Cloud cover and returns: aeromancy or anomaly?

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Abstract  
This thesis investigates the possible weather anomaly for the Stockholm Stock Exchange. In 1990 the Stockholm Stock Exchange changed its open outcry trading system into an electronic trading system. With an electronic trading system less traders are exposed to the same weather, this could affect the possible weather anomaly. Independently of the trading system however, cloud cover does not have an influence on index returns. Changes in cloud cover (today’s cloud cover minus yesterday’s cloud cover) does affect the stock market. However, no evidence was found that the relationship between changes in cloud cover and index return was affected by the introduction of electronic trading.
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1. Introduction

There is some extensive literature about the relationship between mood and local weather. Most papers come from the field of psychology, although economists have an interest in this phenomenon. Saunders (1993) was the first one who investigated if the weather-mood relationship was strong enough to influence the stock market. He found evidence that the weather in New York has an effect on the stocks listed at the New York Stock Exchange. Not all researchers were able to confirm the so called “weather effect” as found by Saunders (1993), but the majority was. Hirshleifer and Shumway (2003) even created a profitable trading strategy based on the weather effect.

For the weather effect it is important that a large group of investors are exposed to the same weather. For instance, in an open outcry trading environment trades are carried out physically at the stock exchange. With the introduction of electronic trading, traders no longer needed to be present at the stock exchange. If traders are more spread over the land, this could diminish the weather effect. Surprisingly, only one paper (Pardo and Valor 2003) took the trading environment into account when studying the weather effect. They wanted to see if the weather effect in Spain changed due to the introduction of an electronic trading environment. However, they could not find any evidence of the weather effect no matter which trading system was used.

The objective of this thesis is to research if the introduction of electronic trading changed the possible weather effect in Sweden. On the 30th of June 1990 the Stockholm stock exchange changed its open outcry trading environment to an electronic trading system. The weather effect will be studied both prior and after the introduction of electronic trading. Two studies will be conducted in this thesis. In the first study the relationship between cloud cover and index returns is researched. Also examined, is whether the introduction of electronic trading has affected this relationship. In the second study the relationship between index returns and changes in cloud cover (today’s cloud cover minus yesterday’s cloud cover) is examined.

The remainder of the thesis is organised as follows. Section 2 describes the current state of literature. Section 3 contains the main research question. In section 4 the methodology and empirical results of the first study will be presented. Section 5 contains the methodology and empirical results of the second study. Finally, section 6 contains the conclusion and recommendations.
2. Current state of literature
There are a number of studies, mainly from the field of psychology, that have showed a significant impact of weather conditions on human behaviour. Cunningham (1979), for example, found a positive correlation between sunshine and the generosity of the tip left for the waitress in a restaurant. Even when people were indoors, sunshine had a (minor) influence on the generosity of the tip and on the self-reports of mood. About 4% of the variation in mood was explained by sunshine if people were indoors. In another study (Lerner, J.S., Small, D.A. and Loewenstein, G., 2004) the impact of emotions on the endowment effect was studied. The endowment effect is the tendency for selling prices to exceed buying prices for the same object. The researchers showed that emotions have an influence on the endowment effect, even when real money was at stake. Bollen, Mao and Zeng (2011) showed that mood is correlated with the stock market. They analysed large-scale twitter feeds to determine society’s collective mood states. They were able to increase the accuracy of Dow Jones Industrial Average predictions.
Saunders (1993) showed that the weather-mood relation was so strong that it even had an effect on stock prices. His research focused on stocks that were listed on the New York Stock Exchange, which at that time used an open outcry auction format. He used cloud cover in New York as a measurement of the New York weather. Hours of sunshine is perfectly correlated with the absence of clouds cover, humidity and cloud cover are almost perfectly correlated and rain tends to fall on days with high levels of cloud cover. The Dow-Jones Industrial Average (DJIA) and NYSE/AMEX index, both equally and value-weighted, where used as portfolios on which the returns where measured. He found that on average, returns on cloudy days were lower than on days with a low cloud cover. Besides that, the percentage of positive returns on sunny days was greater than on cloudy days. A regression showed that cloud cover was significantly correlated with stock returns. Since the firms in the indices were dispersed across the U.S., the New York weather should have no effect on the returns. Besides that, in an earlier paper (Roll 1984) it was found that Florida weather surprises only explained a small fraction of the variation of orange juice futures prices, despite the fact that Florida weather was the most significant influence on the orange crop. Thus, the weather has a minor effect on security prices even when it was expected to matter most. This all considered, a rational explanation can be ruled out. Thereby proving that the New York Stock Exchange is not entirely rational as under the efficient market hypothesis.
A more recent paper (Hirshleifer and Shumway 2003) confirmed the effect of the weather on stock returns. This paper looked at stock exchanges in 26 cities around the world. The weather
has a strong seasonal pattern and to prevent that the results are driven by seasonal effects rather than cloud cover, the data was deseasonalized. This was done by subtracting the average cloud cover of the specific week from the daily mean cloud cover. Note, that the weather data is converted to weather surprises. A logit model showed that the probability of positive returns is inversely correlated with cloud cover. With an OLS regression the significant correlation between sunshine and stock returns was shown. After controlling for sunshine, the effects of rain and snow on returns are insignificant. The authors of the paper even developed a profitable trading strategy, although the profit mitigates away when trading cost are taken into account. The weather effect, with sunshine as its major driver, can thereby be seen as a global capital market anomaly.

Cao and Wei (2005) used a different weather variable in their research. They found that there was a negative correlation between temperature and stock returns. The negative correlation is significant, even after controlling for various known anomalies. It is also robust to alternative tests. Yet, temperature is highly seasonal, and thus it is unclear whether the researchers found a weather anomaly, a seasonal pattern as found by Bouman and Jacobsen (2002) or the SAD anomaly as found by Kamstra, Kramer and Levi (2003). Jacobsen and Marquering (2008) showed that all three of the previous mentioned papers explained the same seasonal anomaly, higher returns in winter and lower returns in the summer. It is impossible to say which of the three papers gave the true explanation of the found anomaly.

Other papers try to find the cause of the weather effect. In the paper of Loughran and Schultz (2004) the weather effect is combined with localized trading, the phenomenon that investors hold and trade more in local companies than in other firms. They found strong evidence of localized trading, but no evidence that local weather is correlated with stock prices. They did however, find weak evidence of lower stock returns and cloudy weather in New York. This could be caused by institutions based in New York, suggesting that the weather effects comes from institutional professional investors and not from small investors. Goetzmann and Zhu (2005) came to a similar conclusion. In their paper they looked at individual investor trading and local weather. They found no relationship between local weather and trading behaviour, even traders located in New York were not influenced by New York weather. They did however find a relationship between cloud cover and Stock returns. Besides that, spreads widen on cloudy days in New York. When this is included in a regression as a possible explanatory variable, the weather effect is greatly reduced. They conclude that the weather effect is caused by market-makers, rather than by individual investors. The most recent paper about the weather effect (Symeonidis, Daskalakis and Markellos 2010) found a relationship
between the weather and stock market volatility. Extreme weather and weather deviations from seasonal norms did offer additional explanatory power in their database. Some other papers however, found no relationship between stock returns and the weather. Trombley (1997) used the same data as Saunders (1993) did, and shows that the test statistics of Saunders are dependent on which returns are compared. Overall there is no significant difference between the returns on cloudy days and sunny days. Only in one of the three periods the weather effect reported by Saunders was found, and it was limited to only a few months per year. In a different paper (Krämer and Runde 1997) the weather effect for a German stock index, traded in Frankfurt, was examined. Depending on which test procedure was used, the way the variables were classified and how the null hypothesis was phrased, the hypotheses can either be significant or rejected. In other words, there is plenty of room for data mining. Overall, they found no weather effect for the German stock market, and concluded that any claims to the contrary might as well be due to a type I error.

Pardo and Valor (2003) tried to find the relationship between the weather effect and the trading environment, using sunshine hours and humidity levels as weather variables. Previous studies did not take the trading environment into account when examining the weather effect. Previous papers about the weather effect rely on the assumption that weather in a location is representative of all the market in that location. The assumption makes sense if trading is carried out physically at the exchange. With an electronic trading system, investors can trade remotely from any location, with different weather characteristics. In 1989 the Spanish market changed its open outcry trading system into an electronic system. Pardo and Valor wanted to compare the weather effect from before and after 1989. The daily (log) returns were separated into sunshine hours and humidity quintiles. If sunshine hours have an influence on the stock price, then the fifth quintile should have positive abnormal returns. If humidity influences stock prices then the fifth quintile will have negative abnormal return. They tested if all the volatilities of the quintiles are equal and if the mean daily return of each quintile was equal. This was done for both timeframes. Independently of the trading system however, they found no evidence of a weather effect in Spain.
3. Main research question

Most of the previous mentioned papers used data from the New York Stock Exchange, which has a Hybrid environment, a mix between open outcry and electronic trading. Also the majority of the datasets come from times when most exchanges had an open outcry environment. Perhaps there used to be a weather effect, but due to the massive adoption of electronic trading systems it diminished. So far only one paper took the trading environment into account. Unfortunately, they could not find any evidence of a weather effect prior and after the introduction of electronic trading.

With an electronic trading system it is possible to make share trades from any locations. Although no research was found about this subject, it is a reasonable assumption that most private investors are scattered across the land. No longer do they need be at the stock exchange or use a broker that is located at the exchange. So a large group of investors is no longer influenced by the weather at the exchange. On the other hand, it is unlikely that all major financial institutions suddenly moved away from the exchange after the introduction of electronic trading. In Sweden for instance, over 50% of all financial institutions are located in Stockholm or its suburbs (Sveriges Riksbank 2013). The other half mostly contains small banks and insurance-agents. Previous research suggest that the weather effect is caused by market-makers, of which the majority is still located near the stock exchange. Suggesting that the weather effect will not be influenced by the introduction of electronic trading systems. When the weather effect changes, or not changes, after the introduction of electronic trading, it could give weak indirect evidence about who caused it.

This thesis will give answers to the previously mentioned problems. Therefore, the main research question of my thesis is:

*Did the weather effect change after the introduction of electronic trading on the Stockholm Stock Exchange?*
4. First study: Cloud cover and index returns
This thesis will focus on the Stockholm stock exchange. On the 30th of June 1990 the Stockholm stock exchange changed its open outcry trading environment to an electronic trading system. The “weather effect” before and after the introduction of electronic trading will be examined and compared. In previous studies cloud cover or its inverse sunshine hours seemed to have the strongest relationship with index returns. Therefore, the influence of cloud cover on index returns is researched in this study. This study studies whether cloud cover has an influence on index returns and if this influence changes after the introduction of electronic trading.

4.1 Methodology
The timeframe for this research is from 1987 till 1990 and from 1991 till 2012. As in previous research about the weather effect, an index is used to determine the returns. Diversification will remove any unsystematic risk and thus noise for the research. The following all-share index is used: OMX Stockholm PI. This index contains all the shares that are listed on the Stockholm Stock Exchange. Price data for the index was downloaded from datastream. Daily returns are calculated as follows: \[ r_t = \log\left(\frac{P_t}{P_{t-1}}\right) \] where \( P_t \) and \( P_{t-1} \) are closing values of OMX Stockholm PI on days \( t \) and \( t-1 \), respectively.

Cloud cover is used as a parameter for the weather. Previous studies showed that cloud cover or its inverse sunshine hours has a relatively strong relationship with index returns. Temperature also seems to have a relatively strong relationship with index returns. However, temperature is highly seasonal and it is unsure if the relationship is caused by temperature or a seasonal anomaly as found by Bouman and Jacobsen (2002). Therefore, temperature is not used as a parameter for the weather. Cloud cover values range from 0 to 8, a 8 signifies cloud cover all day. Daily data about cloud cover is obtained from the European Climate Assessment & Dataset. The weather station used, is named Stockholm and is located at the edge of Vanadislunden, a big park area in Stockholm. The weather station is approximately 4 kilometer away from both the old and the new location of the exchange.

The daily returns are separated in nine quantiles, corresponding with each value of cloud cover. If cloud cover has an effect on returns, the mean return of at least one of the quantiles should be different from the rest. For both timeframes, a parametric F-test is used to determine if all mean returns are equal (\( H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 = \mu_7 = \mu_8 = \mu_9 \), where \( \mu_i \) is the mean return of the \( i \)th quantile). The parametric F-test is sensitive to
misspecification, which could cause type I or type II errors. Therefore, a non-parametric Kruskal-Wallis test is conducted, which does not make any assumption about the sample distribution (H₀: The location of the distribution is the same for all groups). It tests if the samples come from populations such that the probability that random observations from one group is greater than a random observation from another group is 0.5. The Kruskal-Wallis test is also conducted for both timeframes.

For the Kruskal-Wallis test the sample sizes should be at least 5 (Kruskal, W.H. and Wallis, W.A. 1952). For the F-test it is important that the sample means are normally distributed. According to the central limit theorem, this assumption is met when there are at least 30 observations. To ensure that the statistical tests compare the same groups, both tests are executed twice. One time with at least 5 observations per group and one time with at least 30 observations per group.

The previous tests only determines whether one of the quantiles is different from the others, but not if cloud cover and daily returns are correlated. Therefore, a simple OLS regression will be estimated for both periods:

\[ r_t = \alpha + \beta \cdot CC_t + Dummies + e_t \]

\(CC_t\) is the cloud cover at day \(t\). Dummies contains month dummies to control for any seasonal effect. To solve for autocorrelation within daily returns (Akgiray 1989), Newey-West standard errors with a lag of one are used. If cloud cover is correlated with daily returns the beta should be different from zero, this is tested with a t-test (H₀: \(\beta = 0\)).

According to the literature, cloud cover is inversely correlated with stock returns, the beta for the first period should therefore be negative. If the introduction of electronic trading had an influence on the weather effect, the beta for the second period should be different from the first period’s beta. To test this, a dummy variable and an interaction term is added to the regression. The dummy will be 0 if there is an open outcry trading environment and 1 for electronic trading. The dummy forms an interaction term with cloud cover. Please note, that this regression will be estimated over the entire timeframe (1987 - 2012).

\[ r_t = \alpha + \beta_1 \cdot CC_t + \beta_2 \cdot electronic + \beta_3 \cdot (electronic \cdot CC_t) + Dummies + e_t \]

Dummies contains month dummies to control for any seasonal effects. It also contains interaction terms between each dummy and the electronic-dummy. Newey-West standard errors with a lag of one are used to solve for autocorrelation between daily returns.
When the electronic-dummy is 0, there is an open outcry trading environment, the regression transform into:

\[ r_t = \alpha + \beta_1 \cdot CC_t + Dummies + e_t \]

And when the electronic-dummy is 1, there is an electronic trading system, the regression will transform into:

\[ r_t = (\alpha + \beta_2) + (\beta_1 + \beta_3) \cdot CC_t + Dummies + e_t \]

If the introduction of the electronic trading system did not change the linear relationship between cloud cover and daily returns, then \( \beta_3 \) should be zero. When it does change the correlation between the two variables, \( \beta_3 \) should be different from zero. A t-test determines if the difference is significant (H0: \( \beta_3 = 0 \)).
4.2 Empirical results

In table 1 the mean of each quantile for both timeframes are presented. The lower section of
the table shows the outcomes of the parametric F-test and the non-parametric Kruskal-Wallis

When looking at the first timeframe, the means of the first four quantiles seem to be
negatively correlated with the cloud cover values. The other quantiles however, do not show
any type of correlation. Furthermore, the statistical tests could not reject their respective null
hypothesis. Therefore, it cannot be concluded that at least one of the quantiles is different
from the others.

The quantile means of the second timeframe do not seem to be correlated with each other. It is
noticeable that the means lie closer to zero in the second timeframe than in the first
timeframe. Not surprisingly, both statistical test could not reject their respective null
hypothesis.

<table>
<thead>
<tr>
<th>Cloud cover</th>
<th>Observations</th>
<th>Mean (%)</th>
<th>Observations</th>
<th>Mean (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18</td>
<td>0,419</td>
<td>78</td>
<td>0,071</td>
</tr>
<tr>
<td>1</td>
<td>92</td>
<td>0,195</td>
<td>424</td>
<td>-0,006</td>
</tr>
<tr>
<td>2</td>
<td>74</td>
<td>0,120</td>
<td>421</td>
<td>-0,049</td>
</tr>
<tr>
<td>3</td>
<td>75</td>
<td>0,110</td>
<td>600</td>
<td>0,095</td>
</tr>
<tr>
<td>4</td>
<td>84</td>
<td>0,230</td>
<td>617</td>
<td>0,046</td>
</tr>
<tr>
<td>5</td>
<td>108</td>
<td>-0,137</td>
<td>701</td>
<td>0,020</td>
</tr>
<tr>
<td>6</td>
<td>109</td>
<td>-0,088</td>
<td>786</td>
<td>0,084</td>
</tr>
<tr>
<td>7</td>
<td>120</td>
<td>0,036</td>
<td>868</td>
<td>-0,026</td>
</tr>
<tr>
<td>8</td>
<td>210</td>
<td>0,069</td>
<td>1384</td>
<td>0,028</td>
</tr>
</tbody>
</table>

H0: Means of all groups are the same

<table>
<thead>
<tr>
<th>Min. observations</th>
<th>5</th>
<th>30</th>
<th>n.a.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of freedom</td>
<td>8</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>F-test</td>
<td>1,230</td>
<td>1,15</td>
<td>0,74</td>
</tr>
<tr>
<td>P-value</td>
<td>0,273</td>
<td>0,332</td>
<td>0,660</td>
</tr>
</tbody>
</table>

H0: The location of the distribution is the same for all groups

<table>
<thead>
<tr>
<th>Min. observations</th>
<th>5</th>
<th>30</th>
<th>n.a.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of freedom</td>
<td>8</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Kruskal-Wallis</td>
<td>13,357</td>
<td>10,586</td>
<td>5,342</td>
</tr>
<tr>
<td>P-value</td>
<td>0,100014</td>
<td>0,15773</td>
<td>0,720</td>
</tr>
</tbody>
</table>
Table 2 gives the results of the various regressions. For all timeframes, two regressions were estimated, one with and one without month dummies. As can be seen, the coefficient of cloud cover is negative in all regressions. Yet, the null hypothesis \( H_0: \beta = 0 \) can only be rejected for the second regression (Run over the first timeframe and without month dummies). As previously explained, month dummies are included to control for any seasonal effect. Jacobsen and Marquering (2008) showed that there is a seasonal anomaly, but that it is impossible to determine if it is caused by the weather. When month dummies are included, the coefficient becomes insignificant. Therefore, it is not sure if there is a weather anomaly or a seasonal pattern.

When looking at the regression with the interaction term and month dummies, it can be seen that the cloud cover coefficient is equal to the coefficient of the open outcry regression with month dummies. If the interaction coefficient is added up with the cloud cover coefficient, the coefficient of the electronic trading regression with dummies is obtained. Thus, the interaction term coefficient is the difference between the cloud cover coefficients of the first and second timeframe. The null hypothesis \( H_0: \beta_3 = 0 \) of the interaction model cannot be rejected, even when the month dummies are excluded from the regression.

In this study no evidence is found that cloud cover values of day \( t \) has an influence on the index returns of the same day in Stockholm. There is also no evidence that the relationship between cloud cover and index returns changes after the introduction of electronic trading.
Table 2: Regression analysis

This table contains the outcomes of the regression analysis. The first two regressions are run over the sample period from 1 January 1987 till 31 May 1990 when the Stockholm stock exchange had an open outcry trading environment. The third and fourth regression used a timeframe from 1 June 1990 till 31 December 2012, when an electronic trading system was used. The last two regressions were run over the entire timeframe from 1 January 1987 till 31 December 2012. The dependent variable is daily log return of OMX Stockholm PI for all regressions. The table shows the coefficients of the regressions. When month dummies were used, their coefficients are excluded from the table. Within brackets the respective t-values are given.

*significant at 10% level
**Significant at 5% level

<table>
<thead>
<tr>
<th>Independable variable</th>
<th>Open outcry</th>
<th>Electronic trading</th>
<th>Interaction model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month dummies</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Alpa</td>
<td>0.0031797</td>
<td>0.00187</td>
<td>0.0011909</td>
</tr>
<tr>
<td></td>
<td>(2.38)**</td>
<td>(2.54)**</td>
<td>(1.67)*</td>
</tr>
<tr>
<td>Cloud Cover</td>
<td>-0.0001744</td>
<td>-0.0002444</td>
<td>-0.0000579</td>
</tr>
<tr>
<td></td>
<td>(-1.16)</td>
<td>(-1.66)*</td>
<td>(-0.70)</td>
</tr>
<tr>
<td>Electr. dummy</td>
<td></td>
<td></td>
<td>-0.0019888</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-1.32)</td>
</tr>
<tr>
<td>CC*Electronic</td>
<td></td>
<td></td>
<td>0.0001165</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.68)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>889</td>
<td>889</td>
<td>5879</td>
</tr>
<tr>
<td>Adjusted R2</td>
<td>0.0104</td>
<td>0.0015</td>
<td>0.0015</td>
</tr>
<tr>
<td>P-value CC</td>
<td>0.244</td>
<td>0.098</td>
<td>0.482</td>
</tr>
<tr>
<td>P-value CC*Electronic</td>
<td></td>
<td></td>
<td>0.494</td>
</tr>
</tbody>
</table>
5. Second study: Cloud cover changes and stock returns.
In the previous study no evidence was found that cloud cover values at day t has an influence on index returns at day t. The weather of the previous day has not been taken into account. Keller et al (2005) found evidence that the weather-mood relationship is strongest in spring, because of the “depressing” winter that preceded it. Perhaps the weather effect is not caused by the weather of today, but by the changing of weather. If this is the case, a sunny day preceded by a cloudy day will have an influence on the index return, yet a sunny day preceded by another sunny day will have no influence.

5.1 Methodology
In the second study, the same data and timeframes as in the previous study are used. Except for the weather parameter, cloud cover is replaced by changes in cloud cover (changeCC). Changes in cloud cover is calculated as follows: \( \text{changeCC}_t = \text{CC}_t - \text{CC}_{t-1} \) where \( \text{CC}_t \) and \( \text{CC}_{t-1} \) are cloud cover values of days t and t-1, respectively. The range of the new variable is from -8 till 8.

Again, the index log returns are separated into quantiles. Each quantile corresponds with a specific value of the new variable; changes in cloud cover. The null hypothesis of equal means is tested with a parametric F-test. The Kruskal-Wallis test will determine if the location of the distribution of all groups is the same. The two statistical tests are conducted for both timeframes.

For the Kruskal-Wallis test the sample sizes should be at least 5 (Kruskal, W.H. and Wallis, W.A. 1952). For the F-test it is important that the sample means are normally distributed. According to the central limit theorem, this assumption is met when there are at least 30 observations. To ensure that the statistical tests compare the same groups, both tests are executed twice. One time with at least 5 observations per group and one time with at least 30 observations per group.

To detect any linear relationship between the index log returns and changes in cloud cover, a simple OLS regression with Newey-West standard errors is estimated for both timeframes:

\[
r_t = \alpha + \beta \cdot \text{changeCC}_t + Dummies + e_t
\]

\( \text{changeCC}_t \) is the change in cloud cover at day t with respect to cloud cover at day t-1. Dummies contains month dummies to control for any seasonal effect. Newey-West standard
errors with a lag of one are used. If changes in cloud cover is correlated with daily returns the beta should be different from zero, this is tested with a t-test ($H_0: \beta = 0$).

In a third regression a dummy variable that is 1 when electronic trading systems were used is added to the regression. Besides that, an interaction term between this dummy and changes in cloud cover is added to the regression. Please note that this regression will be estimated over the entire timeframe (1987 - 2012).

\[ r_t = \alpha + \beta_1 \cdot \text{changeCC}_t + \beta_2 \cdot \text{electronic} + \beta_3 \cdot (\text{electronic} \cdot \text{changeCC}_t) + \text{Dummies} + \epsilon_t \]

Dummies contains month dummies to control for any seasonal effects. It also contains interaction terms between each dummy and the electronic-dummy. Newey-West standard errors with a lag of one are used to solve for autocorrelation between daily returns.

If the introduction of electronic trading changes the linear relationship between daily returns and changes in cloud cover, than the beta of the interaction term will denote the difference. A t-test determines if the difference is significant ($H_0: \beta_3 = 0$).
5.2 Empirical results
In table 3 the mean return of each quantile for both timeframes is presented. In the first timeframe, the Kruskal-Wallis test changes a lot when more groups are compared. The test can reject its null hypothesis when only quantiles with at least 30 observations are compared. However, when quantiles with at least 5 observations are compared, the Kruskal-wallis test can no longer reject its null hypothesis. This is strange, because if one of the quantiles is different from another quantile, this would still be the case if more quantiles are compared. The most likely explanation is that at least one of the extra quantiles does not have the same distribution as the others. For the Kruskal-Wallis test to work, all the quantiles should have the same type of distribution. Therefore, the outcome of the Kruskal-Wallis test, when quantiles with at least 5 observations are compared, is not trustworthy.

When only quantiles with at least 30 observations are compared, both the parametric F-test as the non-parametric Kruskal-Wallis test reject their respective null hypotheses for the first period. At least one of the tested quantiles is different from the others. Suggesting there is a “weather effect” on the Stockholm stock exchange, before the introduction of an electronic trading system. For the second period, the statistical tests could not reject their respective null hypothesis. Although no evidence was found of a “weather effect” in the second timeframe, there is no hard evidence that the “weather effect” changes after the introduction of the electronic trading system. Further research is required to find more evidence.

Table 4 presents the results from the regression analysis. The regression coefficient of changes in cloud cover is negative in both the open outcry era as in the electronic trading time period. Yet, in the second timeframe the coefficient lies much closer to zero than in the first timeframe. Also, in the first timeframe the coefficient is significant at the 10% level, whereas in the second timeframe it is insignificant. The interaction model determines if the difference between the two time periods is significant. The interaction term coefficient is relatively large, but insignificant. The same results were found when the month dummies were excluded from the regressions.

The exclusion of the month dummies barely changed the coefficients of the regressions. Suggesting that changes in cloud cover does not follow any seasonal pattern.

In this study, evidence was found that there is a relationship between changes in cloud cover and index stock return when there was an open outcry trading environment. Although the coefficient was insignificant in the second timeframe, no evidence was found that the relationship changes after the introduction of electronic trading.
Table 3: Mean return of each quantile for both timeframes

This table shows the mean return in percentiles of each quantile for both timeframes. The first sample period is from 1 January 1987 till 31 May 1990 when the Stockholm stock exchange had an open outcry trading environment. The second sample period is from 1 June 1990 till 31 December 2012, when an electronic trading system was used. The lower section of the table shows the outcomes of both the parametric F-test and the non-parametric Kruskal-Wallis test, and their null hypothesis. Quantiles with less than 30 observations were excluded from the statistical tests. For each timeframe, the statistical tests are executed twice. One time with at least 5 observations per group and one time with at least 30 observations per group.

<table>
<thead>
<tr>
<th>Changes in cloud cover</th>
<th>1 January 1987 to 31 May 1990</th>
<th>1 June 1990 to 31 December 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observations</td>
<td>Mean (%)</td>
</tr>
<tr>
<td>-8</td>
<td>1</td>
<td>2,388</td>
</tr>
<tr>
<td>-7</td>
<td>9</td>
<td>-0,134</td>
</tr>
<tr>
<td>-6</td>
<td>12</td>
<td>0,299</td>
</tr>
<tr>
<td>-5</td>
<td>20</td>
<td>0,045</td>
</tr>
<tr>
<td>-4</td>
<td>35</td>
<td>0,547</td>
</tr>
<tr>
<td>-3</td>
<td>75</td>
<td>0,005</td>
</tr>
<tr>
<td>-2</td>
<td>79</td>
<td>0,093</td>
</tr>
<tr>
<td>-1</td>
<td>114</td>
<td>0,024</td>
</tr>
<tr>
<td>0</td>
<td>173</td>
<td>0,203</td>
</tr>
<tr>
<td>1</td>
<td>119</td>
<td>-0,184</td>
</tr>
<tr>
<td>2</td>
<td>92</td>
<td>0,257</td>
</tr>
<tr>
<td>3</td>
<td>49</td>
<td>-0,269</td>
</tr>
<tr>
<td>4</td>
<td>34</td>
<td>0,061</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>-0,150</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>-0,282</td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td>0,117</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>-</td>
</tr>
</tbody>
</table>

H0: Means of all groups are the same

<table>
<thead>
<tr>
<th></th>
<th>5</th>
<th>30</th>
<th>5</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. observations</td>
<td>14</td>
<td>9</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Degree of freedom</td>
<td>1</td>
<td>0.050</td>
<td>0.009</td>
<td>0.474</td>
</tr>
<tr>
<td>F-test</td>
<td>1,71</td>
<td>2,470</td>
<td>0,98</td>
<td>1,120</td>
</tr>
<tr>
<td>P-value</td>
<td>0,050</td>
<td>0,009</td>
<td>0,474</td>
<td>0,340</td>
</tr>
</tbody>
</table>

H0: The location of the distribution is the same for all groups

<table>
<thead>
<tr>
<th></th>
<th>5</th>
<th>30</th>
<th>5</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. observations</td>
<td>14</td>
<td>9</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Degree of freedom</td>
<td>1</td>
<td>0.158</td>
<td>0.027</td>
<td>0.371</td>
</tr>
<tr>
<td>Kruskal-Wallis</td>
<td>19,196</td>
<td>18,820</td>
<td>16,163</td>
<td>15,857</td>
</tr>
<tr>
<td>P-value</td>
<td>0,158</td>
<td>0,027</td>
<td>0,371</td>
<td>0,257</td>
</tr>
</tbody>
</table>
Table 4: Regression analysis

This table contains the outcomes of the regression analysis. The first regression is run over the sample period from 1 January 1987 till 31 May 1990 when the Stockholm stock exchange had an open outcry trading environment. The second regression used a timeframe from 1 June 1990 till 31 December 2012, when an electronic trading system was used. The third regression was run over the entire timeframe from 1 January 1987 till 31 December 2012. The dependent variable is daily log return of OMX Stockholm PI for all regressions. The table shows the coefficients of the regressions, excluding the seasonal dummies. Within brackets the respective t-values are given.
*significant at 10% level
**Significant at 5% level

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Open outcry</th>
<th>Electronic trading</th>
<th>Interaction model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month dummies</td>
<td>Yes (Yes)</td>
<td>No (Yes)</td>
<td>Yes (Yes)</td>
</tr>
<tr>
<td>Alpa</td>
<td>0,0022771</td>
<td>0,000621</td>
<td>0,0002771</td>
</tr>
<tr>
<td></td>
<td>(2,17)**</td>
<td>(1,47)</td>
<td>(2,18)**</td>
</tr>
<tr>
<td>Changes in Cloud Cover</td>
<td>-0,0002866</td>
<td>-0,0002841</td>
<td>-0,0002866</td>
</tr>
<tr>
<td></td>
<td>(-1,88)*</td>
<td>(-1,87)*</td>
<td>(-1,89)*</td>
</tr>
<tr>
<td>Electr. dummy</td>
<td></td>
<td>-0,0014581</td>
<td>-0,0003326</td>
</tr>
<tr>
<td></td>
<td>(-1,24)</td>
<td>(-0,72)</td>
<td></td>
</tr>
<tr>
<td>changeCC*Electr.</td>
<td>0,0002475</td>
<td>0,0002461</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1,48)</td>
<td>(1,48)</td>
<td></td>
</tr>
<tr>
<td>Number of observations</td>
<td>866</td>
<td>866</td>
<td>5795</td>
</tr>
<tr>
<td></td>
<td>5795</td>
<td>5795</td>
<td>6661</td>
</tr>
<tr>
<td></td>
<td>6661</td>
<td>6661</td>
<td></td>
</tr>
<tr>
<td>Adjusted R2</td>
<td>0,0155</td>
<td>0,0031</td>
<td>0,0017</td>
</tr>
<tr>
<td></td>
<td>-0,0001</td>
<td>0,0026</td>
<td>0,0001</td>
</tr>
<tr>
<td>P-value changeCC</td>
<td>0,061</td>
<td>0,062</td>
<td>0,568</td>
</tr>
<tr>
<td></td>
<td>0,58</td>
<td>0,059</td>
<td>0,062</td>
</tr>
<tr>
<td>P-value changeCC*Electr.</td>
<td>0,138</td>
<td>0,14</td>
<td></td>
</tr>
</tbody>
</table>

6. Conclusion and recommendations

In the first study, the relationship between cloud cover and index returns was examined. Both before and after the introduction of an electronic trading system, no evidence was found that cloud cover values at day t has an influence on index returns at day t. Only when month dummies were excluded from the regression, the cloud cover beta in the first period became significant at the 10% level. However, it is not sure if there is a weather anomaly or a seasonal pattern.

In the second study, a new weather parameter was used. Cloud cover was replaced by changes in cloud cover. The theory was that the weather effect is strongest when the weather changes. A sunny day preceded by a clouded day has a bigger impact on mood compared to a sunny day preceded by another sunny day. With the new parameter some evidence of a weather effect was found. For the open outcry era, the parametric F-test and the Kruskal-Wallis test were able to reject their respective null hypothesis of equality of means and same distribution location of all groups. However, when quantiles with at least 5 observations were added to the Kruskal-Wallis test, it became insignificant. Most likely because one of the new quantiles does not has the same distribution as the other quantiles. Therefore, the result of this specific Kruskal-Wallis test was untrustworthy.

For the second timeframe, an electronic trading system was used, the statistical tests could not reject their respective null hypothesis. The regression analysis showed that changes in cloud cover and index returns are correlated during the first timeframe. The regression coefficient had a p-value of 0.059 and was significant at the 10% level. The regression coefficient in the second timeframe was insignificant. However, this does not mean there is a difference between both timeframes. The null hypothesis that the relationship between changes in cloud cover and index return was affected by the introduction of an electronic trading system, could not be rejected.

The results suggest that there still is a weather effect on the Stockholm Stock Exchange. When assuming that most investors are scattered across the country, but most institutions are still located in Stockholm, it could indicate that financial institutions and not private investors caused the weather effect. However, other explanations are also possible. Over 8% of the Swedes live in Stockholm and over 20% of the Swedes live in the agglomeration Stockholm (Statistics Sweden 2013). A large group of private investors live in Stockholm and could cause the weather effect. Although, this theory contradict with the findings of Goetzmann and Zhu (2005).
Whoever causes the weather effect, why have rational investors not acted against it? Hirshleifer and Shumway (2003) developed a profitable trading strategy based upon the weather. Yet, the trading costs of this strategy are higher than the profits. Therefore, rational investors will not adopt this strategy, because no profits can be made with it.

In future research a larger dataset should be used. The dataset should contain data from multiple exchanges which changed their trading environment. This will provide more evidence about the impact of electronic trading on the weather effect. Changes in cloud cover should be used as a weather parameter, since it has more impact on the stock exchange. Also it does not seem to follow a seasonal pattern.

The weather effect is not a big anomaly. The weather only has a very small impact on index returns and due to transaction costs it cannot be exploited. Previous studies showed that the weather only explains a small proportion of the variation in mood when people are indoors. Yet, it still has an effect on the stock market, even when not all investors are exposed to the same weather. What happens when events happen that have a larger impact on mood? It is unlikely that these events influence a large group of investors simultaneously, but on the individual level there might be some consequences. What kind of investment decisions does a pension fund manager make when he is in the middle of a divorce, or a trader who hears he is going to be a father. The possible investment decision-mood relationship might not have a big impact on the stock market, but could have a large impact on individual portfolios.

More research about this subject needs to be done. Ideally, self-reports on mood from investors should be compared with their investment decisions. Preferably, the investors work at active managed funds or trade on a regularly bases.
References


