	−2.5E−06***
(1.04E−06)	(0.0278)	(0.016045)	(0.036211)	(1.47E−06)

Table VII. Variance equations

Notes: Standard errors are shown in parentheses. *,**,***Statistically significant at 1, 5 and 10 percent levels, respectively be considered as a proxy for the performance of world economy, the increase of oil prices leads to increased stock returns. Furthermore, the dollar exchange rate volatility and high level of risk for the US economy probably weaken the investors' confidence for the European stock market evolution thus affecting negatively the stock returns. Thus, this study provides knowledge of the effect of wind and humidity on investment behavior and explains the mechanism of how humidity and wind can change the judgment and decision making. In addition, the results should trigger investors to be carefully monitor their mood and weather condition when they intend to buy or sell stock equities in order to avoid any mood-induced error. Finally, researchers need to take into account the weather conditions in order to assess qualitative the risk of stock portfolios expanding the portfolio management theory.

This study has some limitations. RobecoSAM and S&P Dow Jones Indices do not provide adequate information regarding its socially responsible assessment methodology. However, transparency for assessment agencies could be an important asset, as it can ensure competitive advantages. Furthermore, the data concern a specific period from 2009 to 2014 concerning mean level for weather data in Europe. Finally, it should pointed out that there the investors of European stock market do no longer assemble in the European geographic location but can come from different places around the world. Further research should be made in order to examine whether environmental variables in relation to global environmental emissions can affect the stock market returns.

Note

1. There is a possibility a part of the parallel increase of gold stock to be attributed to the relationship that those two investments have alternative investments with the interests. This fact will not be further explored, since it does not obstruct the reliable extraction of conclusions as the gold and interest rates variables have been used as control variables.

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