Stock market performance: is the weather a bother in the tropics? Evidence from Ghana

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Abstract

Purpose – In the wake of climate change and its associated impact on firms' performance, this paper attempts to provide a piece of empirical evidence in support of the effect of weather conditions on the stock market performance.

Design/methodology/approach – Monthly time-series dataset and the fully modified ordinary least square (FMOLS) semi-parametric econometric technique are used to establish the effect of weather variables on stock market return.

Findings – This study finds that temperature and wind speed have a negative and statistically significant relationship with stock market performance. Likewise, humidity exhibits a negative relationship with stock market performance, albeit insignificant. The relevant stock market and macroeconomic control variables are statistically significant in addition to exhibiting their expected signs. The findings lend support to advocates of behavioural factors inclusion in asset pricing and decision-making.

Practical implications – For policy purposes, the authors recommend that traders, investors and stock exchange managers must take into consideration different weather conditions as they influence investors' behaviour, investment decisions, and consequently, the stock market performance.

Originality/value – To the best of the authors' knowledge, this study provides the first empirical evidence of the nexus between disaggregated weather measures and stock market performance in Ghana. This study uses monthly data (which are very rare in the literature, especially for developing country studies) to provide empirical evidence that weather influences stock market performance.

Keywords Stock market return, Temperature, Humidity, Wind speed, FMOLS, Ghana

Paper type Research paper

1. Introduction

Several attempts to attract investments in the form of foreign direct investment into Ghana and other African countries have not yielded the expected impact on poverty, inequality, economic growth and economic development. Some authors have even argued that these attempts have failed and have called for alternative forms of investment (see Rolfe and Woodward, 2004). One investment opportunity that has experienced tremendous growth rates over the past decade and can be capitalised on has been the stock market. Available evidence as provided by Adjasi and Biekpe (2006) shows that from 1992 to 2002 the number of stock markets in Africa rose by about 100%. They argue further that the African stock market is fairly young, yet the performance of Ghana Stock Exchange (GSE) has been very impressive to the extent that it was adjudged the world's best in the first quarter of 2004.

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However, in 2016 the GSE composite index reached a record low of 1,528.10 whiles in 2018 it recorded an all-time high of 3553.60 (GSE, 2018). The trend in 2019 has shown a decrease by 10.23% (GSE, 2019). We forecast a recovery and a record high index of about 4400 in the first quarter of 2020. So far, the data shows fluctuations in the performance of the GSE. Generally, researchers have shown that macroeconomic factors are the main drivers of the stock market performance (see Garcia and Liu, 1999).

In this study, the key research question is, apart from the macroeconomic factors, does Ghana's geographical location with its unique weather conditions matter in determining the performance of GSE? Admittedly, several behavioural finance studies have shown that the impact of weather on stock market returns has been mixed. While some studies have shown a positive relationship (see Shu, 2010; Lucey and Dowling, 2005), others have also found a negative relationship (see Floros, 2011; Worthington, 2017). This study has become very necessary given the fact that Floros (2011) as part of his recommendations proposed that further investigation is needed in the relationship between humidity and stock market performance. More so, to the best of our knowledge, this is the only study in Ghana that has sought to disaggregate measures of weather and unravel its effect on the stock market performance.

The main transmission mechanism through which weather factors influence stock market return is via investor's requisite disposition which is observed in their moods and emotions. Swings in moods and emotions are argued by Shu (2010) to influence investor preference and decision-making. Empirical studies on behavioural finance relate the psychological elements of moods and emotions to stock market return. It does so mostly by employing weather-related proxies whose effect on the stock market is well recognised and statistically measurable (Hirshleifer and Shumway, 2003). Lucey and Dowling (2005) have asserted that if weather variables affect performance and mood of investors, then they have the propensity to influence significant changes in market prices. It has become more evident that location is one of the most important factors in the study of the link between weather and stock market, since climatic conditions vary with place. Therefore, the climatic factors that will aid stock market return in the temperate zone may not have significant effect in the tropical region. Again, one should also expect some amount of variations with regard to characteristics and psychological traits of people across geographical regions and cultures. It is therefore plausible that different market reactions can be activated in response to the same weather conditions, considering the stock exchange location. A given number of studies highlight the heterogeneous influence of weather factors on different stock markets. Geographical location of the stock market determines changes in the stock market returns (Keef and Roush, 2007). Considering this evidence, we investigate the weather effect on the Ghanaian stock market, an emerging market. The empirical results seek to provide significant implications, given its position among the stock markets in Africa. The fundamental reasons that inspired this research are the pervasive cognition of the effect of weather factors on human activities and investment behaviour including buying and selling of stocks in Ghana. Surprisingly, there is paucity of research on the link between weather and stock market return in Ghana. Identifying the effect of weather on stock returns in Ghana will not only create an association between mood and investments, but also throw more light on the link between psychology and economic/financial theory.

In an attempt to provide an answer to the research question, this study uses monthly time-series dataset and the FMOLS econometric technique to establish that temperature and wind speed have a negative and statistically significant relationship with stock market performance in Ghana. Similarly, humidity exhibits an inverse relationship with stock market performance, albeit statistically insignificant. In addition, the control variables exhibited their expected signs and are statistically significant.

The remainder of this article is organised as follows. Section 2 presents a brief overview of the weather in Ghana. Section 3 reviews the literature on the effect of weather on stock market performance. Section 4 discusses the data and methodology used for the study. Section 5 presents and discusses results of the study. Finally, Section 6 presents conclusions and recommendations.

2. Brief overview of the weather in Ghana

Ghana is located only a few degrees north of the Equator. It is therefore in the tropical zone with warm climate. It has Gulf of Guinea to the south, Togo and Ivory Coast to the east and west, respectively, and Burkina Faso to the north. The eastern coastal belt is warm and comparatively dry, the south-west corner of Ghana is hot and humid, and the north of Ghana is hot and dry.

Rainfall: Ghana experiences two main seasons: the wet and the dry seasons. The north of Ghana experiences its rainy season from April to mid-October usually associated with strong winds, attaining its peak in August, whiles the south of Ghana experiences its rainy season from March to mid-November with the peak in May/June. The southern and middle parts of Ghana experience two raining seasons. The main seasons occur from mid-April to ending of June and the other from late September to early November. The tropical climate of Ghana is relatively mild for its latitude. Rainfall figures in Ghana ranges from 780 millimetres to 2160 millimetres annually.

Humidity: Humidity is the concentration of water vapour present in air. Absolute humidity describes the water content of air at a given temperature and is expressed in either gram per cubic metre or gram per kilogramme. Relative humidity is a measure of the current humidity in relation to a given temperature. The Harmattan, a dry desert wind, blows in north-east Ghana from December to March, lowering the humidity and causing hotter days and cooler nights in northern part of Ghana. Humidity in Ghana hovers between 77% in December to February and 86% in May to July. This figure falls in line with the rainy season and dry seasons of Ghana. The "cooler" months tend to be more humid than the warmer months. Humidity affects mood and tends to make people more tired and irritable. One would expect that, humidity levels of 70% or higher are associated with more negative sentiments.

Temperature: Daily temperatures range from average figure of 30°C (86°F) during the day to 24°C (75°F) during the night. Very little variation in temperature occurs throughout the year. The mean monthly temperature ranges from 25.9°C (78.6°F) in August (the coolest) to 29.6°C (85.3°F) in March (the hottest), with an annual average of 27.6°C (81.7°F). The warmer months and particularly during the windy Harmattan season, the city experiences a breezy "dry heat" that feels less warm than the "cooler". Studies have shown that very cold and high temperatures affect moods and decision-making (Cunningham, 1979).

Wind: As a result of proximity of Ghana to the equator, the daylight hours are practically uniform during the year. Relative humidity is generally high, varying from 65% in the mid-afternoon to 95% at night. The wind direction in Accra is primarily from the West-South-West to the North-North-East. Wind speed normally ranges between 8 and 16 km/h. In extreme cases the country records maximum wind of 107.4 km/h (58 knots). Strong winds are associated with thunderstorm activity, which often cause damage to property. Several areas of Accra experience microclimatic effects. Devastating effects during and after severe winds are likely to affect moods and decision-making.

Accra metropolis which lies in the Greater Accra Region is in the south eastern part of Ghana. The coast of Accra is located in the Dahomey Gap, where it runs parallel to the prevailing moist monsoonal winds. Accra features a tropical savanna climate that borders on a hot semi-arid climate. The average annual rainfall is about 730 mm, which falls primarily during Ghana's two rainy seasons – main rainy season begins in April and ends in mid-July, whilst the minor rainy season occurs in October. Rain usually falls in short intensive storms and causes local flooding in which drainage channels are obstructed.

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Average wind speed in the Greater Accra Region is 14 km/h among the highest in Ghana. These winds which are laden with dust especially in the Harmattan seasons reduce work effort and generally bring discomfort to Ghanaians. These weather conditions are likely to affect moods of people including investors of the GSE.

3. Literature review

3.1 Theoretical literature review

The theoretical propositions by Calderon-Rossell (1990, 1991) posit that the stock market performance can be explained by the classical financial theory in relation to stock market. Similarly, the relationship between weather conditions and stock market performance has its foundations in the theory of behavioural finance. We attempt to conceptualise a unique relationship that synthesises these theories. Following the theoretical model of Calderon-Rossell, we specify Eqn (1) which conceptually explains the stock market performance as:

$$SM = f(\varnothing, \theta, \gamma) \tag{1}$$

where SM is a measure of the stock market performance which mainly depends on domestic and international stock market characteristics (θ), macroeconomic factors ($\varnothing$) and risk and uncertainties (γ). Next, we transform the variables into natural logarithm for simplicity of interpretation and present Eqn (2) as:

$$\ln SM = \ln(\varnothing, \theta, \gamma) \tag{2}$$

Also, the partial differential of the dependent variable (log difference) which measures growth, determines growth in the stock market performance. An appreciable previous growth rate in the stock market, or an expected growth rate in the stock market, is expected to drive growth in the stock market performance positively. This is presented as Eqn (3):

$$\frac{\partial \ln SM}{\partial \ln \varnothing} > 0 \tag{3}$$

In line with theoretical underpinning, we posit that a robust macroeconomic environment is expected to positively drive growth in the stock market performance. This is shown as Eqn (4):

$$\frac{\partial \ln SM}{\partial \ln \theta} > 0 \tag{4}$$

Again, risk and uncertainties which also include uncertainties in weather patterns are expected to influence growth in the stock market performance. High risk factors and uncertainties (γ') are expected to drive growth in the stock market performance negatively. This is illustrated as Eqn (5):

$$\frac{\partial \ln SM}{\partial \ln \gamma'} < 0 \tag{5}$$

Thus, we expect that all else held constant, unfavourable weather conditions will negatively drive the stock market performance. Hence our final theoretical framework is presented as Eqn (6):

$$\ln SM = \ln(\overline{\varnothing}, \overline{\theta}, \gamma^{'})\langle 0 \quad (6)$$

3.2 Empirical review

3.2.1 Weather effect on mood. Classical finance theory assumes that people are rational in decision taking. In other words, people are assumed to always assess the accuracy and probability of possible outcomes with the aim of maximising expected utility. A rational investor will make decisions based on fundamental analysis and modern portfolio theory, which require certain assumptions about the future. However, many factors affect stock markets, and the complexity of these factors is beyond the comprehensive capability of investors. Unfortunately, the classical finance theory fails to explain this phenomenon.

From a psychological perspective, human behaviour is driven by thought, which is derived from individual feelings. The influence of moods and emotions on investor decision-making has been investigated by psychology, economics and finance scholars (Forgas, 2000; Forgas and Ciarrochi, 2001; Lucey and Dowling, 2005; Tetteh and Hayfron, 2017).

Investors in a good mood are generally expected to be more auspicious in their judgement and decision-making (Wright and Bower, 1992) and therefore are likely to allot a higher value to investment choices (Forgas and Ciarrochi, 2001). Some psychologists have argued that moods and emotions influence the cognitive evaluation process and eventually the decision (Loewenstein *et al.*, 2001). However, Forgas (1995) asserted that the effect of emotions on decision-making may be situation dependent. This implies that the greater the complexity and uncertainty, the greater the effect of emotions on decision-making regarding risk. These assertions have been buttressed by Au *et al.* (2003) who established that traders tend to be overconfident, more risk takers in their decisions when they are in a pleasant or good mood. On the other hand, traders tend to be more conservative in their decision-making when they are in bad mood.

3.2.2 Weather, mood and stock returns. A number of scholars in psychology, economics and finance have endeavoured to establish a link between mood and stock market behaviour. A good number of studies have also argued that moods and emotions that influence change in stock market returns are to a greater extent caused by weather factors. That is to say, for mood to present itself as a powerful determinant of asset prices, a more powerful mood proxy variable should in the first place influence the mood of investors. Thus, weather becomes very visible as an eminent candidate. Weather has been a powerful influencer on human life and activities, and has attracted considerable attention from scholars especially psychologists and behavioural economists. These links may appear improbable in the rationality theory entrenched in traditional economics and finance. However, considerable documentary evidence exists that investors are normally weather-sensitive, and the mood they exhibit in addition to their mental and physical health often change with the weather (see Kals, 1982; Parrott and Sabini, 1990).

3.2.3 Weather effect on stock market returns. Saunders (1993) in his seminal works on the link between weather and the daily New York Stock Exchange (NYSE) index used weather variable as mood proxy to examine the relationship between public mood and stock prices. Using a sample of 63-years period (1927–1989), Saunders found that major US indices were negatively related to cloud cover. He established that stock returns tend to be higher on sunny days, an effect presumed to result from investor optimism influenced by the good weather. On the other hand, poor performance of the stock market on murky days is deduced to result from investor depression. The works of Saunders drew the attention of researchers to the possible effect of weather changes on stock market returns. The findings of Saunders, however, have not received hundred percent support from subsequent studies. Trombley (1997) reported that the sunlight effect was not as strong as Saunders had claimed. Using a different statistical methodology, he attained findings different from that of Saunders. Similar divergent results of no cloud effect were also found in Pardo and Valor (2003). It is imperative to state that the finding of Saunders has been confirmed by Hirshleifer and Shumway (2003) and Cao and Wei (2005). Hirshleifer and Shumway (2003) identified significant negative influence of cloud cover on stock market returns from 1982 to 1997 using 26 countries, confirming the findings of Saunders. Their findings support the assertion that sunlight influences mood, causes misattribution, and therefore influences stock returns. Stock returns, therefore, tend to increase on sunny days, as investors are more optimistic and have the propensity and the willingness to purchase more stocks. Thus, there is the high probability of an increase in mood with sunny weather. They however found that rainfall has no effect on stock market returns.

Kang *et al.* (2010) sampled data from the Shanghai Stock Exchange and found that extreme weather affects market volatility. Similarly, Lee and Wang (2011) indicated that the effects of sunshine on the Taiwanese stock market have endured after the Asian financial crisis. Again, Hirshleifer and Shumway (2003) reported that weather conditions affect investor moods besides stock return. They established that stock returns are higher in sunny days than in rainy days.

Kamstra *et al.* (2000) investigated the relationship between daylight saving time and the stock returns and found that equity returns fluctuate with daylight saving. Keef and Roush (2005) studied the correlation between weather variables, namely cloud cover, temperature, wind speed and equity market returns in New Zealand. They reported that low temperatures are related with high stock returns due to aggressive risk-taking, while higher temperatures are linked with either higher or lower stock returns, depending on whether aggression (linked with risk-taking) or apathy (linked with risk-averting) prevails. The temperature effect was confirmed by Chang *et al.* (2006) and Keef and Roush (2007) who established that temperature and cloud cover had a negative influence on the stock markets of Taiwan and Australia.

Yoon and Kang (2009) established that temperature negatively affects stock returns. In addition, high humidity exerted adverse impact on returns. Furthermore, Floros (2011) established that temperature has negative effect on stock market return in Portugal. The findings also show the existence of January effect. The winter season of Portugal falls in the month of January, hence they believed that it is the low temperature that leads to higher returns in January as compared to any other months in the year. Also, Cao and Wei (2005) investigated the impact of temperature on returns of nine (9) international stock markets. They identified a negative influence of temperature on stock returns for four markets but no effect on the remaining five stock markets. Relating their studies with prior studies, they asserted that very high or very low temperature figures have the propensity to cause aggression. Chang *et al.* (2006) however, established that when the weather is intense, whether hot or cold, the stock returns are more likely to be low in the case of Taiwan. This result is supported by Wang *et al.* (2012) who also found that temperature effect on stock return is insignificant in Taiwan.

The negative effect of strong wind on human mood and emotions has also been widely recognised. A significant number of studies have agreed that strong winds cause malaise in humans, incurs uncomfortable feelings and adversely affects performance (e.g. Bottemaa, 2000; Toros *et al.*, 2005). Toros *et al.* (2005) for instance stressed that wind speed, together with air temperature and absolute humidity, are the most important meteorological influences on human comfort, while wind speed is the most practical one. After studying seventy-nine (79) cities in Turkey, they reported that high wind speed causes discomfort for humans.

Another interesting observation found in the literature is the work by Pizzutilo and Roncone (2016). The authors used intraday weather and market data to re-examine the weather effect on the Italian equity market. Contrary to earlier findings of the relationship between weather variables and stock market, Pizzutilo and Roncone (2016) debunked this perspective in the case of the Italian market. They concluded that, there is no systematic effect between weather and the Italian stock market. They argued further that their evidence could be founded on the fact that the Italian market exhibits high level of efficiency and, in addition, the Italian traders have the expertise in dealing with weather-induced anomalies. However, the authors cautioned against the use of stock indices in such studies. In as much as their position is valid, we also argue that for developing countries with paucity of data, stock market indices cannot be completely ruled out as it provides the opportunity for stock market relationships to be empirically tested.

Given the overwhelming effect of weather on human life, comfort and mood, there is a surprising insufficient research on how wind influences human behaviour and activities in Ghana, especially its effects on behavioural pattern of investors and ultimately the GSE Composite Index. In addition, as earlier mentioned, some studies have proposed that further investigation is needed in the relationship between humidity and stock market performance (see Floros, 2011). Furthermore, to the best of our knowledge, this is the only study in Ghana that has sought to disaggregate measures of weather to include wind, humidity and temperature.

3.2.4 Macroeconomic variables and stock market. In line with literature the core variables commonly found in studies are treasury bills as a proxy of cost of debt (interest rates) as it serves as an alternative investment sector to stocks, consumer price index (CPI) as a measure of uncertainties in commodity prices, exchange rate and real gross domestic product.

The results produced from previous studies on the relationship between stock returns and inflation have been inconsistent. A significant number of empirical studies have proven a negative relationship between stock returns and inflation (Fama and Schwert, 1977; Gallager and Taylor, 2002; Kyereboah-Coleman and Agyire-Tetteh, 2008; Naik and Padhi, 2012) Contrary to the findings of these studies other scholars have found a positive relationship between inflation rate and stock returns in four high inflation countries (Ibrahim and Aziz, 2003; Kuwornu, 2012). Principal among some of the reasons given by most authors for the positive effect is the active role of governments in preventing price increase as the economy continues to grow.

Indeed, some studies have reported a positive association between interest rates and stock market (Hasan and Javed, 2009), however, bulk of the literature have rather established a negative relationship (Abugri, 2008; Lv *et al.*, 2015).

Similarly, several studies have established negative relationship between exchange rate and stock market returns (Hasan and Javed, 2009; Dusgupta, 2012). The inverse relationship between exchange rate and stock market index depicts that the depreciation of the domestic currency has negative effects on the performance of the stock market. However, a number of authors have established positive exchange rate influence on stock returns (Maysami and Koh, 2000).

Gross domestic product (GDP) serves as a measure of economic growth. Previous studies have established a predominant positive relationship between stock market prices and real GDP/nominal GDP (Maysami and Koh, 2000; Türsoy *et al.*, 2008). According to Ibrahim and Aziz (2003), an increase in real GDP will affect prices of stocks positively through increase in corporate profits. It is imperative to state, however, that these macroeconomic variables correlate among themselves and the authors of this study are not oblivious of this fact. Hence, the choice of macroeconomic variables used for the present study is dependent on the degree of correlation with other covariates.

4. Data and methodology

4.1 Data

Most African countries introduced stock exchange markets only in the 1990s. This has been a major weakness carrying out annual time-series analysis of the stock market as its existence has not been long enough for meaningful cyclical market analysis. To overcome this empirical challenge, this study uses monthly time-series composite indexes of Ghana Stock Exchange (GSE-CI). The period for the study is 228 months (January, 2000 to December, 2018). The monthly GSE-CI were obtained from the websites of GSE and Bank of Ghana in 2019. The monthly data of weather measures for the city of Accra where the stock market is located include: temperature (TEMP), humidity (HUM) and wind speed (WIND). These were obtained by a written request to the Ghana Meteorological Agency in Accra. Temperature is measured in degree Celsius (°C), humidity in percentage (%) and wind in kilometre per hours (km/h).

4.2 Model specification

In line with the theoretical framework presented in section 2.1, we re-specify Calderon-Russell's model by incorporating the characteristics of weather, market characteristics and macroeconomic characteristics. This is presented as:

$$\ln SM_t = \beta_0 + \beta_1 \text{Weather}_t + \beta_2 \text{lnMarket}_t + \beta_3 \text{lnMacro}_t + \alpha_t + u_t \tag{7}$$

where ln*SM* is as defined in Eqn (2), βs are the unknown parameters to be estimated, weather is a vector of weather characteristics which include temperature, humidity and wind speed, market is a vector of the natural logarithm of stock market characteristics measuring previous (lag) and expected/future (lead) stock market performance, Macro is a vector of the natural logarithm of macroeconomic characteristics measuring market volatility (consumer price index) and performance of the economy (RGDP), α and u are time specific fixed effect and the usual error term which is assumed to be normally distributed. Detailed description of variables and their respective sources are presented in Table A1. However, we present a brief description of the variables and their respective *a priori* expectations as follows:

4.2.1 Stock market returns (SM). In line with previous studies such as Kuwornu (2012), we used the composite index of the GSE for all listed stocks on the exchanges. The composite index is determined by dividing the current market capitalisation by a base period market capitalisation. The composite index which measures the cumulative gain of the stock market, is used as the performance indicator of stock markets. Thus, it serves as a proxy to the stock market return. Other studies used alternative proxies to the stock market return. Adam and Tweneboah (2008) in their study on the effect of macroeconomic indicators on stock returns in Ghana chose the Databank stock index (an alternative means of determining stock market index) as proxy of the stock market returns. In this study, the stock market return is calculated as natural logarithms of the monthly composite index of the GSE.

4.2.2 Weather variable 1: temperature. Temperature is a salient weather condition that has been reported to determine human mood and behaviour. Studies have established that average or mid temperatures tend make people experience comfortable feeling and therefore are likely to work more efficiently. However, very low and very high temperatures create negative moods, feeling of irritability, depression and negatively influence people's reasoning. Temperature was used as one of the explanatory variables of this study.

4.2.3 Weather variable 2: humidity. It is the concentration of water vapour in the atmosphere. The empirical results indicate that not only do changes in humidity affect investment decisions of investors but also the stock market returns.

4.2.4 Weather variable 3: wind speed. Wind speed is another important weather factor that has been reported to exert influence on the feeling of people. A gentle breeze brings comfortable feeling and enhances people's spirit; while sustained strong winds cause discomfort and hinder the normal breath (Cunningham, 1979).

4.2.5 Market variables: leads and lags. In line with theory and empirical literature, information is very critical to investor decision-making. Consistent with the theory of expectations and information diffusion hypothesis, we included *lags* and *leads* in the stock market. These variables play a critical role in investors' decision about whether to invest or not. Froyen (2005) states that "expectations are formed on the basis of all available information concerning the variable being predicted" (p. 263). Thus, whiles leads are formed on the basis of expected future stock market performance, lags are formed on the basis of past stock market performance. In effect, investors would expect to invest more when their expectations are positive. However, investors would shy away from the market when expectations are negative. The *lag* and *lead* were measured as the $SMR-1$ and $SMR+1$, respectively.

4.2.6 Macroeconomic variable 1: consumer price index (market fluctuations). Inflation is a persistent rise in the general price levels for goods and services. Economic theory indicates that inflation decreases purchasing power. Changes in inflation expectation therefore affect cost of doing business, hence it is expected that inflation will correlate negatively with stock returns. Inflation in this study constitute the monthly consumer price index (CPI).

4.2.7 Macroeconomic variable 2: real gross domestic product (RGDP). The study employed the real GDP as the proxy for economic growth instead of the widely used nominal GDP and the IPI. The IPI is often used for monthly studies as a result of the non-availability of monthly data for GDP even though GDP measures the growth of economy better than the IPI (Naik, 2013). However, a good number of previous studies used either annual or quarterly GDP data (Akkum and Vuran, 2003; and Tursoy *et al.*, 2008). This study resolves this problem by using real GDP instead of GDP growth which is in line with previous studies such as Daferighe and Aje (2009). Nominal GDP fails to give the real situation since it is largely distorted by inflation. Estimates for monthly real GDP data were interpolated from available quarterly real GDP data based on the Chow-Lin interpolation procedure using Matlab temporal disaggregation library developed by Abad and Quilis (2005).

4.3 Estimation technique

The purpose of the linear model specified in Eqns (1) and (2), is to test for a long-run relationship among the variables. Once this test rejects the null hypothesis, we have evidence of cointegration, so it can be argued that possible disturbances in the short-run cannot persist in the long-run. In line with a summary provided by Adom and Bekoe (2013) and Kwablah *et al.* (2014), we posit that several approaches have been used to test this relationship and these include but are not limited to residual based test by Engel and Granger (1987), Johanesen and Juselius approach (Johansen and Juselius, 1990; Johansen. 1991), Dynamic ordinary least square (OLS) (Stock and Watson, 1993) and FMOLS by Phillip and Hansen (1990).

The residual based test requires that residuals from the OLS regression are obtained followed by a unit root test. Where the residuals are stationary it means there is evidence of cointegration. Alternatively, where the residuals are not stationary, it means there is no evidence of cointegration. Following from Eqn (1), we re-specify a residual based model as

$$y_t = v + \beta' x_t + u_{1t} = \Gamma' z_t + u_{1t} \tag{3}$$

$$\Delta X_t = u_{2t}$$

where the OLS estimator, $\Gamma = (v, \beta')'$ is inefficient, albeit consistent, and $z_t = (1, x_t')$ is an observed time-series variable just as the case of equation one (1). Given that there are identification challenges such as endogeneity and serial correlation challenges with the OLS regression, we follow the recommendation by Phillip and Hansen (1990) and use the FMOLS. This econometric technique is a semi-parametric technique which uses an instrumental variable estimator. In the absence of stationarity and cointegration, this technique proves to be robust and churns out consistent estimates. Also, with the same equation, this technique allows for both non-stationarity and stationarity of variables. In cases where the sample is small, FMOLS does not under perform as a result of sample size biases. This technique provides a modification of the OLS method and accounts for both endogeneity and serial correlation error of the regression. Indeed, the FMOLS estimator can be presented as:

$$\widehat{\theta}_{\text{FME}} = \left(\sum_{t=1}^{T} z_t z_t{'}\right)^{-1}\left(\sum_{t=1}^{T} z_t y_t^{+} - T\widehat{J}+\right)$$

where the terms for correcting endogeneity and serial correlation are $\widehat{y}_t^{+} = y_t - \widehat{\lambda}_{0x}\widehat{\lambda}_{xx}^{-1}\widehat{\lambda}_{xx}\Delta x_t$ and $\widehat{J}^{+} = \widehat{\Delta}_{0x} - \widehat{\lambda}_{0x}\widehat{\lambda}_{xx}^{-1}\widehat{\lambda}_{xx}\widehat{\Delta}\text{xx}$, respectively. In these terms are the kernel estimates of the long-run co-variances and the kernel estimates of the one-sided long-run co-variances which are represented as $\widehat{\lambda}_{0x}$, $\widehat{\lambda}_{xx}$ and $\widehat{\Delta}_{0x}$, $\widehat{\Delta}_{xx}$, respectively. Given the strengths of the FMOLS relative to the OLS in the presence of possible identification challenges, we consider the former as our preferred model.

Generally, macroeconomic variables (e.g. GDP, foreign direct investment, etc.) are intuitively endogenous. In contrast, naturally occurring variables such as weather, earthquakes, among others, are intuitively exogenous. Additionally, the present study has weather as its variable of interest while all other variables are used as controls, we argue that we do not expect endogeneity to pose as an empirical challenge in our estimation. Next, we subject our work to the relevant time-series diagnostics before we proceed to estimate Eqn (2), using the FMOLS estimator and present the results in Table 1.

5. Results and discussion

The results and associated discussions of the study are presented in this section. First, the unit root test results are presented, followed by the cointegration test results, then the regression results and discussions.

Table 1.
Unit root test results

Variable	ADF test statistic	PP test statistics
Temp	−1.82	−3.26**
DTemp	−15.47***	−10.44***
Wind	−1.64	−7.40***
DWind	−12.49***	24.211***
Rainfall	−3.03**	−11.67***
DRainfall	−15.51***	−90.35***
lnCPI	−2.53	−6.73***
DlnCPI	−13.86***	−46.22***
Lead	−2.25**	−1.53*
DLead	−9.58***	−7.21***
Lag	−8.77***	8.74***
DLag	−9.93***	−12.83***
lnRGDP	−6.12***	−4.30***
DlnRGDP	−11.93***	−11.02***

Note(s): $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

5.1 Unit root test and cointegration test results

An important requirement in the application of time series is to investigate the unit root properties of the data as well as ensuring that the series are cointegrated.

Dickey and Fuller's (1979) augmented Dickey–Fuller (ADF) and Phillip and Perron's (1988) Phillip–Perron (PP) tests are used in investigating the unit root properties of the time-series data. We apply these tests for robustness purposes and present the test results in Table 1. First, we tested for stationarity at levels and found mixed and inconsistent results amongst the estimators. That is the test for stationarity did not converge under the ADF and PP tests applied. So, we proceeded with the first difference in the series and found evidence of stationarity. Thus, we have evidence of no unit root in the series when the series are integrated of order one (I(1)) at 1% level of significance.

5.2 Cointegration test results

In Table 2, the results from both the trace and maximum eigen statistics from the Johansen cointegration test results show that irrespective of the model type, there is evidence of a long-run equilibrium between the dependent variable and the independent variables as already defined.

5.3 Diagnostic test

5.3.1 Serial correlation test. A key statistical test relevant in undertaking time-series estimation is the test for serial correlation. This seeks to test a possible relationship that exist between a variable and its lag or a test of autocorrelation in the errors over various time intervals. This test is based on the null hypothesis of no serial correlation or no autocorrelation. Using the Breusch-Godfrey serial correlation Lagrange multiplier (LM) test as presented in Table 3, there was no evidence to reject the null hypothesis that there is no autocorrelation or serial correlation concerns in our data.

5.3.2 Heteroscedasticity test. Another relevant test in time-series estimation is the test for heteroscedasticity (i.e. no homoscedasticity). This seeks to test whether the variance in the error terms are equal or unequal. This is important as standard assumptions of classical linear regression models may not be reliable because of efficiency concerns. From Table 4, under the null hypothesis that no heteroscedasticity exists, or homoscedasticity exists, there was no evidence to reject the null hypothesis. Thus, there is evidence of a constant variance in the error terms.

Data trend	None	None	Linear	Linear	Quadratic
Test type	No Intercept No trend	Intercept No trend	Intercept No trend	Intercept Trend	Intercept Trend
Trace	3	3	3	3	4
Max-Eigen	2	3	3	3	3

Note(s): Selected at 0.05 level. *Critical values based on MacKinnon *et al.* (1999)

Table 2. Number of cointegrating relations by model

Test type	F-statistic	Obs*R-squared
Value	0.720257	1.518530
Probability value	0.4878	0.4680

Note(s): $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 3. Breusch-Godfrey serial correlation LM test

5.3.3 Stability test. Again, we subjected our model to Ramsey's reset stability test. This is a general test of model specification errors. This test helps to find out whether our model suffers from omitted variable bias as it makes the coefficients of the estimated model bias. Under the null hypothesis that the restricted model is appropriate, the study argues that from Table 5, there is no evidence to reject the null hypothesis and that the model is appropriate. Thus, there is no specification error in its present situation.

5.4 FMOLS regression test results

Table 3 provides some evidence to support the views as expressed in the literature. Weather is captured in the model by three different variables namely wind, temperature and humidity. Generally, wind-speed is empirically found to be insignificant (Lu and Chou, 2012), howbeit, one cannot say same for all countries given the different environmental conditions. In this study, the results show that a one kilometre per hour (km/h) increase in wind speed is associated with a 0.0038% decrease in the stock market performance. This is statistically significant at one percent level. This evidence is plausible owing to the fact that most of the roads and communities in Ghana are not tarred and mostly dusty. This causes wind speed to generate dust and dust storms which are deleterious to human health. Edwards *et al.* (2015) have demonstrated that wind speed has a negative effect on total physical activity of human beings. Similarly, Shu and Hung (2009) have found that there is an inverse relationship between wind speed and stock market returns. By implication, once human physical activity is negatively affected, the corresponding adverse impact on productivity within the investment or equity space is inevitably affected.

Temperature is considered a common factor in explaining the performance of the stock market in both developed and developing countries. Interestingly, the literature has not been conclusive on the direction of impact. While some have found a positive effect (see Kang *et al.*, 2010), others have also found a negative effect (Yoon and Kang, 2009) with different magnitudes of impact. In Ghana, the temperature is averagely high which is generally expected to cause hysteria and apathy for productive activities. This study finds that a degree Celsius increase in temperature decreases stock market performance by 0.0063%, which can be considered as a negligible effect. Irrespective of the magnitude, there is a highly statistically significant negative relationship between high temperatures and the stock market performance in Ghana. The results for Ghana, is consistent with that of Korea where Yoon and Kang (2009) found that the relationship between temperature and stock returns is negative. Similarly, Keef and Roush (2002), found a small impact of temperatures on stock returns in New Zealand. For China, Kang *et al.* (2010) found a sign that is inconsistent with Ghana's case.

Table 4. Breusch-Pagan-Godfrey test

Test type	*F*-statistic	Obs**R*-squared
Value	1.199119	11.93860
Probability value	0.2929	0.2892

Note(s): $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 5. Ramsey reset test

Test type	*t*-Statistic	*F*-statistic
Value	0.782731	0.612668
Probability value	0.4347	0.4347

Note(s): $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 6. FMOLS regression results

VARIABLES	(1) FMOLS	(2) FMOLS	(3) FMOLS	(4) FMOLS	(5) FMOLS
Weather characteristics					
Wind speed	-0.0035^{***} (0.001)			-0.0026^{***} (0.001)	-0.0038^{***} (0.001)
Temperature	-0.0191^{***} (0.002)			-0.0052^{***} (0.002)	-0.0063^{***} (0.001)
Humidity	−0.0001 (0.001)			−0.0005 (0.000)	−0.0004 (0.000)
Control variables					
Market characteristics					
Lag effect		0.0860^{***} (0.018)			0.0783^{***} (0.007)
Lead effect			0.0940^{***} (0.013)		0.0896^{***} (0.007)
Macroeconomic variables					
Log CPI				-0.0955^{***} (0.010)	-0.0860^{***} (0.008)
Log Real GDP				0.9974^{***} (0.033)	0.9449^{***} (0.027)
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Constant	7.2844^{***} (0.084)	6.1203^{***} (0.119)	6.0675^{***} (0.088)	-1.0046^{***} (0.292)	-1.6926^{***} (0.238)
Observations	227	226	226	227	225
R-squared	0.965	0.965	0.974	0.968	0.977

Note(s): Dep Variable: log Stock Market Returns
Standard errors in parentheses, $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

In line with some of the evidences found in the literature, humidity is found to be negative (see Kang *et al.*, 2010) albeit, insignificant (Lu and Chou, 2012). It follows therefore that generally, measures of weather in an emerging economy like Ghana have averagely had a negative effect on the stock market returns.

In order to control for the possible effect of missing variable bias in the model, we included measures of stock market characteristics. The study included *lead* and *lag* effects as proxies for stock market characteristics. This is because according to Hou (2007), several empirical studies have shown evidence of *lead* and *lag* patterns. Three main reasons are provided in his work for such patterns and this include stock price-stickiness, time-varying expected returns and heterogeneous reaction to common market information. This is because, equity markets are generally characterised by frictions which impede the easiness in the transmission of information. To test them independently, a *lead* variable was included with the expectation that industry leading firms will drive industry following firms to impact positively on the stock market performance. With a *lead* coefficient of 0.0783%, we argue in line with expectation that there is an evidence of a positive and statistically significant association between expected future market performance and current market performance. Given a *lag* coefficient 0.0896%, we show an evidence of a positive and statistically significant association between past market performance and current market performance. The evidences provided show the presence of lead-lag effect is robust across estimated models.

Additional controls included in the model are macroeconomic variables. First, we included a measure of market volatility is proxied by consumer price index (CPI). As expected, the study has a statistically significant evidence that if CPI increases by one percent, the stock market performance will decrease 0.0860%. This implies that market volatility is deleterious to the stock market performance. In addition, a measure of the performance of the economy was included. In line with *a priori* expectation, we have a statistically significant evidence that if RGDP should increase by one percent, the stock market performance will simultaneously increase by 0.95%. This implies that a strong economy is an indication that the stock market will perform well.

6. Summary and conclusion

Ghana is a country characterised by tropical climatic conditions. Unfortunately, in recent times the patterns of Ghana's weather have remained very erratic leaving such an agrarian economy and an emerging stock market to the mercy of uncertainty in weather patterns. Scores of studies have established a positive relationship between erratic weather conditions and poverty. Similarly, evidences from empirical literature have shown a possible relationship between weather conditions (mainly measured by temperature) and stock market index through psychological factors. Unfortunately, no study to the best of our knowledge has investigated the relationship between disaggregated weather conditions and stock market prices in Ghana. This has become necessary given the fact that, currently, Ghana's stock market is regarded as one of the best performing markets on the continent. In addition, Floros (2011) has called for the relationship between other measures such as humidity and stock market performance to be investigated. This study attempts to provide a response to this call.

In this study, we model disaggregated measures of weather which includes humidity, temperature and wind speed to find out the extent to which each specific measure affects stock market performance. Although weather measures are generally considered as random and issues of reverse causality may not arise. However, given that the error term may capture missing variables to cause identification problems (e.g. endogeneity and serial correlation), we used the FMOLS econometric technique which seeks to address such identification challenges.

In line with *a priori* expectation, we found a statistically highly significant inverse relationship between all measures of weather except humidity which had the expected sign, albeit insignificant. This result is robust with and without relevant controls as well as time trends. In all, the findings support the assertion that weather factors can affect stock market performance directly or indirectly through psychological factors. However, we acknowledge that for a well-developed market with experts to handle possible weather-based anomalies, a different finding is possible. Nonetheless, for an emerging market, the present study serves as an eye opener to both existing and potential investors in stocks. Investors can benefit from becoming aware of their moods in order to avoid mood-based errors in their investment decisions. By way of recommendation, we argue that in as much as GSE is an emerging yet a well performing market, traders and investors of GSE need not assemble in the tropics to trade in stocks. Online trading with the aid of Internet can be explored. In as much as online options are being proposed, we also propose that measures should be put in place to making internet services in Ghana relatively cheaper and unstable as a way of promoting the GSE.

6.1 Suggestions for future studies

Future research may consider a comprehensive study to cover a number of markets in Africa. In addition, a study on a possible weather effect on foreign investors of stock markets in Ghana or Africa is worthy of study. Finally, we suggest a study that establishes a comparison between empirical results of developed and emerging markets. Lastly, an interaction between psychological factors that measures mood and weather is highly recommended going forward.

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Appendix

Notation	Variable	Brief description of data	Sources
SMR	Stock market index	Monthly GSE composite index used as proxy for stock market return	Ghana Stock Exchange
TEMP	Temperature	Monthly temperature	Ghana Meteorological Agency
WIND	Wind speed	Monthly wind speed	Ghana Meteorological Agency
HUMD	Humidity	Monthly humidity	Ghana Meteorological Agency
RGDP	Real gross domestic product	Monthly RGDP	Ghana Statistical Service
CPI	Consumer Price Index	Monthly consumer price index used as proxy for inflation	Bank of Ghana website (bog.gov.gh) Ghana Statistical Service website www.statsghana.gov.gh

Table A1. Description of variable and sources

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