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The Influence of Investors' Mood on the Stock Prices: Evidence from Energy Firms in Warsaw Stock Exchange, Poland

Waldemar Tarczyński [1], Urszula Mentel [2], Grzegorz Mentel [3,*] and Umer Shahzad [4]

1 Department of Sustainable Finance and Capital Markets, Institute of Economics and Finance, University of Szczecin, 71-101 Szczecin, Poland; waldemar.tarczynski@usz.edu.pl
2 Department of Projects Management and Security Policy, Faculty of Management, Rzeszow University of Technology, 35-959 Rzeszow, Poland; u.mentel@prz.edu.pl
3 Department of Quantitative Methods, Faculty of Management, Rzeszow University of Technology, 35-959 Rzeszow, Poland
4 School of Statistics and Applied Mathematics, Anhui University of Finance and Economics, Bengbu 233030, China; umer@aufe.edu.cn
* Correspondence: gmentel@prz.edu.pl; Tel.: +48-608591330

Abstract: The subject of this publication is an analysis of the sentiment of stock exchange investors in terms of making investment decisions in the energy sector of the Polish stock exchange. The investment mood is considered in the context of the possible impact of weather factors on investment decisions. Possible effects are verified in relation to the rates of return and the volume of trading of energy sector entities. The analysis is carried out both in terms of co-integration analyses as well as in econometric terms, in the cross-section of classic OLS models or causality analysis using VAR vector autoregression models. The main purpose of the issues discussed is the problem of indicating (illustrating) the presence or absence of mutual relations between weather factors and the stock market in terms of the methods considered.

Keywords: energy market; stock market; mood; emotions; weather; causality

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1. Introduction

The traditional theory of finance assumes that market participants are rational, and the goal they all pursue is profit maximization, which translates into high market efficiency. However, since the 1980s, many studies have suggested the existence of behavioral aspects of the market that are difficult to explain on the basis of traditional financial theory. The examples include the research conducted by Rajnish Mehr and Edward C. Prescott [1]. They noticed that there was a 6% gap between the return on the S&P 500 index and the risk-free interest rates, which is difficult to explain in a rational way. Of course, there are many more examples of this type. Consequently, this leads to certain market disturbances caused by the lack of complete market information. As suggested by Daniel Kahneman, Jack L. Knetsch and Richard Thaler [2], people are concerned about phenomena, situations that are not described by traditional financial theory.

As a result, contemporary research is mainly related to the analysis of the impact of non-economic factors on financial markets and the mechanisms governing them. Consequently, this translates into an analysis of the behavior of investors as basic market participants. An important element of the analyses carried out in this area is an attempt to determine the possible impact of weather factors on the stock exchanges. According to psychologists, the weather has a significant impact on people's moods and, therefore, on their decision-making processes. This state of affairs may cause changes in, for example, share prices. According to many [3,4], climate change has a significant psychological impact on people, prompting them to behave in certain ways. However, in order for the factors under consideration to influence the decisions made, decision makers must be exposed to their influence [5].

Weather factors and natural biorhythms can be described as non-economic variables in terms of traditional equity pricing models. Differences in these variables have been shown to have a significant impact on people's moods [6]. This is important because, as argued by Loewenstein G. [7], feelings experienced during decision making "often direct behaviors in different directions from those dictated by balancing the long-term costs and benefits of different actions". As capital valuation relates essentially to the risk of future cash flow of capital and net cash flow participation rights of capital, an increasing number of behavioral finance scientists are investigating whether and to what extent mood swings, mainly caused by weather changes, affect or may affect the stock market.

Based on studies that have found a relationship between weather and sentiment, investors tend to price stocks higher (optimistically) when they are in a good mood due to the weather and lower (pessimistic) for negative weather influences. Saunders E.M. [8], who analyzed the relationship between cloudiness in New York and returns on the US stock market, moved towards this direction. In his research, he indicated the importance of cloud cover, and, thus, also insolation, for the percentage changes in share prices. Several years after these studies, Hirshleifer D. and Shumway T. [9], extending their scope, additionally analyzed the impact of rainfall and snow on returns in the Irish Datastream market index. Others, in turn, such as Floros C. [10], checked in their analyses the relationship between the temperature factor and market returns. The possible impact of weather on the variability of Korean KOSPI200 options was analyzed by Shim H. et al. [11] concluding that the volatility tends to increase on windless days. Subsequent research extended the study of the relationship between weather and stock prices to include different weather phenomena (i.e., temperature, precipitation, humidity, wind speed) and different countries [12–15]. These studies additionally confirm the theses that changes in mood caused by a number of weather phenomena are related to changes in stock prices.

There is really a lot of research indicating the significant impact of weather factors on stock market investments or those of slightly less importance in this respect, and it is impossible to list them all here. Nevertheless, a number of them document a strong link between weather patterns and stock index returns, providing indirect evidence of the impact of investor sentiment on asset prices.

Investigating the impact of weather patterns on the actual perception of investors is important, for instance, to establish the credibility of the weather effect from existing evidence. Therefore, in order to assess the significance of the possible impact of weather factors, research in this area should be continued.

Thus, the motivation of the considerations presented in the paper is not so much influenced by the traditional financial theory, but by the emotional reactions caused by the change in weather conditions affecting the performance of the quotations of the energy sector companies. Its content consists of considerations on weather factors as causative elements in the context of the investment sentiment analysis. Therefore, the research hypothesis is based on the assumption that in the case of quotations measured by the rate of return and the trading volume, the above-mentioned meteorological factors are an important causal element. The entire analysis is carried out both in terms of co-integration as well as formal causality in the Granger sense.

2. Emotions–Weather–Market

Psychological literature considers how emotions and moods influence people's decision making. People who are in a good mood seem to be more optimistic about their own choices. A very strong effect in this regard is that people in a positive mood have many kinds of positive assessments, such as satisfaction with life, with past events, with people or even consumer products [16,17]. There is a mood-compatible effect in which people with a bad or good mood tend to find that negative or positive material, respectively, is more accessible or more pronounced [18,19]. More importantly, it is stated that mood most strongly influences relatively abstract judgments about which no specific information is available [20,21].

Research also shows that in a good mood, we are more likely to use simplified heuristics to aid our decision-making process [22,23]. There is an ongoing debate as to whether this type of use of heuristics reflects possible cognitive deficiencies associated with good mood, or is it more the effective use of measures to simplify complex data.

Some of the studies conducted so far indicate that a bad mood induces investors to undertake analytical activities to a large extent, while a good mood refers to less critical methods of information processing [24–26]. As reported, for example, by Bless H. et al. [27] good moods result in greater reliance on information about the category and, thus, simplify stereotypes. Thus, in their view, good moods make people rely more on "pre-existing structures of knowledge", which does not necessarily result in a general decline in motivation or the ability to think effectively. Positive moods also have their advantages. In a good mood we often tend to create unusual associations, we become better at creative problem solving, and we show much greater mental flexibility. Moreover, being in a good mood, we tend to work out more detailed tasks with neutral/positive (at least not negative) stimulus material [23].

Emotions influence assessments of both the favorable outlook for the future [28,29] and risk assessments [30,31]. The direction of the influence of mood on the perception of risk is a complex process depending primarily on the task itself and the situation in which we are.

An important thread of emotions or moods (the so-called affective states theory) is that they provide individuals with information about the environment [24,32]. A significant amount of research confirms the informative role of the effect, as in [24,33] and [20]. The feelings-based decision-making procedure was named by Slovic P. et al. [31] as "Affect Heuristics".

We very often attribute our feelings to the wrong source, leading to wrong judgments. An example of this is that people are happier on sunny days and are less positive on cloudy days. The influence of sunlight on their perception of happiness is much weaker when we ask about the weather [34]. Presumably, this is due to the fact that they attribute the good mood to the sun and not to long-term considerations.

Psychology has long documented the relationship between weather and behavior, focusing its research mainly on the effect of insolation. The vast majority of analyses suggest that we feel better when we are directly exposed to sunlight. Therefore, we are more optimistic on sunny days and more likely to buy stocks. Thus, a positive correlation is very often seen between insolation and rates of return. Moreover, information (as in the weather forecast) that a particular day will be sunny should not trigger an immediate and full positive response from stock prices. Only the exposure to sunlight itself should cause the price movement of financial instruments. However, it should be remembered that insolation in one specific place is not representative of weather conditions in the entire economy. It is also important that sunlight is a transient variable. The amount of the expected insolation today is not strongly correlated with the amount that will occur in a few days, weeks, or months.

As was shown much earlier, there is evidence that the sun influences markets. The confirmation of this can be found in the research of Saunders E.M. Jr. [8], which was mentioned in the introduction. In his research, apart from showing a negative dependence between cloud cover and returns from the New York Stock Exchange, he also proves that this correlation is resistant to various stock index selections and regression specifications.

As one can see, bad weather can complicate the market situation, communication or other activities. Hence, it seems reasonable to analyze the possible impact of other weather factors on the stock market as not only the right amount of sun can cause significant changes in the stock markets. There are a number of studies showing the importance of other weather determinants, such as temperature or atmospheric pressure (Table 1). Therefore, further research in this area may turn out to be extremely interesting and possible observations will give a new look at some dependencies.

Table 1. Review of literature research on the emotions–weather–stock market relationship.

Author (Authors)	Conclusions
Howarth, E. and Hoffman, M.S [6]	They verified the impact of eight weather variables on ten mood measures. As a result of the research, they indicated that meteorological factors such as humidity, temperature and sunshine have a significant influence on the mood. In their opinion, the duration of sunlight was associated with higher scores in terms of optimism, while high levels of humidity with lower scores in terms of concentration, and a possible increase in temperature with lower scores in terms of anxiety and skepticism.
Loughran, T. and Schultz, P. [35]	They showed that cloudy days have little effect on a company's trading volume apart from extreme weather conditions, which can be attributed to other factors that may be unrelated to mood.
Saunders, E.M. [8]	He was the first to investigate the relationship between New York City weather and returns on the New York Stock Exchange (NYSE). As a result of the analyses, he drew the attention of economists to the possible impact of weather changes on the returns on the stock exchange. It showed a significant correlation between cloud cover and percentage changes in stock prices.
Kamstra, M.J., Kramer, L.A., and Levi, M.D. [36]	In their opinion, in autumn and winter, market profits are on average lower than in spring and summer. They characterized it as the beginning of a seasonal affective disorder, i.e., a depression associated with a decline in daylight. This phenomenon is particularly strong in the Scandinavian countries. According to them, due to the lack of sun, people become more depressed, which lowers the general good mood and the willingness to invest. If investors had realized this sooner, they could have prevented irrational decisions.
Keller, M.C., Fredrickson, B.L., Ybarra, O., Côté, S., Johnson, K., Mikels, J., Conway, A., Wager, T. [5]	They found that a pleasant temperature and atmospheric pressure are associated with better mood. Trading activity correlates strongly with the skills, personalities and moods of traders.
Hirshleifer, D. and Shumway, T. [9]	They investigated whether the sun can lead to a good mood, which would additionally translate into positive plot twists. In their research, they proved that there was a significant positive correlation between insolation and the rates of return. They found that investors could benefit from knowledge about their mood at any given time. Thanks to this, they can avoid mistakes caused by an unsuitable mood.
Kang, S.H., Jiang, Z., Lee, Y. and Yoon, S.M. [37]	They proved that weather conditions had an impact on type A funds and not on type B funds. In the period after market opening, only type B funds are heavily influenced by weather conditions, while in the profitability of both type A and type B funds, the weather has led to volatility; Shanghai Stock Exchange, 1996–2007.
Dowling, M. and Brian, M.L. [38]	A positive correlation was found between the results of the moisture analysis and the performance indicators in relation to slightly different opinions in this regard in the literature. The authors found the reasons for this different result of the analysis in the unusual weather conditions prevailing in Ireland; Irish Stock Exchange; 1988–2001.

Table 1. *Cont.*

Author (Authors)	Conclusions
Symeonidis, L., Daskalakis, G. and Markellos, R.N. [39]	According to the authors, cloudy days and extending and reducing night hours have a negative impact on the volatility of the stock markets. They state that the performance of the S&P index tends to have a negative effect on cloudy days; 26 international exchanges, 1982–1997.
Goetzman, W.N. and Zhu, N. [40]	On rainy days, market participants tend to finish trading earlier, according to the team. They note the effect of cloudy days on both liquidity and volatility; 2005.
Loughran, T. I Schultz, P. [35]	They addressed the issue of low volume. They saw the reasons for this condition in the difficulties in getting to work on days with snowstorms; 2004.
Hong, H., Kubik, J. and Stein, J. [41]	They argued that investors are more sociable and open to communication with each other on sunny days, which may explain the high volatility currently observed in the stock market; 2004
Vlady, S., Tufan, E. and Hamarat, B. [42]	They showed that there was a significant change in profitability on the Australian Stock Exchange on rainy days; Australia 1992–2006.
Kang, S.H., Jiang, Z. and Yoon, S.M. [37]	They stated that the Hong Kong Stock Exchange was not vulnerable to extreme weather conditions; Hong Kong Stock Exchange 1999–2008.
Worthington, A. [43]	He examined the effects of meteorological conditions such as evaporation, relative humidity, high and low temperatures, hours of sunshine, and the direction and speed of a severe storm on the Australian stock price index and found no impact on market earnings; 1958–2005.
Keef, S.P. and Roush, M.L. [44]	They observed that off-season temperatures had a stronger and negative impact on stocks compared to normal temperature parameters. On the other hand, the speed of the storm and the number of cloudy days did not have such an effect; 1992–2003
Floros, C. [10]	The impact of daily temperatures on the stock markets in Austria, Belgium, France, Greece and the UK was studied at different times and a negative correlation was identified between daily temperature parameters and the yields of the stock markets in Austria, Belgium and France. In turn, in the case of Greece and the UK, this correlation was positive but not statistically strong. In another study, Floros (2011) showed that weather conditions had a negative impact on market profitability, using data from the Lisbon Stock Exchange (PSI-20) in 1995–2007. The researcher also found that safety indicators were positive in January, mainly due to the low temperatures, which lead to aggressive risk taking; Austria, Belgium, France, Greece and UK Equity Markets, 2008.
Chang, T., Nieh, C.C., Yang, M.J. and Yang, T.Y. [14]	They examined the effect of weather conditions on earnings, against factors such as temperature, humidity and cloudy days. According to the research results, the following had a significant influence in this case: temperature and cloudy days; Taiwan Stock Exchange, July–October 2006.
Wang, Y., Lin, C.T. and Lin, J.D. [45]	They did not identify the impact of rainy days on market profits but showed that sunny days and temperature had a significant impact; Taiwan Stock Exchange, 2001–2007.
Tuna, G. [46]	He examined the effect of humidity and cloudy days on the profitability of the Istanbul Stock Index and found no effect; Istanbul Stock Exchange, 1987–2006.

Table 1. *Cont.*

Author (Authors)	Conclusions
Silva, P. and Almeida, L. [47]	Thanks to their analysis, a correlation between low temperature and high efficiency was identified; Portuguese Stock Exchange, 2000–2009.
Zadorozhna, O. [48]	Correlations between profitability indices, individual safety indices, commercial value, and weather conditions (storm, cloudy days, pressure, rain and humidity) at different times were examined. While correlations were identified in some countries, they were found to be low; 13 countries of Central and Eastern Europe, 2009

3. Materials and Methods

The research sample in these analyses are energy companies listed on the Warsaw Stock Exchange in 2015–2021. Possible causes of weather factors were analyzed in relation to the rates of return and the value of their trading volumes. The meteorological data were taken from the Institute of Meteorology and Water Management and concerned such weather factors as temperature, daily rainfall, sunshine duration, rainfall duration, average daily cloud cover, average daily wind speed, average relative humidity and average daily pressure at sea level. The location of the weather station was consistent with the seat of a given company listed. The research was limited to the Polish capital market due to the fact that there are no potential analyses of this type for the countries of Central and Eastern Europe. The cases of world studies concern either Asian markets, the American market or European countries with strong economies and well-functioning financial markets.

The analysis of the possible impact of meteorological factors on the stock market of energy companies should begin with the study of the phenomenon of co-integration. In this case, the correlation study did not bring satisfactory results as it did not talk about the long-term interdependence of the series. Thus, the correlation coefficients were not a suitable measure to rate the effect in question. Importantly, the co-integration effect may also occur when a low correlation is identified.

The most common approaches used to test the phenomenon are the Engle–Granger method [49] and the Johansen method [50]. The authors of the first proposed a relatively simple approach to the estimation of the degree of co-integration, namely the use of least squares regression and its application to the studied series. Then they proposed to perform a stationarity test (unit root test) for the residuals of the estimated regression model. However, both presented approaches are applicable in the case of non-stationary time series.

Therefore, initially, the stationarity of time series is analyzed using the most commonly used tests in this area, i.e., ADF (Augmented Dickey–Fuller test) and KPSS (Kwiatkowski, Phillips, Schmidt and Shine test) [51]. In the former, the null hypothesis is that the series is non-stationary. Thus, the alternative hypothesis is its negation. In the case of the KPSS test, we deal with the reverse system of hypotheses.

The use of these tests is also recommended by Hamulczuk, Grudkowska, Gędek, Klimkowski and Stańko [52] as the so-called confirming analysis. According to this, one deals with "strong" stationarity when it is found by both tests. In another variant, we talk about the lack of stationarity of the time series.

The possible finding of stationarity (or lack thereof) for dependent and independent variables generates two approaches to the causality analysis. In the case of a pair of doubly stationary variables, it is used in the classic OLS regression analysis (ordinary least squares). This approach allows the study of two-dimensional relationships between variables. Thus, this method is limited to model estimation

$$y_t = \alpha_0 + \alpha_1 x_{ti} + \xi_t, \quad (1)$$

where x_{ti} is the independent variable (regressor) for the i-th measurement.

In turn, in the variant when one of the variables analyzed or both are non-stationary, the best approach is VAR modeling (vector autoregressive model). In this case, assuming the same delays for both variables k, a test of the total significance of the delays of a given variable is applied in the equation explaining the second variable

$$y_t = \alpha_{10} + \sum_{j=1}^{k} \alpha_{1j} y_{t-j} + \sum_{j=1}^{k} \beta_{1j} x_{t-j} + \varepsilon_{1t} \quad (2)$$

$$x_t = \alpha_{20} + \sum_{j=1}^{k} \alpha_{2j} y_{t-j} + \sum_{j=1}^{k} \beta_{2j} x_{t-j} + \varepsilon_{2t} \quad (3)$$

The Akaike (AIC), Schwartz–Bayesian (BIC) or Hannan–Quinn (HQC) criteria are most often used when selecting lags. In this case, it is worth emphasizing that a one-way analysis showing the impact of meteorological variables on the stock market is substantively justified. The analysis in the reverse direction is pointless in terms of possible inference.

4. Results

The aforementioned analysis of the occurrence of the unit root in the context of the dependent variables (rate of return, trading volume) is illustrated by the results of Table 2.

Table 2. Results of stationarity tests of the analyzed stock market time series.

Instrument	ADF Test				KPSS Test	
	Delay	Test Statistic	p	Autocorrelation of First-Order Residuals	Test Statistic	Critical Value α = 5% and α = 1%
				Będzin		
rate of return	0	−45.1744	0.0001	−0.015	0.267245	0.462/0.743
trading volume	0	−26.9194	1.220×10^{-44}	−0.048	1.551350	
				Enea		
rate of return	0	−35.7359	1.209×10^{-24}	0.001	0.033697	0.462/0.743
trading volume	0	−29.3397	4.378×10^{-41}	−0.047	1.593400	
				Energa		
rate of return	0	−38.5467	4.595×10^{-16}	0.000	0.167231	0.462/0.743
trading volume	0	−24.3335	2.797×10^{-46}	−0.077	15.80410	
				Kogeneracja		
rate of return	0	−43.3854	0.0001	0.000	0.244913	0.462/0.743
trading volume	0	−32.4472	4.448×10^{-46}	−0.014	0.622624	
				ML System		
rate of return	0	−23.4542	1.643×10^{-39}	0.008	0.227393	0.462/0.743
trading volume	0	−11.0043	5.512×10^{-21}	−0.132	17.56750	
				PGE		
rate of return	0	−35.2625	4.451×10^{-26}	0.000	0.033137	0.462/0.743
trading volume	0	−32.7535	2.832×10^{-33}	−0.020	0.711201	
				Polenergia		
rate of return	0	−37.1847	3.350×10^{-20}	0.002	0.512327	0.462/0.743
trading volume	0	−32.4881	5.693×10^{-34}	−0.017	0.564129	
				Tauron		
rate of return	0	−34.277	5.311×10^{-29}	0.002	0.197904	0.462/0.743
trading volume	0	−22.4762	5.342×10^{-46}	−0.066	6.307180	
				ZE PAK		
rate of return	0	−39.7838	1.823×10^{-12}	0.000	0.220253	0.462/0.743
trading volume	0	−31.2886	5.690×10^{-37}	−0.020	1.216120	

The analysis of the values of individual test statistics allows the conclusion that the rate of return of the instruments considered is a stationary value in the "strong" sense. On the other hand, slightly different results are obtained when verifying the time series in the form of the trading volume. They are not homogeneous for both the tests. The KPSS test clearly excludes the stationary effect in this case. With a critical value of 0.743 for $\alpha = 0.01$ in three cases, Kogeneracja, PGE and Polenergia, one could assume that the series is stationary. However, if we take the classical significance level of 0.05 (critical value 0.462), the occurrence of the unit root is common. Therefore, it is assumed that the trading volume is a non-stationary series. A possible increase in the number of delays does not significantly improve the value of the KPSS test statistics.

A similar analysis for weather variables requires a breakdown into individual weather stations (depending on the location of a given listed company) across the analyzed meteorological factors (Table 3).

Table 3. Results of stationarity tests of the analyzed weather time series.

Instrument	ADF Test				KPSS Test	
	Delay	Test Statistic	p	Autocorrelation of First-Order Residuals	Test Statistic	Critical Value $\alpha = 5\%$ and $\alpha = 1\%$
			Gdańsk			
average daily temperature	0	−6.65853	3.412×10^{-09}	−0.072	1.770400	0.462/0.743
	4	−4.07270	0.001076	−0.005	0.383428	
daily sum of precipitation	0	−34.7505	1.292×10^{-27}	−0.003	0.163824	
insolation	0	−19.4848	5.023×10^{-43}	−0.153	0.640190	
	1	−13.3531	4.477×10^{-30}	−0.030	0.401188	
duration of rainfall	0	−29.8175	3.587×10^{-40}	−0.013	0.224766	
mean daily overall cloudiness	0	−21.8798	1.193×10^{-45}	−0.030	0.328337	
average daily wind speed	0	−25.6320	9.492×10^{-46}	−0.008	0.175068	
average daily relative humidity	0	−19.9723	1.030×10^{-43}	−0.080	1.547060	
	6	−8.10506	2.454×10^{-18}	−0.003	0.428725	
mean daily sea level pressure	0	−36.5630	4.060×10^{-22}	−0.001	0.082570	
			Katowice			
average daily temperature	0	−7.13979	1.901×10^{-10}	−0.014	1.205010	0.462/0.743
	2	−5.85133	2.707×10^{-07}	−0.019	0.426140	
daily sum of precipitation	0	−29.7677	2.896×10^{-40}	0.011	0.251548	
insolation	0	−21.4800	2.414×10^{-45}	−0.090	0.562847	
	1	−15.8271	1.435×10^{-37}	−0.027	0.368371	
duration of rainfall	0	−29.1066	1.678×10^{-41}	−0.011	0.124021	
mean daily overall cloudiness	0	−23.4955	2.661×10^{-46}	−0.001	0.395364	
average daily wind speed	0	−23.9630	2.561×10^{-46}	−0.033	0.334759	
average daily relative humidity	0	−18.0161	1.659×10^{-40}	−0.091	0.953594	
	2	−11.5877	2.313×10^{-24}	−0.016	0.436156	

Table 3. *Cont.*

Instrument	ADF Test				KPSS Test	
	Delay	**Test Statistic**	***p***	**Autocorrelation of First-Order Residuals**	**Test Statistic**	**Critical Value α = 5% and α = 1%**
mean daily sea level pressure	0	−37.7039	1.303×10^{-18}	−0.000	0.058875	
				Koło		
average daily temperature	0	−8.67207	9.310×10^{-15}	−0.072	1.414050	0.462/0.743
	3	−5.65398	7.779×10^{-07}	−0.013	0.394922	
daily sum of precipitation	0	−34.2158	3.527×10^{-29}	−0.010	0.382024	
insolation	0	−19.3793	7.278×10^{-43}	−0.111	1.743280	
	6	−6.88035	6.935×10^{-10}	−0.007	0.439224	
duration of rainfall *	-	-	-	-	-	
mean daily overall cloudiness *	-	-	-	-	-	
average daily wind speed	0	−24.3227	2.808×10^{-46}	0.004	2.583170	
average daily relative humidity	0	−20.5403	2.046×10^{-44}	−0.088	0.723716	
	2	−13.4426	2.324×10^{-30}	−0.006	0.360950	
mean daily sea level pressure	0	−24.4785	3.020×10^{-46}	0.018	0.237739	
				Poznań		
average daily temperature	0	−6.65828	3.418×10^{-09}	−0.072	1.768160	0.462/0.743
	4	−4.07820	0.001053	−0.005	0.382957	
daily sum of precipitation	0	−34.7403	1.222×10^{-27}	−0.003	0.163108	
insolation	0	−19.4890	4.976×10^{-43}	−0.153	0.637882	
	1	−13.3568	4.357×10^{-30}	−0.031	0.399831	
duration of rainfall	0	−30.5269	1.066×10^{-38}	−0.010	0.264330	
mean daily overall cloudiness	0	−23.0241	3.292×10^{-46}	−0.023	0.436696	
average daily wind speed	0	−25.5923	9.047×10^{-46}	−0.008	0.174762	
average daily relative humidity	0	−19.9831	1.002×10^{-43}	−0.080	1.534470	
	6	−8.11923	2.229×10^{-13}	−0.003	0.425760	
mean daily sea level pressure	0	−36.5527	3.827×10^{-22}	−0.001	0.082906	

Table 3. *Cont.*

Instrument	ADF Test				KPSS Test	
	Delay	**Test Statistic**	***p***	**Autocorrelation of First-Order Residuals**	**Test Statistic**	**Critical Value α = 5% and α = 1%**
			Rzeszów			
average daily temperature	0	−4.90820	3.714×10^{-05}	−0.086	2.201240	0.462/0.743
	5	−2.44556	0.1293	−0.003	0.410210	
daily sum of precipitation	0	−20.6487	1.856×10^{-39}	0.006	0.367610	
insolation *	-	-	-	-	-	
duration of rainfall	0	−19.7419	7.614×10^{-39}	−0.001	0.484120	
	1	−19.7419	7.614×10^{-39}	−0.001	0.393551	
mean daily overall cloudiness	0	−13.9563	6.826×10^{-29}	0.005	0.465584	
	1	−13.9563	6.826×10^{-29}	0.005	0.305371	
average daily wind speed	0	−13.9629	6.574×10^{-29}	−0.026	0.793649	
	2	−13.9629	6.574×10^{-29}	−0.026	0.416820	
average daily relative humidity	0	−10.5698	9.411×10^{-20}	−0.057	1.241470	
	3	−6.3716	1.453×10^{-08}	−0.010	0.442910	
mean daily sea level pressure	0	−10.5538	1.045×10^{-19}	0.123	0.253807	
			Warszawa			
average daily temperature	0	−6.76346	1.839×10^{-09}	−0.011	1.511100	0.462/0.743
	3	−4.81845	4.731×10^{-05}	−0.011	0.405907	
daily sum of precipitation	0	−32.9775	1.137×10^{-32}	−0.015	0.181474	
insolation	0	−19.1301	1.774×10^{-42}	−0.108	1.491150	
	5	−8.64524	5.879×10^{-15}	−0.003	0.422109	
duration of rainfall	0	−28.8845	6.807×10^{-42}	−0.031	0.364404	
mean daily overall cloudiness	0	−21.0338	6.075×10^{-45}	−0.042	0.449521	
average daily wind speed	0	−26.2856	2.938×10^{-45}	0.016	0.207873	
average daily relative humidity	0	−15.1308	7.267×10^{-34}	−0.096	0.971395	
	2	−12.3351	8.475×10^{-27}	−0.022	0.560530	
mean daily sea level pressure	0	−9.91117	6.393×10^{-19}	−0.010	0.408821	
	1	−16.5259	2.494×10^{-37}	0.127	0.604866	

Table 3. *Cont.*

Instrument	ADF Test				KPSS Test	
	Delay	Test Statistic	p	Autocorrelation of First-Order Residuals	Test Statistic	Critical Value α = 5% and α = 1%
				Wrocław		
average daily temperature	0	−7.19858	1.324×10^{-10}	−0.053	1.269010	0.462/0.743
	2	−5.60812	9.898×10^{-07}	−0.017	0.449098	
daily sum of precipitation	0	−34.2791	5.387×10^{-29}	−0.001	0.244142	
insolation	0	−20.6760	1.440×10^{-44}	−0.083	0.819525	
	2	−12.5505	1.695×10^{-27}	−0.017	0.406633	
duration of rainfall	0	−31.9303	2.108×10^{-35}	−0.007	0.146045	
mean daily overall cloudiness	0	−24.2092	2.697×10^{-46}	−0.004	0.726690	
	2	−16.4118	3.403×10^{-39}	−0.005	0.423752	
average daily wind speed	0	−23.7511	2.549×10^{-46}	0.005	0.425851	
average daily relative humidity	0	−17.8176	4.064×10^{-40}	−0.079	1.371260	
	4	−9.09078	2.496×10^{-16}	−0.007	0.434634	
mean daily sea level pressure	0	−16.6966	1.012×10^{-37}	0.119	0.880180	
	2	−15.7554	2.294×10^{-37}	0.001	0.407097	

* no data for a given weather station.

The data presented in the table above confirm to a large extent the non-stationarity of weather time series. Of course, there are cases of stationarity but they mainly relate to variables such as the daily sum of precipitation or the duration of rainfall. This is in some ways due to the nature of the data. One could assume some kind of "dichotomy" here. In ranks of this type, there are many observations when we deal with the lack of a phenomenon, hence, many values are just null.

Therefore, by making a distinction between stationary and non-stationary variables, one can perform the causality analysis in accordance with the principles presented a little earlier. Thus, in the case of a pair of double-stationary variables (explained and explanatory), the analysis of the influence of the weather factor on the market variable is carried out using classical econometric modeling (OLS). The results of this type of analysis are presented in Table 4.

Modeling, by means of regression equations, presented in Table 3 does not indicate the existence of a cause and effect relationship between the rate of return and the weather instrument of a stationary nature. However, it should be remembered that this type of analysis indicates linear relationships but nonlinear relationships may take place here as well. Since the presented analysis is based on a direct relationship at the same moment, it would be worth considering whether it is better to carry out similar tests but in relation to the shifted values of a given weather factor. After all, signals from a given meteorological regressor may have consequences on the next day, and, thus, affect the behavior of rates of return with a certain delay. There is little logical justification for examining a larger scale of delays than one. Hence, Table 5 presents the results of OLS estimation for the rates of return of the companies in question depending on the one-period lag of the stationary weather factor.

Table 4. OLS estimation results for the rate of return depending on the stationary weather factor along with testing the properties of the residual component.

	Testing the Significance of the Parameters		**Testing the Correctness of the Model Form**		**Normality Test**		**Autocorrelation Analysis**		**Heteroscedasticity Analysis**	
	***t*-Student Test**		**Nonlinearity Test for Squares**		**Doornik–Hansen Test**		**Durbin–Watson Test**		**Breusch–Pagan Test**	
Independent Variable	***t* Statistic**	***p***	**TR^2 Statistic**	***p***	**chi-Square Statistic (2)**	***p***	**d Statistic**	***p***	**LM Statistic**	***p***
Energa—Gdańsk										
daily sum of precipitation	0.4155	0.6778	0.538936	0.46287	989.230	0.0000	1.99345	0.44892	0.489294	0.48424
duration of rainfall	0.1203	0.9043	0.031045	0.86014	987.966	0.0000	1.99303	0.45175	0.581807	0.44560
mean daily overall cloudiness	0.2338	0.8152	0.160692	0.68852	988.727	0.0000	1.99356	0.44737	0.083981	0.77197
average daily wind speed	−0.2360	0.8135	0.401483	0.52632	987.547	0.0000	1.99280	0.44222	0.484559	0.48636
mean daily sea level pressure	1.0570	0.2908	0.048854	0.82507	990.031	0.0000	1.99468	0.46791	0.237134	0.62628
Tauron—Katowice										
daily sum of precipitation	−1.1410	0.2542	0.703611	0.40157	464.169	0.0000	1.76016	$1.7 \cdot 10^{-06}$	4.685670	0.03042
duration of rainfall	−0.0890	0.9291	0.062104	0.80320	464.985	0.0000	1.75960	$1.5 \cdot 10^{-06}$	0.437466	0.50835
mean daily overall cloudiness	−0.4410	0.6593	0.095458	0.75735	465.626	0.0000	1.75837	$1.3 \cdot 10^{-06}$	0.325955	0.56805
average daily wind speed	−0.5350	0.5927	0.186623	0.66574	460.212	0.0000	1.76062	$1.7 \cdot 10^{-06}$	1.531245	0.21593
mean daily sea level pressure	−0.1077	0.9143	0.293223	0.58816	465.123	0.0000	1.75907	$1.5 \cdot 10^{-06}$	0.126153	0.72245
ZE Pątnów—Koło										
daily sum of precipitation	−0.4699	0.6385	6.173630	0.01297	1288.18	0.0000	2.05608	0.86340	0.112137	0.73772
average daily wind speed	−0.4356	0.6632	0.097398	0.75498	1289.83	0.0000	2.05659	0.86580	1.244608	0.26459
mean daily sea level pressure	−0.0828	0.9340	1.345360	0.24609	1289.82	0.0000	2.05640	0.86053	3.586737	0.05824
Będzin—Poznań										
daily sum of precipitation	−0.7680	0.4426	0.218907	0.63987	1463.51	0.0000	2.30515	1.00000	7.552060	0.00599
duration of rainfall	0.7455	0.4561	1.032730	0.30952	1460.58	0.0000	2.30857	1.00000	16.61387	0.00005
mean daily overall cloudiness	0.7873	0.4312	0.112266	0.73758	1459.29	0.0000	2.30795	1.00000	9.245279	0.00236
average daily wind speed	0.0740	0.9410	0.070044	0.79127	1461.21	0.0000	2.30783	1.00000	8.849761	0.00293
mean daily sea level pressure	−0.2565	0.7976	0.468392	0.49373	1461.11	0.0000	2.30805	1.00000	0.245686	0.62013
Enea—Poznań										
daily sum of precipitation	1.1510	0.2498	1.031410	0.30983	423.939	0.0000	1.84101	0.00103	3.028158	0.08183
duration of rainfall	0.1389	0.8896	0.940882	0.33205	421.976	0.0000	1.84188	0.00108	3.063442	0.08007
mean daily overall cloudiness	−0.7836	0.4334	0.881376	0.34783	420.630	0.0000	1.84282	0.00112	1.085435	0.29749
average daily wind speed	0.4623	0.6440	0.242990	0.62206	427.272	0.0000	1.84247	0.00109	1.143693	0.28487
mean daily sea level pressure	1.6950	0.0903	1.948870	0.16271	407.771	0.0000	1.84513	0.00127	3.561509	0.05913
ML System—Rzeszów										
daily sum of precipitation	0.2710	0.7865	0.318978	0.57222	564.198	0.0000	1.87726	0.06118	0.683641	0.40834
mean daily sea level pressure	1.0790	0.2811	2.873300	0.09006	560.000	0.0000	1.88292	0.06773	2.398701	0.12144
PGE—Warszawa										
daily sum of precipitation	0.4121	0.6803	0.946749	0.33055	1061.63	0.0000	1.81504	0.00017	7.425154	0.00643
duration of rainfall	−1.2760	0.2022	0.173579	0.67695	1068.89	0.0000	1.81437	0.00016	1.945605	0.16306
mean daily overall cloudiness	−0.2345	0.8147	1.143880	0.28483	1067.41	0.0000	1.81533	0.00016	2.888960	0.08919
average daily wind speed	1.2950	0.1955	0.207160	0.64899	1081.99	0.0000	1.81814	0.00021	2.970178	0.08481

Table 4. *Cont.*

	Testing the Significance of the Parameters		Testing the Correctness of the Model Form		Normality Test		Autocorrelation Analysis		Heteroscedasticity Analysis	
	t-Student Test		Nonlinearity Test for Squares		Doornik–Hansen Test		Durbin–Watson Test		Breusch–Pagan Test	
Independent Variable	***t* Statistic**	***p***	**TR^2 Statistic**	***p***	**chi-Square Statistic (2)**	***p***	**d Statistic**	***p***	**LM Statistic**	***p***
Polenergia—Warszawa										
daily sum of precipitation	0.7020	0.4828	1.732770	0.18806	1362.74	0.0000	1.92028	0.06106	0.001298	0.97126
duration of rainfall	−0.9413	0.3467	2.126270	0.14479	1359.18	0.0000	1.92113	0.06271	4.954596	0.02602
mean daily overall cloudiness	0.9738	0.3303	0.302700	0.58219	1368.22	0.0000	1.92125	0.06305	0.080192	0.77704
average daily wind speed	0.3699	0.7115	4.804840	0.02838	1364.89	0.0000	1.92187	0.06516	1.637421	0.20068
Kogeneracja—Wrocław										
daily sum of precipitation	2.2120	0.0271	0.443257	0.50556	1177.49	0.0000	2.22979	0.99999	1.820133	0.17729
duration of rainfall	0.6508	0.5153	0.005482	0.94098	1179.43	0.0000	2.22825	0.99999	1.784164	0.18164
average daily wind speed	0.0730	0.9418	1.069210	0.30112	1179.77	0.0000	2.22818	0.99999	8.293205	0.00398

Table 5. OLS estimation results for the rate of return depending on the one-period stationary lag of the weather factor together with testing the properties of the residual component.

	Testing the Significance of the Parameters		Testing the Correctness of the Model Form		Normality Test		Autocorrelation Analysis		Heteroscedasticity Analysis	
	t-Student Test		Nonlinearity Test for Squares		Doornik–Hansen Test		Durbin–Watson Test		Breusch–Pagan Test	
Independent Variable	***t* Statistic**	***p***	**TR^2 Statistic**	***p***	**chi-Square Statistic (2)**	***p***	**d Statistic**	***p***	**LM Statistic**	***p***
Energa—Gdańsk										
daily sum of precipitation	−0.2857	0.7751	0.449465	0.50259	984.144	0.0000	1.99164	0.43788	0.221894	0.63760
duration of rainfall	−0.5902	0.5551	0.211027	0.64596	980.543	0.0000	1.99148	0.43221	1.036973	0.30853
mean daily overall cloudiness	1.6430	0.1006	0.002522	0.95994	990.410	0.0000	1.99091	0.43538	7.889667	0.00497
average daily wind speed	0.8886	0.3744	0.012163	0.91218	976.356	0.0000	1.99326	0.44422	0.566568	0.45163
mean daily sea level pressure	0.4858	0.6272	0.034527	0.85259	986.594	0.0000	1.99338	0.44953	0.660328	0.41644
Tauron—Katowice										
daily sum of precipitation	−0.8023	0.4225	0.753009	0.38553	462.422	0.0000	1.76025	$1.7 \cdot 10^{-06}$	12.86008	0.00034
duration of rainfall	−0.1507	0.8802	2.076000	0.14963	463.182	0.0000	1.75928	$1.5 \cdot 10^{-06}$	7.571485	0.00593
mean daily overall cloudiness	1.2590	0.2083	2.394450	0.12177	464.987	0.0000	1.75920	$1.4 \cdot 10^{-06}$	8.975215	0.00274
average daily wind speed	−1.2620	0.2070	0.001042	0.97425	454.976	0.0000	1.75933	$1.4 \cdot 10^{-06}$	1.963433	0.16115
mean daily sea level pressure	2.2650	0.0236	0.305251	0.58061	451.535	0.0000	1.76494	$2.6 \cdot 10^{-06}$	3.708909	0.05412

Table 5. *Cont.*

	Testing the Significance of the Parameters		Testing the Correctness of the Model Form		Normality Test		Autocorrelation Analysis		Heteroscedasticity Analysis	
	t-Student Test		Nonlinearity Test for Squares		Doornik–Hansen Test		Durbin–Watson Test		Breusch–Pagan Test	
Independent Variable	***t* Statistic**	***p***	**TR^2 Statistic**	***p***	**chi-Square Statistic (2)**	***p***	**d Statistic**	***p***	**LM Statistic**	***p***
ZE Pątnów—Koło										
daily sum of precipitation	0.2622	0.7932	5.117830	0.02368	1291.79	0.0000	2.05552	0.85831	5.324408	0.02103
average daily wind speed	−0.0807	0.9357	1.055140	0.30433	1288.13	0.0000	2.05631	0.86044	0.603302	0.43732
mean daily sea level pressure	0.3064	0.7593	0.046081	0.83003	1286.21	0.0000	2.05603	0.86063	0.322038	0.57039
Będzin—Poznań										
daily sum of precipitation	1.706	0.0883	5.49766	0.01904	1444.07	0.00000	2.30599	1.00000	1.987446	0.15861
duration of rainfall	0.5572	0.5774	0.252543	0.61529	1450.39	0.0000	2.30707	1.00000	0.030353	0.86169
mean daily overall cloudiness	0.0598	0.9523	0.361593	0.54762	1458.44	0.0000	2.30771	1.00000	17.95416	0.00002
average daily wind speed	0.0740	0.9410	0.070045	0.79127	1461.21	0.0000	2.30783	1.00000	8.849761	0.00293
mean daily sea level pressure	−0.2531	0.8002	0.470542	0.49274	1458.93	0.0000	1458.93	1.00000	0.110635	0.73942
Enea—Poznań										
daily sum of precipitation	1.3080	0.1910	0.887971	0.34603	424.912	0.0000	1.84457	0.00130	0.478429	0.48914
duration of rainfall	0.9757	0.3294	0.676544	0.41078	424.901	0.0000	1.84248	0.00114	1.699012	0.19242
mean daily overall cloudiness	−0.5893	0.5558	3.017120	0.08239	421.705	0.0000	1.84184	0.00106	0.770240	0.38014
average daily wind speed	1.7110	0.0872	0.116634	0.73271	436.200	0.0000	1.84156	0.00106	3.902850	0.04820
mean daily sea level pressure	−0.2861	0.7748	2.381920	0.12275	422.420	0.0000	1.84127	0.00101	1.544707	0.21392
ML System—Rzeszów										
daily sum of precipitation	1.3390	0.1810	0.029227	0.86426	570.439	0.0000	1.87622	0.06036	1.226202	0.26815
mean daily sea level pressure	0.7083	0.4791	0.205789	0.65009	556.432	0.0000	1.87715	0.05981	13.06857	0.00030
PGE—Warszawa										
daily sum of precipitation	−0.5808	0.5614	1.302680	0.25372	1065.26	0.0000	1.81608	0.00018	0.347363	0.55561
duration of rainfall	0.9768	0.3288	2.234830	0.13493	1073.48	0.0000	1.81185	0.00013	3.504961	0.06118
mean daily overall cloudiness	1.0510	0.2935	2.340300	0.12606	1063.41	0.0000	1.81333	0.00015	0.961013	0.32693
average daily wind speed	1.1170	0.2641	3.389190	0.06563	1082.99	0.0000	1.81813	0.00020	0.491088	0.48344
Polenergia—Warszawa										
daily sum of precipitation	−0.3721	0.7099	0.730131	0.39284	1361.23	0.0000	1.92104	0.06799	0.055163	0.81431
duration of rainfall	−0.4245	0.6712	0.097101	0.75534	1357.61	0.0000	1.92176	0.06443	2.794717	0.09458
mean daily overall cloudiness	0.0946	0.9801	0.228107	0.63293	1360.39	0.0000	1.92137	0.06474	0.076028	0.78276
average daily wind speed	1.4880	0.1370	2.246850	0.13389	1353.90	0.0000	1.92221	0.06802	1.848813	0.17392

Table 5. *Cont.*

	Testing the Significance of the Parameters		Testing the Correctness of the Model Form		Normality Test		Autocorrelation Analysis		Heteroscedasticity Analysis	
	t-Student Test		Nonlinearity Test for Squares		Doornik–Hansen Test		Durbin–Watson Test		Breusch–Pagan Test	
Independent Variable	***t* Statistic**	***p***	**TR^2 Statistic**	***p***	**chi-Square Statistic (2)**	***p***	**d Statistic**	***p***	**LM Statistic**	***p***
					Kogeneracja—Wrocław					
daily sum of precipitation	0.2983	0.7655	1.817510	0.17761	177.484	0.0000	2.22857	0.99999	1.888471	0.16938
duration of rainfall	−0.7427	0.4578	1.598320	0.20614	1176.80	0.0000	2.22607	0.99999	4.402569	0.03589
average daily wind speed	0.9691	0.3327	0.000476	0.98259	1171.36	0.0000	2.22919	0.99999	23.58994	0.00001

The regression analysis illustrated in the table above does not show any clear relationships between the delayed weather factor and the rate of return.

The analysis of causality for pairs of non-stationary variables or those in which at least one variable is non-stationary is much more interesting. Essentially, it is the analysis of the dependent variable in terms of trading volume but not limited to this. Vector autoregression analysis (VAR) with co-integration tests has already been described in the methodological section. The results of the research are presented in Table 6.

Table 6. VAR causality test results for trading volume and weather factors with co-integration analysis.

Independent Variable	VAR				Johansen's Test					Engle–Granger Test	
	Delay	F Statistic	*p*	Row of the Matrix	Eigenvalue	λ_{trace} Test	*p*	λ_{max} Test	*p*	*t* Statistic	*p*
						Energa—Gdańsk					
average daily temperature	5	2.9141	0.0127	0	0.04954	92.606	0.000	75.966	0.000	−8.00159	5.465×10^{-08}
daily sum of precipitation	5	0.7631	0.5764	0	0.36116	904.30	0.000	669.47	0.000	−24.7666	6.223×10^{-51}
insolation	5	1.1266	0.3441	0	0.05908	151.25	0.000	91.042	0.000	−8.11206	2.590×10^{-12}
duration of rainfall	4	1.6614	0.1565	0	0.45144	1157.7	0.000	897.68	0.000	−28.9309	7.866×10^{-48}
mean daily overall cloudiness	4	0.4648	0.7616	0	0.45005	1055.2	0.000	893.91	0.000	−28.8953	6.965×10^{-48}
average daily wind speed	4	2.8127	0.0242	0	0.45061	1109.2	0.000	895.43	0.000	−28.4388	1.598×10^{-48}
average daily relative humidity	5	1.9973	0.0763	0	0.06720	168.75	0.000	104.00	0.000	−8.08309	3.152×10^{-12}
mean daily sea level pressure	4	0.1414	0.9668	0	0.44992	1207.1	0.000	893.54	0.000	−28.9597	8.688×10^{-48}

Table 6. *Cont.*

Independent Variable	VAR				Johansen's Test					Engle–Granger Test	
	Delay	F Statistic	p	Row of the Matrix	Eigenvalue	λ_{trace} Test	p	λ_{max} Test	p	t Statistic	p
Tauron—Katowice											
average daily temperature	5	0.3876	0.8576	0	0.05513	105.11	0.000	84.771	0.000	−9.02435	4.371×10^{-15}
daily sum of precipitation	4	0.5833	0.6748	0	0.41019	1072.5	0.000	789.30	0.000	−26.1031	1.242×10^{-50}
insolation	5	1.2505	0.2830	0	0.06217	174.31	0.000	95.963	0.000	−9.01031	4.835×10^{-15}
duration of rainfall	4	0.2780	0.8923	0	0.40887	1067.7	0.000	785.94	0.000	−26.1105	1.252×10^{-50}
mean daily overall cloudiness	4	0.0112	0.9998	0	0.40869	979.99	0.000	785.49	0.000	−26.1055	1.245×10^{-50}
average daily wind speed	4	0.4384	0.7809	0	0.40928	995.57	0.000	786.99	0.000	−26.0606	1.186×10^{-50}
average daily relative humidity	5	1.3608	0.2363	0	0.05960	161.69	0.000	91.863	0.000	−9.01169	4.787×10^{-15}
mean daily sea level pressure	4	1.1416	0.3352	0	0.40902	1108.3	0.000	786.34	0.000	−26.0966	1.233×10^{-50}
ZE Pątnów-Adamów-Konin—Koło											
average daily temperature	5	1.0597	0.3810	0	0.10145	184.83	0.000	159.82	0.000	−12.7955	2.035×10^{-27}
daily sum of precipitation	7	0.4583	0.8649	0	0.25201	608.13	0.000	432.93	0.000	−20.8275	5.928×10^{-48}
insolation	5	0.5252	0.7574	0	0.10039	223.14	0.000	158.06	0.000	−12.7453	2.973×10^{-27}
duration of rainfall *	-	-	-	-	-	-	-	-	-	-	-
mean daily overall cloudiness *	-	-	-	-	-	-	-	-	-	-	-
average daily wind speed	6	1.1919	0.3077	0	0.27398	628.87	0.000	477.71	0.000	−18.0341	1.315×10^{-42}
average daily relative humidity	4	0.3609	0.8365	0	0.11399	306.15	0.000	180.94	0.000	−12.9202	7.944×10^{-27}
mean daily sea level pressure	8	0.1075	0.9998	0	0.18964	420.92	0.000	312.90	0.000	−18.0277	1.362×10^{-42}
Będzin—Poznań											
average daily temperature	3	1.7209	0.1607	0	0.15566	278.99	0.000	253.13	0.000	−15.3990	1.359×10^{-35}
daily sum of precipitation	6	18.777	0.0000	0	0.32158	775.85	0.000	578.88	0.000	−22.5578	5.839×10^{-50}
insolation	2	0.3416	0.7107	0	0.19807	499.23	0.000	330.44	0.000	−16.5536	7.275×10^{-39}
duration of rainfall	6	3.3540	0.0028	0	0.32266	777.70	0.000	581.26	0.000	−22.5154	6.348×10^{-50}
mean daily overall cloudiness	6	1.4174	0.2042	0	0.32704	725.07	0.000	590.93	0.000	−22.5244	6.235×10^{-50}
average daily wind speed	6	1.0896	0.3663	0	0.32428	745.37	0.000	584.83	0.000	−22.4460	7.304×10^{-50}
average daily relative humidity	3	0.7523	0.5210	0	0.15539	400.10	0.000	252.65	0.000	−15.3476	1.927×10^{-35}
mean daily sea level pressure	6	0.3789	0.8928	0	0.32463	809.98	0.000	585.60	0.000	−22.5294	6.174×10^{-50}

Table 6. *Cont.*

Independent Variable	VAR				Johansen's Test					Engle–Granger Test	
	Delay	F Statistic	*p*	Row of the Matrix	Eigenvalue	λ_{trace} Test	*p*	λ_{max} Test	*p*	*t* Statistic	*p*
Enea—Poznań											
average daily temperature	5	2.5835	0.0246	0	0.08286	148.72	0.000	129.31	0.000	−10.2803	4.150×10^{-19}
daily sum of precipitation	5	0.5230	0.7590	0	0.36300	890.40	0.000	673.77	0.000	−25.3005	6.814×10^{-51}
insolation	5	0.8618	0.5061	0	0.08343	195.65	0.000	130.24	0.000	−10.1827	8.637×10^{-19}
duration of rainfall	5	0.6469	0.6639	0	0.36332	872.54	0.000	674.51	0.000	−24.6077	6.353×10^{-51}
mean daily overall cloudiness	9	0.7969	0.6318	0	0.23890	475.30	0.000	406.48	0.000	−18.8800	1.762×10^{-44}
average daily wind speed	5	2.0417	0.0702	0	0.36093	874.31	0.000	668.92	0.000	−25.2936	6.795×10^{-51}
average daily relative humidity	3	1.7005	0.1650	0	0.14339	324.14	0.000	231.70	0.000	−13.6977	2.411×10^{-30}
mean daily sea level pressure	5	0.5034	0.7739	0	0.36113	856.48	0.000	669.40	0.000	−18.7718	2.979×10^{-44}
ML System—Rzeszów											
average daily temperature	3	0.7697	0.5113	0	0.05273	45.701	0.000	33.751	0.000	−5.44588	1.857×10^{-05}
daily sum of precipitation	9	1.8289	0.0527	0	0.22283	204.51	0.000	155.04	0.000	−10.8954	3.939×10^{-21}
insolation *	-	-	-	-	-	-	-	-	-	-	-
duration of rainfall	3	1.3027	0.2726	0	0.19452	166.58	0.000	134.77	0.000	−5.40644	2.248×10^{-05}
mean daily overall cloudiness	3	0.3462	0.7919	0	0.13308	121.10	0.000	88.972	0.000	−5.39844	2.912×10^{-06}
average daily wind speed	3	0.3950	0.7566	0	0.14536	130.14	0.000	97.855	0.000	−5.45341	1.790×10^{-05}
average daily relative humidity	3	0.5936	0.6194	0	0.07885	83.565	0.000	51.165	0.000	−5.40631	2.249×10^{-05}
mean daily sea level pressure	2	0.3052	0.7371	0	0.58743	674.03	0.000	551.57	0.000	−20.7258	8.382×10^{-48}
PGE—Warszawa											
average daily temperature	4	1.9605	0.0981	0	0.13958	247.93	0.000	224.89	0.000	−13.4403	1.620×10^{-29}
daily sum of precipitation	5	0.6327	0.6748	0	0.35467	879.10	0.000	654.37	0.000	−25.8567	9.735×10^{-51}
insolation	3	0.5616	0.6404	0	0.17672	406.56	0.000	291.11	0.000	−15.4866	7.512×10^{-29}
duration of rainfall	4	1.8345	0.1197	0	0.13899	370.14	0.000	223.88	0.000	−13.3520	3.125×10^{-29}
mean daily overall cloudiness	5	1.7493	0.1203	0	0.35566	784.62	0.000	656.66	0.000	−25.7137	8.657×10^{-51}
average daily wind speed	5	0.7229	0.6063	0	0.35473	875.77	0.000	654.49	0.000	−25.6844	8.470×10^{-51}
average daily relative humidity	3	1.8621	0.1341	0	0.17679	386.58	0.000	291.24	0.000	−15.4671	8.564×10^{-36}
mean daily sea level pressure	3	0.8564	0.4632	0	0.17839	528.05	0.000	294.15	0.000	−15.4749	1.469×10^{-36}

Table 6. *Cont.*

Independent Variable	VAR			Johansen's Test						Engle–Granger Test	
	Delay	F Statistic	*p*	Row of the Matrix	Eigenvalue	λ_{trace} Test	*p*	λ_{max} Test	*p*	*t* Statistic	*p*
						Polenergia—Warszawa					
average daily temperature	3	1.0736	0.3592	0	0.18866	343.14	0.000	312.77	0.000	−16.2404	5.264×10^{-38}
daily sum of precipitation	2	0.6598	0.5171	0	0.25947	887.13	0.000	449.67	0.000	−18.6107	6.605×10^{-44}
insolation	3	0.1714	0.9157	0	0.18862	427.96	0.000	312.70	0.000	−16.2300	5.629×10^{-38}
duration of rainfall	2	0.1277	0.8801	0	0.25479	805.61	0.000	440.26	0.000	−18.6316	5.952×10^{-44}
mean daily overall cloudiness	3	0.4706	0.7028	0	0.18898	497.84	0.000	313.35	0.000	−16.2540	4.826×10^{-38}
average daily wind speed	2	1.2637	0.2829	0	0.26709	891.80	0.000	465.17	0.000	−18.7068	4.098×10^{-44}
average daily relative humidity	3	0.2849	0.8363	0	0.18863	407.94	0.000	312.71	0.000	−16.2288	5.671×10^{-38}
mean daily sea level pressure	2	1.7225	0.1790	0	0.25732	742.44	0.000	445.33	0.000	−18.6071	6.726×10^{-44}
						Kogeneracja—Wrocław					
average daily temperature	3	1.4784	0.2186	0	0.19417	354.10	0.000	322.95	0.000	−15.6308	2.850×10^{-36}
daily sum of precipitation	1	0.6244	0.4295	0	0.44553	1667.2	0.000	883.44	0.000	−22.8552	3.387×10^{-50}
insolation *	4	0.9464	0.4361	0	0.14203	337.36	0.000	229.01	0.000	−14.4136	1.324×10^{-32}
duration of rainfall	1	0.0479	0.8268	0	0.41688	1578.1	0.000	807.96	0.000	−22.8612	3.353×10^{-50}
mean daily overall cloudiness	1	0.1080	0.7425	0	0.41325	1293.9	0.000	798.68	0.000	−22.8629	3.343×10^{-50}
average daily wind speed	4	3.3118	0.0104	0	0.13993	440.17	0.000	225.36	0.000	−14.3291	2.427×10^{-50}
average daily relative humidity	3	1.1463	0.3291	0	0.19548	447.90	0.000	325.40	0.000	−15.6591	2.359×10^{-36}
mean daily sea level pressure	2	0.8535	0.4261	0	0.26064	753.60	0.000	452.06	0.000	−18.8891	1.687×10^{-36}

* no data for a given weather station.

In the causal analysis, using the VAR test, some dependencies of the trading volume on weather factors are noticed, but it is difficult to clearly identify the essential determinants in this respect. The most positive indications are from the variable wind speed. However, this is not a spectacular result because it only occurred in three cases out of nine analyzed entities. Other significant variables in this respect are average temperature, a daily sum of precipitation, duration of precipitation and, in a single case, humidity. Although the aforementioned relations are not very clear, they illustrate, to some extent, the impact of weather variables on the trading volume.

In order to complete the analysis, a causality study between the rate of return, stationary factor and non-stationary meteorological components should also be carried out (Table 7). The hitherto analysis of the rate of return concerned the regression analysis where a few factors were characterized by the lack of the unit root (Tables 4 and 5). Therefore, the remaining weather factors for which the series stationary was excluded were omitted. The table below supplements the considerations so far.

Table 7. VAR causality test results for the rate of return and non-stationary weather factors along with co-integration analysis.

Independent Variable	VAR			Johansen's Test						Engle–Granger Test	
	Delay	F Statistic	*p*	Row of the Matrix	Eigenvalue	λ_{trace} Test	*p*	λ_{max} Test	*p*	*t* Statistic	*p*
Energa—Gdańsk											
average daily temperature	3	0.0343	0.9915	0	0.37114	1135.1	0.000	693.46	0.000	−19.5541	8.061×10^{-46}
insolation	3	0.6701	0.5704	0	0.43516	1297.0	0.000	853.97	0.000	−19.5467	8.325×10^{-46}
average daily relative humidity	4	2.0181	0.0895	0	0.36893	1027.4	0.000	687.74	0.000	−18.2126	5.092×10^{-43}
Tauron—Katowice											
average daily temperature	3	0.2039	0.8937	0	0.36995	1132.4	0.000	690.61	0.000	−18.7265	3.721×10^{-44}
insolation	3	2.4909	0.0587	0	0.25564	591.49	0.000	441.66	0.000	−18.7269	3.713×10^{-44}
average daily relative humidity	2	1.9430	0.0500	0	0.33044	859.74	0.000	598.90	0.000	−15.8048	8.959×10^{-37}
ZE Pątnów-Adamów-Konin—Koło											
average daily temperature	3	1.1687	0.3204	0	0.38497	1175.0	0.000	726.70	0.000	−19.5512	8.163×10^{-46}
insolation	4	1.1284	0.3414	0	0.38592	1068.6	0.000	728.52	0.000	−17.5784	1.626×10^{-41}
average daily relative humidity	4	1.1366	0.3376	0	0.36625	1021.1	0.000	681.43	0.000	−17.6007	1.433×10^{-41}
Będzin—Poznań											
average daily temperature	3	0.5154	0.6717	0	0.37201	1327.6	0.000	695.53	0.000	−23.3028	1.719×10^{-50}
insolation	3	0.3157	0.8140	0	0.43482	1487.6	0.000	853.06	0.000	−23.3071	1.710×10^{-50}
average daily relative humidity	4	0.9332	0.4437	0	0.36905	1153.2	0.000	688.04	0.000	−20.9834	3.539×10^{-48}
Enea—Poznań											
average daily temperature	2	0.4365	0.6464	0	0.44470	1464.4	0.000	880.01	0.000	−22.5165	6.334×10^{-50}
insolation	4	0.5869	0.6721	0	0.37956	1062.7	0.000	713.12	0.000	−18.0414	1.265×10^{-42}
average daily relative humidity	3	1.3326	0.2621	0	0.41224	1231.0	0.000	794.50	0.000	−19.7667	3.261×10^{-46}
ML System—Rzeszów											
average daily temperature	4	0.5883	0.6713	0	0.34336	381.81	0.000	261.20	0.000	−10.2085	7.120×10^{-19}
duration of rainfall	5	1.4409	0.2076	0	0.39570	408.82	0.000	312.28	0.000	−9.29655	6.103×10^{-16}
mean daily overall cloudiness	4	2.0564	0.0851	0	0.37888	418.96	0.000	295.73	0.000	−10.1933	7.980×10^{-19}
average daily wind speed	4	0.6256	0.6444	0	0.37334	412.30	0.000	290.22	0.000	−10.2076	7.167×10^{-19}
average daily relative humidity	5	1.2802	0.2707	0	0.36187	374.94	0.000	278.52	0.000	−9.3072	5.648×10^{-16}
mean daily sea level pressure	2	0.5462	0.5794	0	0.47732	697.93	0.000	404.19	0.000	−15.7550	1.246×10^{-36}

Table 7. *Cont.*

Independent Variable	VAR				Johansen's Test					Engle–Granger Test	
	Delay	F Statistic	*p*	Row of the Matrix	Eigenvalue	λ_{trace} Test	*p*	λ_{max} Test	*p*	*t* Statistic	*p*
PGE—Warszawa											
average daily temperature	3	0.4157	0.7418	0	0.36547	1118.3	0.000	680.04	0.000	−19.3625	1.875×10^{-45}
insolation	3	1.6534	0.1752	0	0.25511	556.27	0.000	440.61	0.000	−19.3561	1.929×10^{-45}
average daily relative humidity	3	1.1135	0.3424	0	0.39355	1186.7	0.000	747.71	0.000	−19.3471	2.009×10^{-45}
mean daily sea level pressure	3	0.7133	0.5440	0	0.37141	1130.0	0.000	694.10	0.000	−19.3177	2.293×10^{-45}
Polenergia—Warszawa											
average daily temperature	2	1.9365	0.1446	0	0.44713	1509.1	0.000	886.59	0.000	−22.7157	4.333×10^{-50}
insolation	4	0.8714	0.4804	0	0.36359	1048.1	0.000	675.16	0.000	−17.8496	3.586×10^{-42}
average daily relative humidity	2	2.6845	0.0686	0	0.50785	1688.2	0.000	1060.6	0.000	−22.7127	4.356×10^{-50}
mean daily sea level pressure	3	0.0136	0.9978	0	0.37191	1138.2	0.000	695.27	0.000	−20.5336	1.650×10^{-47}
Kogeneracja—Wrocław											
average daily temperature	2	0.0877	0.9160	0	0.44752	1540.7	0.000	887.63	0.000	−22.2746	1.051×10^{-49}
duration of rainfall	5	0.6319	0.6754	0	0.33407	920.97	0.000	607.02	0.000	−17.1305	2.176×10^{-40}
mean daily overall cloudiness	3	0.3249	0.8073	0	0.44509	1310.0	0.000	880.47	0.000	−19.7930	5.163×10^{-47}
average daily relative humidity	5	1.2834	0.2684	0	0.31770	885.81	0.000	570.76	0.000	−17.1103	2.453×10^{-40}
mean daily sea level pressure	2	0.5638	0.5692	0	0.44485	1530.9	0.000	880.42	0.000	−22.2951	1.005×10^{-49}

The occurrence of simultaneous covariance between the random components of individual equations included in the VAR model allows the creation of the so-called structural models [53]. Structural VAR models enable the construction of the impulse response function (IRF), which allows the description of the time dependence. It illustrates the time distribution of changes in the magnitude of one variable in response to disturbances in the other's residuals. Most often, the IRF is presented graphically. The analysis of the impulse response function relates to three components: the direction of the impulse's interaction, the strength of the impulse as well as the time distribution and the rate of decay [52]. An example of the IRF function is shown in Figure 1. In the case under consideration, the structure of the graph is as follows: the value of the rate of returns caused by a change in a given weather factor is placed on the graph's ordinate, and the abscissa shows the time horizon of this impulse expressed in days. It is clear that changes in some weather variables trigger reactions in the percentage price changes (in this case, the Tauron company) in the first few periods. The decay of the pulses in both cases occurs fairly quickly, so the main reactions take place in the first few periods. The situation is similar in the case of impulse responses in relation to the trading volume (Energa case—Figure 2).

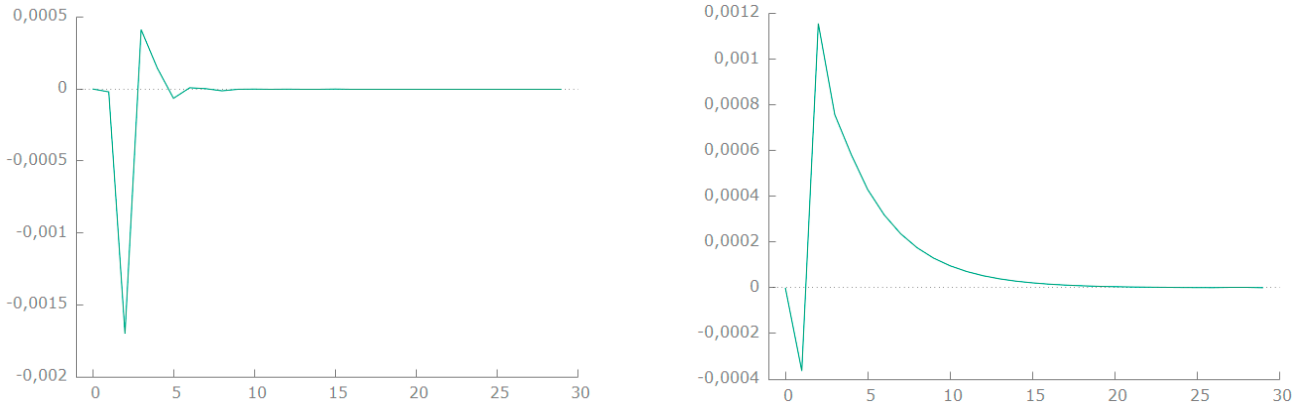

Figure 1. Examples of functions of the rate of return reaction for Tauron, Katowice to an impulse: (**a**) insolation; (**b**) average daily relative humidity.

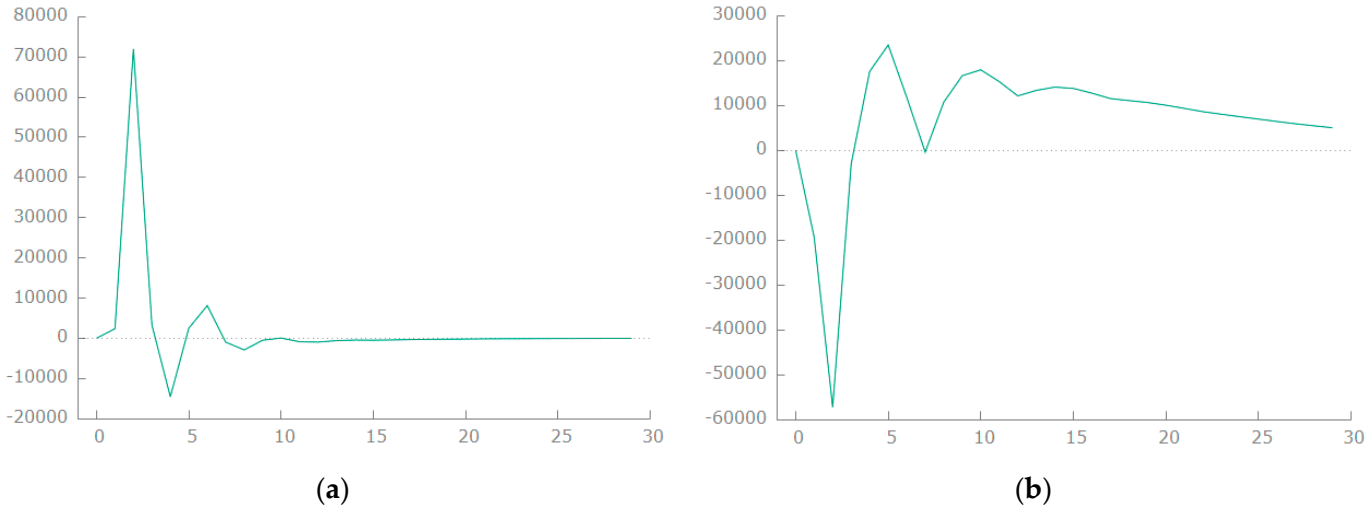

Figure 2. Examples of the response functions of the trading volume for Energa, Gdańsk to the impulse: (**a**) average daily wind speed; (**b**) average daily relative humidity.

In the case of the VAR analysis for the relation rate of return ← the meteorological variable with the highest frequency of impact is relative humidity (33%). The variables insolation or cloudiness level have unitary indications in this regard. Thus, it is hard to define a tendency here. In this respect, it seems reasonable to make a summary list, which is a kind of compilation of the indications obtained so far in the section of the applied methodology. The results are presented in Table 8.

Table 8. The frequency of occurrence of the weather factor in the case of modeling the rate of return and the volume of trading in the cross-section of the methods used.

	Dependent Variable		
	Rate of Return		Trading Volume
	OLS	VAR	VAR
average daily temperature			2
daily sum of precipitation	1		2
insolation		1	
duration of rainfall			1
mean daily overall cloudiness		1	
average daily wind speed			3
average daily relative humidity		3	1
mean daily sea level pressure	1		

5. Discussion and Conclusions

Summarizing the conclusions drawn, it can be stated that:

- not all analytical methods are equally effective. This can be clearly seen in the example of the VAR analysis. The number of positive indications obtained in this case significantly exceeds the relevance of weather factors in the OLS modeling. The limitations of the OLS methodology are described earlier;
- co-integration analysis with the use of the Engle–Granger and Johansen tests is in a sense unjustified as it always indicates relationships between variables. It, therefore, disrupts the general view of causal relationships;
- determining the direction of the relationship weather factor $\rightarrow$ rate of return may be based only on the values of the tangent of the angle of inclination in the regression analysis;
- the most common determinants of the rate of return and the volume of trading include the weather factor in the form of average daily relative humidity and average wind speed. The first of these weather variables is the cause of the percentage changes in stock prices, the second is responsible for changes in the trading volume. The results in this case are different from those obtained in the studies of the team of Tarczyński et al. [54] with the use of ARCH class models. Then, the variable with a clear influence was atmospheric pressure. Therefore, it can be assumed that the considered causality depends on the methodology used;
- the trading volume seems to be much more susceptible to possible influences from independent variables;
- impulse response functions turn out to be extremely useful in VAR analyses, allowing additional inference in the case of dependence from meteorological time series;
- it would be advisable to continue research in the causality area and to verify the effectiveness of indications in the context of the distribution of the analyzed variables. Perhaps the nature of the distribution itself (convergence or divergence with the normal distribution) may affect the final indications;
- in the case of some weather variables, consideration should also be given to take into account the phenomenon of seasonality over a longer period of time;
- in general, it can be said that the indications depend on the type of method used and the nature of the test itself. Hence, weather variables play a role in modeling the mood of stock market investors investing in the energy sector, mainly in the context of Granger causality analysis.

Summarizing all of the research conducted, it is impossible to notice that there is no unique systematic and permanent correlation in the weather–stock market relationship. While in the case of one study we have confirmation of a certain state and assumptions, when studying subsequent studies we may have a different opinion, or previous beliefs

may not be so important. Therefore, when summarizing the information presented in this paper, it should be noted that there are many potential reasons for the lack of this consensus.

Time is a factor that must certainly be considered. As already stated, Chang S.C. et al. [55] proved the influence of changes in weather factors during the market opening. On the other hand, Akhtari M. [56] discovered that there was not only the time of day that needed to be considered but also specific moments of time. Additionally, he noticed a certain cyclical nature of the whole process over the years. Trombley M.A. [57] and Lee Y.M and Wang K.M. [58] additionally stated that the analyzed relationships tended to fluctuate somewhat throughout the year.

Location may be another important element in this regard. For instance, Keef S.P. and Roush M.L [44] showed that the significance of various weather factors depends to a large extent on the analyzed (specific) location. In their opinion, it is one of the most critical factors in this type of analysis as climatic conditions vary from place to place. Moreover, there is a certain degree of heterogeneity with regard to individuals as well as their psychological characteristics in different cultures and regions; therefore, it is very likely that this could trigger different market reactions in response to the same weather conditions depending on the location of the stock markets. This fact was also confirmed by Simeonidis L., Daskalakis G. and Markellos R. [39]. The team of Loughran T. and Schultz P. [35] indicated that the volume of trading in shares differs depending on the place of residence of stock investors, which also confirms the previous thesis. Therefore, different conclusions from similar studies can be explained by the significant variation in variables and locations.

Moreover, attention should be paid to the definitions and hypotheses used. They often turn out to be crucial. It is not only the way of formulating the null hypothesis that is important but also the definitions [59]. This has a direct impact on the final conclusions.

In addition, the type of investors is important. Levy O. and Galili I. [60] and Shu H. [61] proved that the significance of the meteorological determinant largely depends on the type of investors. Moreover, the test procedures and statistics applied may give erroneous results [57,60].

Generally, whether a given weather factor is significant or not depends on many components: time, place, weather definition, formulation of hypotheses, type of investor, the procedure used and test statistics used in the research.

In addition, modeling the impact of weather factors should also take into account other aspects that may often result in complex, often contradictory, results of research on analyzed weather–investor behavior relations:

- many studies of this type do not take into account the phenomenon of the seasonality of twists. This may cause a distortion of the causal relationships between investor behavior and meteorological factors;
- some analyses did not investigate whether variables take into account other weather indicators. For instance, the effect of a certain temperature level on mood may depend on whether or not it is raining;
- as a rule, this type of analysis does not take into account the behavior of investors at different times of the year. There may be a dependence that higher winter/summer temperatures may positively/negatively affect decision-making processes;

There are many questions and possible doubts. Therefore, there remains the issue of seeking answers that will actually confirm the relations considered. Thus, any question marks appearing in the article constitute the background for further research on the analyzed problem.

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