A Work Project presented as part of the requirements for the Award of a Master's degree in Management from the Nova School of Business and Economics.

THE GRETA THUNBERG EFFECT:

AN ANALYSIS OF CORPORATE TWEETS

ON CLIMATE CHANGE

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And if a few children can get headlines all over the world just by not going to school, then imagine what we could all do together if we really wanted to. You only speak of green eternal economic growth because you are too scared of being unpopular.

Greta Thunberg, Katowice, December 12th, 2018.

Abstract

The debate on climate change has increasingly attracted attention. Although Twitter provides valuable insights into the climate change discussion and how it is reflected in companies' communication behavior, previous research has only examined public opinion. This is the first study that analyzes corporate climate change tweets under the influence of climate activist Greta Thunberg. We register and code the volume and sentiment of tweets from German DAX30 companies and Greta Thunberg between 2016 and 2020. The findings reveal a significant relation between corporate climate change tweets and Greta's tweets. Furthermore, we identify an overall positive sentiment for corporate tweets.

Key words: Corporate Twitter Use, Climate Change, Greta Thunberg, Twitter, Sentiment Analysis.

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Introduction

Around 2900 cities in 160 countries and a total of 1.4 million protesters in Germany alone: these figures gauge the social impact of the global climate strike on September 20, 2019. The strike was initiated by the Swedish climate activist Greta Thunberg and *Fridays for future*, her global network of pupils and students against climate change (Tagesschau.de, 2019a). On that day, 63% of respondents of a survey from the national public broadcaster prioritized climate protection over economic growth. Young people, higher educated and female respondents in particular, favored fighting climate change (Tagesschau.de, 2019b). When asked how to combat climate change, 38% of Germans said it would be the responsibility of businesses and industry (Eurobarometer, 2017).

Climate change refers to global climatic changes on our planet. The term anthropogenic climate change is also used because, as almost the entire scientific community agrees, it is partly human-induced, inter alia, through greenhouse gas emissions (Houghton et al., 2001). Greta Thunberg has contributed decisively to bringing climate change into the focus of public opinion, especially in Germany, the country with the most *school strikes for climate* (Fridaysforfuture.org, 2020). Since Greta's first tweet in June 2018, she has reached over 4 million followers on Twitter. However, the discussion on climate change is highly emotional (Höijer, 2010), as is the controversy over Greta, which attracts both support and opposition to her efforts. With the increasing public attention, both online (Kirilenko and Stepchenkova, 2014; United Nations (UN) Global Pulse, 2015) and offline (UN Development Program, 2020), corporations experience increased pressure and face a responsibility to act (Levy, 2005; Porter and Kramer, 2011). Corporate climate action is often limited to decarbonization measures (Sarasini and Jacob, 2014; Krabbe et al., 2015). However, corporate climate action can be used in a broader sense as a subcategory of Corporate Sustainable Responsibility (CSR) (Brenner & Molander, 1977; Roberto & Mariano, 2004; Sdrolia & Zarotiadis, 2019). Throughout this paper

it therefore means that companies "integrate (…) environmental (…) concerns into their business operations and core strategy in close cooperation with their stakeholders" (European Commission, 2011, p.1). This definition, covering all environmental concerns, such as reducing pollution, operating resource-efficiently and protecting natural capital, better intersects with the topics pointed at by Greta Thunberg. With the growing use of the internet as a communication platform, social networks such as Twitter gain users and importance. Hence, companies feel the need to join this trend to increase their visibility (Cho et al., 2016). Globally, Twitter lists 340 million accounts (Kemp, 2020) with Germany ranking number 18 among the countries with most users. Nevertheless, very little research has covered German Twitter data.

This project adds to the literature by presenting an original approach to research corporate communication in social media and the role of climate activists as opinion leaders. This is the first study that evaluates the climate change related tweets of companies and their sentiment under the influence of Greta Thunberg to reveal whether a *Greta Thunberg effect* exists, such that it impacts corporate tweeting behavior, either in its volume or sentiment. We coded a novel and extensive dataset of tweet characteristics by listed German companies and Greta Thunberg.

The work project is structured as follows. After the introduction, a brief overview of previous literature is given. Chapter two explains the methodology. Hereby, the research question, data processing as well as the experimental methodology of volume and sentiment analysis are described in detail. Subsequently, the findings are discussed in chapter three. Finally, a reflection on the results assists to draw a conclusion and make recommendations.

Literature Review

In the following chapter, the significance of Twitter and related fields of research on corporate climate change action and reporting are outlined and the climate activist Greta Thunberg is introduced. No previous studies have captured corporate sentiment on climate change in Germany through text mining Twitter, although Germany is the European country with the third

most climate change related tweets per day (Kirilenko and Stepchenkova, 2014).

Twitter and its importance in social sciences

Twitter is a social media platform used by private and professional accounts to exchange views on politics, news, and trends with a global community (Kwak et al., 2010; Anuprathibha & Selvib, 2016). Short messages, so-called tweets, which contain text, hyperlinks and images, form a micro-blog. Information is posted instantly and; hence, a valuable and timely insight is given. The change of the initially asked question, from *What are you doing?* to *What's happening?* (Reinhardt & Ebner, 2009), shows how Twitter plays a crucial role in the evolution from print media to internet-based news portals. While users were previously encouraged to focus on private updates, the new question requires them to report on their perception of their environment (Ebner et al. 2010). Besides, the maximum number of characters per tweet has been doubled from 140 to 280 (Cody et al., 2015; Haunschild et al., 2019), providing twice as much space for content.

Likewise, this shift offers additional opportunities for companies. They use the internet to exchange information and connect with all kinds of stakeholders. On Twitter, companies can passively seek for information regarding what stakeholders care about but also actively shape their reputation through corporate accounts e.g. with regard to their environmental actions (Fieseler, Fleck &Meckel 2010). 96% of the Fortune 500 companies manage an active Twitter account (Barnes, Mazzola, and Killeen 2020). Having identified a positive effect of Twitter engagement on overall sales, Barnes (2013) recommends companies to focus their social media activities towards it. Unlike companies themselves, CEOs are less present on Twitter, but the ones that are, achieve high stakeholder interaction (Capriotti and Ruesja 2018). This demonstrates stakeholders' demand for engagement on Twitter. Certain groups have also power on twitter, as tweets from consumer associations and trade unions, have a significant negative influence on the stock price and trading volume (Gomez-Carrasco & Michelon, 2017).

Several studies covered the public discussion of climate change on Twitter. In 2014, a daily base volume of 140,000 English-language climate change tweets was estimated. Outstanding was the peak in positive sentiment on World Environment Day, on June 5th (UN Global Pulse, 2015). Dahal, Kumar & Li (2019) carried out a volume and sentiment analysis as well as topic modelling to evaluate public climate change tweets. Their results suggest a negative global sentiment, especially if tweets co-occur with political events such as the United States (US) withdrawal from the Paris Agreement or extreme weather events such as hurricanes. They noted a lack of consensus on the climate change issues in different geographical areas. In Australia the most discussed topic is energy, in the United Kingdom it is the ecological footprint and, in the US, people talk most about hurricanes. Koenecke & Feliu-Fabà (2019) identified that extreme weather events increase the amount of climate change affirming tweet sentiment in the US. In Australia, climate change affirming users communicate more with likeminded users (Pearce et al., 2014). Leas et al. (2016) discovered that a single person can influence the conversation about climate change on twitter. The *DiCaprio effect* describes an abnormal significant increase in climate-related tweets after actor Leonardo DiCaprio had mentioned climate change in his speech at the 2016 Oscars.

Climate change action of the DAX30 companies

Scientific requirements to decarbonize society, presented at the International Panel on Climate Change (IPCC), have put climate change on the agenda of political and business leaders (IPCC, 2007). The associated challenges (Ramanathan & Feng, 2008) require companies to adjust strategies and operations (Weinhofer & Hoffmann, 2010; Downie & Stubbs, 2012). The 2015 Paris Climate Agreement has been crucial in setting new targets on carbon emissions for participating countries (IPCC, 2014; UNFCC, 2015) being the basis for several regulations that affect companies strategies and financial returns (Tsalis & Nikolaou, 2017; Pham et al., 2019; Cadez, Czerny & Letmathe, 2019; De Sousa Jabbour, Vazquez-Brust, Jabbour, & Ribeiro,

2020). Germany has presented itself as a pioneer in climate protection and set successive sectoral targets to achieve greenhouse gas neutrality by 2050, as confirmed in the *Climate Action Plan 2050* (BMU, 2016). Despite an increasing number of regulations, market stakeholders, such as employees, customers, and investors as well as non-market stakeholders, such as activists, citizens, and governments demand climate-friendly practices beyond regulatory compliance (Delmas &Toffel, 2004; Reid & Toffel, 2009). Particularly in Germany, an increasing demand for sustainable finance, led to the creation of a new Environmental Social and Governance (ESG) DAX50 Index in March 2020 (Deutsche Börse 2020).

But not all stakeholders are equally powerful (Cadez et al., 2019). Following the stakeholder theory (Freeman 1984) a firm's actions against climate change are motivated by the pressure and demands of its stakeholders (Fieseler et al., 2010; Cadez et al., 2019; Zhang & Zhu, 2019). Stakeholders are affected by while also themselves influencing organizations. Depending on organizational characteristics and the issuer of the institutional pressure, companies participate in governmental programs, comply with voluntary standards of Non-governmental organizations (NGOs) or directly interact with customers and suppliers (Delmas & Toffel, 2012). Moreover, companies respond to stakeholder pressure with green innovations, both product- and process-related (Zhang & Zhu, 2019). Firms that adjust their overall strategy also enhance their performance towards reducing emissions (Banerjee, 2002; Cadez et al., 2019). To create visibility for climate change actions, stakeholders need to be informed. Annual reports present a higher number of environmental topics than corporate webpages. The opposite happens for other CSR topics (Branco & Rodrigues, 2008).

Some preliminary work was carried out on sustainability reporting in Germany. Kilian & Hennigs (2011) reviewed the annual reports of DAX30 companies for CSR activities between 1998 and 2009. For environmental topics, stakeholder- and value-oriented communication had increased in contrast to performance-oriented communication which suggests effective

stakeholder pressure on DAX30 companies. The findings also reflect increasing relevance of sustainability reporting although no uniformity among companies was observed (Greiwe & Schönbohm, 2011; Dietsche, Lautermann & Westerman, 2019). Previous results on DAX30 companies must be viewed with caution as index membership varies over time (*Appendix 2*).

The Greta Thunberg effect

Greta Thunberg is a Swedish climate activist. In August 2018, amid the hottest summer in Sweden, and at the age of 15, Greta started her climate strikes by stopping to go to school on Fridays (Thunberg, 2019). Shortly after, Greta gained broad media coverage and inspired pupils and students to join her campaign known under the hashtag *#FridaysForFuture*. Today *Fridays for future* represents an international youth movement, characterized by a series of about 60.000 school strikes in over 200 countries (Fridaysforfuture.org, 2020). But it is not solely the young generation that listens to her. On Twitter, where Greta generated positive and negative sentiment paired with political polarization (Jung et al., 2020), influential accounts mention her to underscore and make visible their own position and opinion. Examples include various media channels like *The New York Times Media* or *BBC News (World) Media*, political leaders such as *Barack Obama*, private sector executives such as *Elon Musk* and civil rights activists (Jung et al., 2020). The internet can function as a suitable platform where unheard and financially underprivileged groups can give their opinion a voice (Amichai-Hamburger, McKenna & Tal, 2008). In fact, Twitter is the reason for Greta to be heard by a global audience. Greta Thunberg has accumulated over 4 million followers in less than two years. Compared to her, 2014 Nobel Peace Prize laureate and female rights advocate Malala, who also started her activism as a teenager, accumulated only 1.6 million twitter followers (Twitter, 2020a). Greta Thunberg was elected Time's person of the year 2019 for creating a global climate change global movement (Alter, Haynes &Worland, 2019) and nominated for the Nobel Peace Prize. Greta's speeches at conferences such as the UN Climate Summit achieved global reach with phrases like *How dare*

you? or *Our house is on fire* (Jung et al., 2020).

Her influence was reported as the Greta Thunberg effect for several issues. Swedes minimized their domestic flights inspired by Greta's call upon reducing greenhouse gas emissions (The Economist, 2019). In the UK, the effect caused an increase in children's use of social media for activism, and businesses investing four times more in carbon offsetting to reduce their climate impact (The Guardian, 2019). Bucchi (2020) describes the change in the communication of scientific topics and the improvement of public perception of nature and climate change as the *Greta effect*. 78% of the employees in CSR responding the *Sustainable Business Leadership Survey 2020*, agreed that *the Greta Effect* has helped to raise attention on corporate sustainability. (Edie, 2020). On January 11, 2020, Greta actively asked Siemens to close a project because of its negative climate impact whereupon a German representative of *Fridays for the Future* was offered a position in the Siemens supervisory board, which she rejected (Twitter, 2020b; Die Welt, 2020). Later that month, Greta attended the World Economic Forum (WEF) in Davos for the second time in a row, where she called on companies to take climate change seriously and to stop using fossil fuels. This marks a peak in the international attention Greta Thunberg has received and the endpoint of this study.

Methodology

After the thematic background above, this section explains the research method. In particular, we formulate the research question and present the strategy for data processing. After those steps, two separate analyses were conducted: a volume analysis and a sentiment analysis. For both analyses, Pearson correlation values and linear regressions were calculated.

Research question

A common limitation of previous research is the unclear impact of communicating climate change topics to stakeholders (Branco & Rodrigues, 2008; Kilian & Hennigs, 2011; Cadez et

al., 2019). Research has mainly focused on the information published by the issuer rather than the visibility to and the response of the recipient. Annual reports and corporate webpages attract mostly investors and the financial community (Esrock & Leichty, 2000) while social media enables organizations to interact with a wide range of stakeholders (Kaplan & Haenlein, 2010). Hence, this study focuses on Twitter where visibility and response rate are ensured and measured in tweets marked as favorites, retweets, and followers. The DAX index contains the shares of the 30 largest and most liquid German companies, which together account for around 80% of Germany's stock market capitalization. DAX30 companies are assumed to be more active on Twitter than smaller companies as pointed in earlier studies of organizational theory, which imply that a company's characteristics determine visibility (Bowen, 2000). Visibility, measured in media observation, increases with the size of a company. With greater media observation, the stakeholder pressure intensifies and therefore large companies tend to respond more actively to climate change issues (Sharma & Nguan, 1999; Branco & Rodrigues, 2008; Morales-Raya, Martín-Tapia & Ortiz de Mandojana, 2019). Due to the leading role of DAX30 companies, their analysis is expected to provide information on far-reaching trends in the corporate use of social media for climate change communication in Germany. So far, the most influential stakeholders identified were market stakeholders and regulators (Cadez et al., 2019).

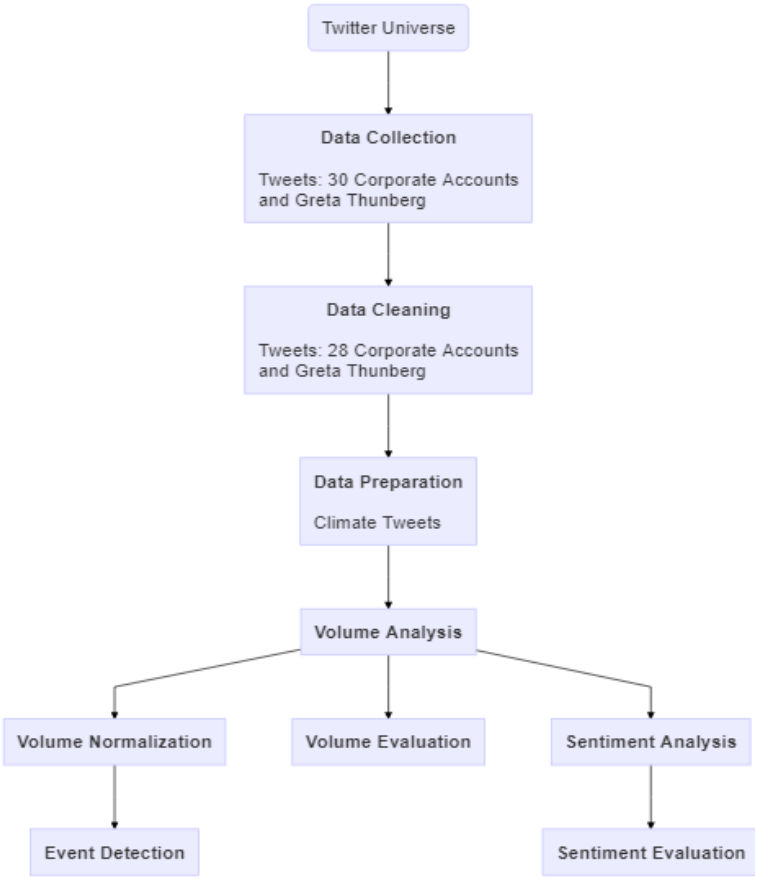

Figure 1: Research Workflow

With the global attention on the persona Greta Thunberg, the question arises whether and to what extend she has impacted the importance of climate change topics. The purpose of this study is to investigate whether a *Greta Thunberg effect* exists, such that it impacts the tweeting behavior of companies, either in its volume or sentiment. However, with this research being pioneering, several questions need to be answered first. The volume analysis provides insights on how often DAX30 companies tweet and whether the share of climate change related tweets varies over time and correlates with events organized or tweets published by Greta Thunberg. The sentiment analysis answers whether the sentiment of total corporate tweets differs significantly from that of climate change related corporate tweets (further as *climate change tweets*). Additionally, it shows whether the corporate and Greta Thunberg's tweet sentiment are related. The research workflow is visualized in *Figure 1*.

Data processing

The process of data collection, treatment and organization consisted of several steps. First, the tweet data of relevant Twitter profiles was collected through data scraping techniques. Second, the raw data was structured, cleaned, and checked for completeness. Finally, the data was prepared, and a subset of data pertinent to climate change issues created.

Data Collection In a first stage, tweets of the DAX30 companies and Greta Thunberg were derived from Twitter using the getoldtweets3 package in Python (Mottl, 2018; Henrique, 2017; Van Rossum & Drake, 1995). The official Twitter Application Programming Interface (API) permits only to derive tweets of the last seven days. However, the getoldtweets3 package allows to scrape all tweets from an account's timeline in a defined period. This is legally allowed for academic research since the data is publicly accessible. The scraping process was repeated, and the data saved for all accounts individually but compiled afterwards. Tweet data collected consists of the publishing date and time, account name, tweet text, and the number of favorites and retweets (*Appendix 3*). Favorites describe the number of users who show their consent and

retweets the number of users who share the message in their own account. Retweets of the relevant accounts were not considered, so only organic tweets published by the user itself were scraped. The reasons are that a user cannot control content, volume, and timing or sentiment of a retweet. The period of observation ranges from January 1, 2016, or upon account creation, to January 31, 2020. Greta Thunberg created her account on June 21, 2018 with the beginning of her climate strikes. Tweets are equally timestamped as all accounts are located either in Germany or Sweden. The companies selected were those listed in the DAX30 index in January 2020. The last change to the index occurred in September 2019. Previous literature has not mentioned whether index membership per se is related to a higher tweeting activity. As membership is relatively constant, this aspect has been neglected.

Data Cleaning The identification of official Twitter accounts is based on the Twitter search tool and the links on the company's website (*Appendix 2*). All 30 companies have a Twitter account[1] and 26 mainly tweet in English (over 80% of the tweets contain English language[2]). Three accounts[3] are dominated by German language. A balance is needed between a representative data set and accuracy in the sentiment analysis, which is based on an English vocabulary. Automated translation was not used, as it decreases the accuracy of sentiment measurements (Brooke, Tofiloski, and Taboada 2009). Hence, the largest German dominated account, Deutsche Telekom (*@deutschetelekom*), was excluded. Accounting for 7.5% of the dataset, it would substantilly reduce the quality of the sentiment analysis. Heidelberg Cement (*@the_hc_group*) was excluded as it has not published any tweet. In summary, the dataset covers 101,382 tweets of 28 DAX30 companies and 1,314 tweets of Greta Thunberg. For the

[1] All accounts are official accounts as declared by Twitter. Exceptions are Fresenius, Fresenius Medical Care and MTU. Still, the account description labels them as corporate account. If several official accounts exist, the English language account was chosen (@DeutscheBank, instead of @DeutscheBankAG). Furthermore, for the Lufthansa AG, two official accounts were found. @lufthansaNews was chosen because it is linked from the group's website.
[2] The language of tweets was identified using the textcat package (Hornik et al. 2013).
[3] Deutsche Telekom (8.164 tweets), RWE (3.292 tweets), and MTU Aero Engines (84 tweets).

sentiment analysis, further data cleaning steps were undertaken to exclude words not conveying any sentiment such as pronouns and articles, as shown in *Appendix 4*. The cleaning process reduced the initial amount of 2,174,564 words contained in corporate tweets to 1,156,402 words and the 24,613 words of Greta's tweets to 11,628 words.

Data Preparation We developed an original, purpose-built dictionary in R (R Core Team 2013) to classify tweets into climate and non-climate related. It is tailored to both corporate and Greta Thunberg related topics and incorporates insights from previous literature as displayed in *Appendix 5*. The final list of keywords intersects with the *Taxonomy for studying Climate Change tweets* of the UN Global Pulse (2015) and the list by Dahal et al. (2019) who both researched public opinion on climate change. According to Dahal et al. (2019) the word *emission* happens to be a false positive, occurring often in non-climate change tweets, hence it was not included. Even though our dictionary was applied in an unsupervised design, further keywords were identified from a manual review of a random sample of 1,000 tweets. After the first classification, another random sample of 1,000 tweets was taken to control for the right identification of climate change tweets (Dahal et al., 2019). All sampled tweets were assigned correctly. Applying the final dictionary to categorize all corporate tweets resulted in a subset consisting of 6,257 climate change tweets from 28 accounts. For tweets of Greta Thunberg, this separation was not made. The assumption is that Greta herself reflects the climate change movement and all her tweets carry this effect.

Volume analysis

The volume analysis is a critical first step to explore a dataset and can bring compelling insights (Dahal et al., 2019). It is performed to determine account-specific and temporal facts about the data set and to present the relation of total and climate change tweets. In addition, the visualization of the 25 most common words in a wordcloud, shall reveal some of the topics discussed. The more frequent a word occurs, the larger its representation in the wordcloud

(Fellows, 2018). Hashtags are included as they are part of the tweet text. To account for the increasing use of Twitter and the growing volume of tweets over time, data can be normalized, relating it to the number of total tweets in Germany. Although the figure for Germany is not known, with over 400 million tweets per day globally (Worldometer, 2020), the amount of data can neither be scraped nor handled within this project. Therefore, the volume analysis focuses mostly on absolute values. Only in the event detection, climate change tweets are looked at from a normalized perspective. Therefore, the number of climate change tweets in week *t* is divided by the number of total tweets in week *t* (*Appendix 6*). No adjustments have been made to compensate differences in tweet volume by account to preserve the holistic perspective of the group of DAX30 companies. Accordingly, companies with high tweet activity have more salience. This represents authentically a user's perspective following all accounts on Twitter.

Sentiment analysis

The sentiment analysis is performed to uncover the emotional content and polarity of the tweet text and compare across Twitter accounts (Muhammad et al., 2016). In human interaction, the brain automatically evaluates the emotion of a statement. For the written text, a lexicon-based, unsupervised sentiment approach was used. The sentiment lexicon is a list of words. Whenever one of these words occurs in the text sample, a sentiment from a preconstructed sentiment classification is assigned to the word (Öztürk & Ayvaz, 2018). The NRC Lexicon or EmoLex (Mohammad & Turney, 2010) is one of the most comprehensive lexica that consists of 14,182 English words, constructed using a public questionnaire on Amazon's crowdsourcing website Mechanical Turk. Each word was manually assigned to either of two polarity classifications *positive* or *negative* and eight emotions *anger*, *anticipation*, *disgust*, *fear*, *joy*, *sadness*, *surprise*, *trust* with a binary indicator - 0 for not associated, 1 for associated (Mohammad & Turney, 2012). These eight basic psychological emotions are based on the psychological concept of Plutchik's wheel, which frames emotions to be either interrelated such as anticipation and joy

or opposing such as joy and sadness. We used the NRC Emotion Lexicon in combination with the Tidytext package (Silge & Robinson, 2017) following Kušen & Strembeck (2018). Tidytext assesses the sentiment of a text as the sum of the individual sentiments of words. This is especially useful for the evaluation of short tweets which are technically restricted in the number of characters. The workflow of the sentiment analysis is shown in *Appendix 7*. To undertake the analysis, each tweet text was split into a list of single words to which sentiment values were assigned. The overall sentiment of each tweet consists of the aggregated sentiment values of its words. We hereby created polarity and emotional values. The sentiment analysis can only consider words in a string format, i.e. images or links do not imbue any sentiment. This analysis is carried out on a daily and a weekly basis, and specific tweet sentiments measured for each period. Sentiment scores were not normalized. Average scores would allow to compare several days, independently of the tweet volume. However, as the lexicon assigns binary emotion indicators, the sentiment intensity of messages repeated in several tweets would be lost. Therefore, instead of normalization, the sentiments for climate change tweets are compared to the sentiments of the total tweets to identify parallels and asymmetries.

Given the novel setting of our research, a simple linear regression was calculated to predict the corporate tweeting behavior, based on Greta's tweeting behavior. We evaluated the contemporaneous and lagged response of relationships between tweet volumes and sentiments including a continuous time variable (*WeekNo*) to inspect for a time trend. We formulated the following hypotheses:

H0: Greta's tweeting behavior has no instant effect on corporate climate change tweeting behavior.

H1: Greta's tweeting behavior has an instant effect on corporate climate change tweeting behavior.

Moreover, we used four models for testing:

$$Climate\ tweet_{it} = \alpha_{it} + \beta_1\, Greta_{it} + \beta_2\, WeekNo_{it} + \varepsilon_{it} \quad (1)$$

$$Climate\ tweet_{it} = \alpha_{it} + \beta_1\, Greta_{i(t-1)} + \beta_2\, WeekNo_{it} + \varepsilon_{it} \quad (2)$$

$$Non\ climate\ tweet_{it} = \alpha_{it} + \beta_1\, Greta_{it} + \beta_2\, WeekNo_{it} + \varepsilon_{it} \quad (3)$$

$$Non\ climate\ tweet_{it} = \alpha_{it} + \beta_1\, Greta_{i(t-1)} + \beta_2\, WeekNo_{it} + \varepsilon_{it} \quad (4)$$

Our dependent variable is, alternatively, the count or sentiment *i* of corporate *Climate tweet* or *Non climate tweet* for week *t* (*Appendix 8*). We expect that climate change tweets can be predicted by Greta's tweeting behavior (1), but that non-climate change tweets cannot (3). Further, we suppose to see this effect only for a contemporaneous response and not for lagged tweeting behavior in (2), and (4) for which the independent variable is Greta's count or sentiment ($Greta_{i(t-1)}$) of the previous week.

Experimental results and discussion

This section describes and examines the results of volume and sentiment analysis. First, basic descriptive statistics are presented, and common topics revealed through wordclouds. We proceed with detecting external events that explain peaks in the share of climate change tweets. We then discuss the polarity and emotions of tweets. Correlation results are primarily discussed within the volume analysis, regression results are outlined in the sentiment analysis. The results from each method of analysis are examined in relation to the tweets of Greta Thunberg.

Volume analysis

Account-specific The number of total tweets and climate change tweets by corporate account is shown in *Figure 2*. Most tweets were published by Adidas (10,782), representing 10% of the data, least tweets by MTU (84). The wide range in the number of tweets per account is a first indicator of the fundamental differences in Twitter usage. The average tweet number per account is 3,621. 6.17% of total tweets were identified as climate change tweets ranging from a total of 1,023 for Covestro to 1 tweet for MTU. Most companies published less than the mean of 224 climate change tweets over the 37 months period. Covestro performs strongest on climate change tweets (29.35%) while Fresenius and Vonovia perform lowest in relative terms (0.22%).

Both total and climate change tweets show a high variance which remains true within some industries. For instance, in the automotive sector, while Daimler (8,456) ranks among the five most actively tweeting accounts, BMW (2,313) and Volkswagen (1,758) rank much lower.

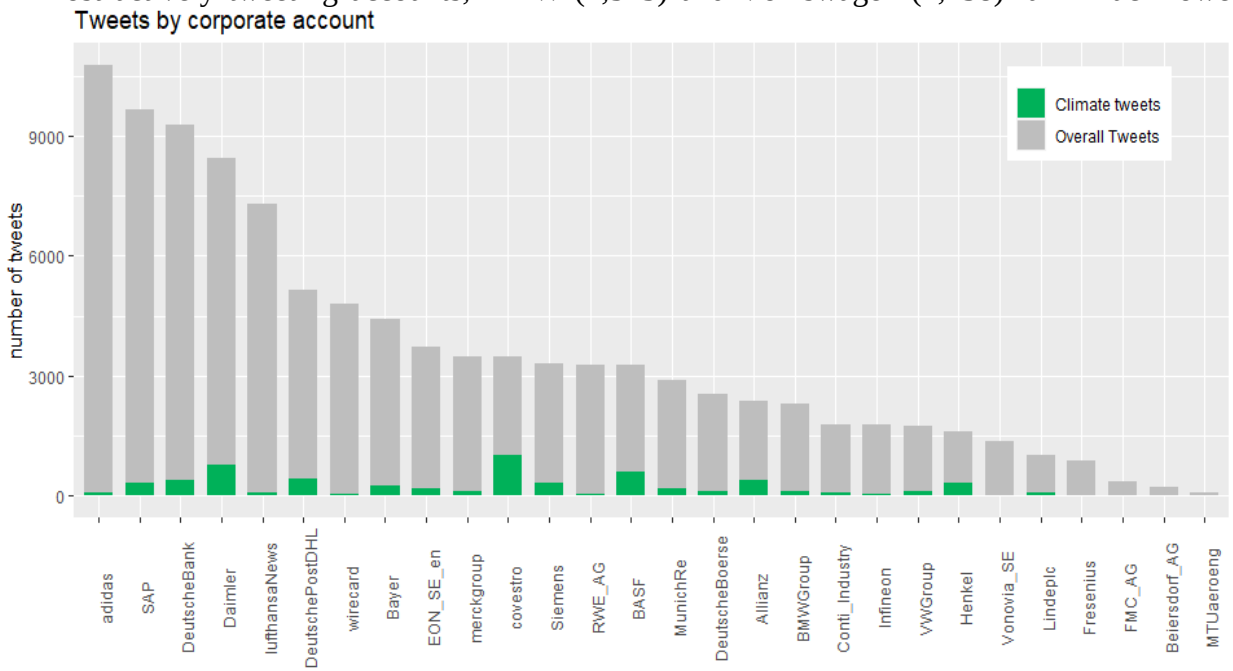

Figure 2: Total tweets per corporate account

Similarly, Daimler published 9.35% climate change tweets, BMW only 5.27% and Volkswagen 7.57%. The variation cannot be explained with sales in which Volkswagen leads, followed by Daimler (*Appendix 2*). In contrast, the pharmaceutical and medical care companies (Bayer, FMC, Fresenius, Merck) uniformly have less than 5% of climate change tweets. The pharmaceutical and medical care companies as well as the chemical companies (BASF, Covestro, Henkel) are expected to be similar in their processes. None of the two groups is among the top five total tweeters. But when it comes to relative proportion of climate change tweets, the chemical companies are the three companies leading, while being identified the largest consumers of energy (Banerjee et al., 2012), causing high amounts of greenhouse gas emissions, and the largest plastic polluter (GTAI, 2018). With the highly negative impact of the chemical industry, higher stakeholder pressure might be reflected in their tweeting behavior but not in their actual emission reduction targets which are among the lowest (Right, 2019). The fourth most climate change tweeting account is Allianz, which however, has the highest

emission reduction targets among the DAX30 (Right, 2020). While the chemical companies seem to solely talk about climate change without aiming to reduce their negative impact, Allianz reduces its environmental impact and communicates about climate topics. Another decisive factor for overall tweet volume could be innovativeness with five of the ten most tweeting companies being among the top ten DAX30 investors in innovation (Hilpert et al., 2019).

Temporal For further analysis, a weekly perspective is adopted to reduce the noise caused by individual tweeting behavior on certain days of the week. The course of the non-climate tweets over time shows high fluctuations from a minimum of 21 tweets to 884 tweets weekly and an average of 438 tweets per week (*Figure 3*). Climate change tweets range from 0 to 102, with 29 tweets on average per week. No seasonal pattern is observable over the four years shown in

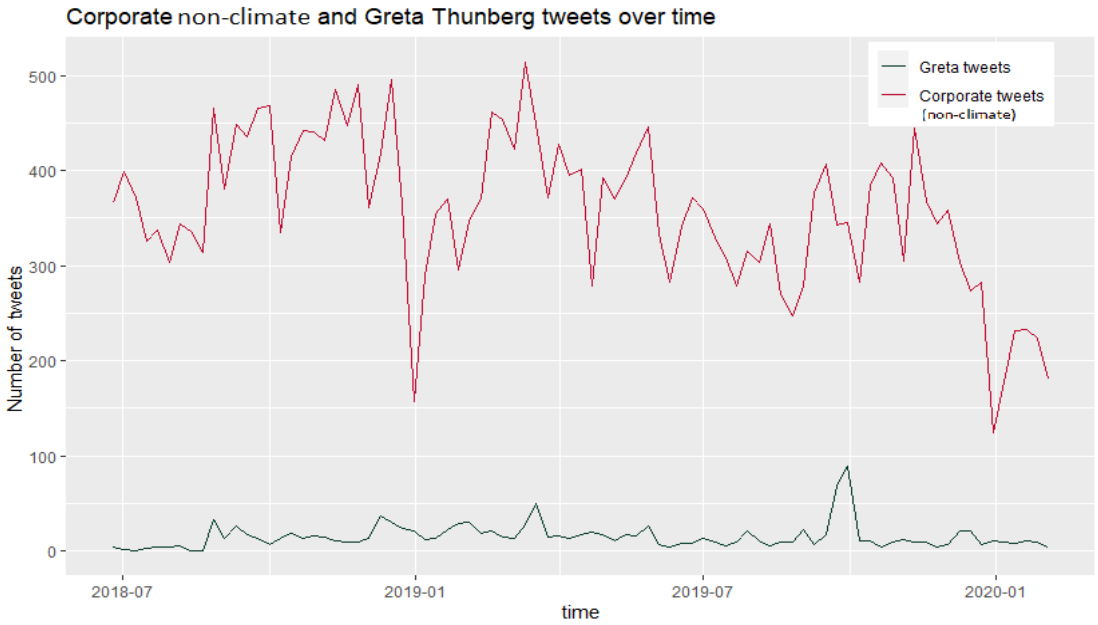

Figure 3: Corporate non-climate and Greta Thunberg tweets

Appendix 9. The second quarter 2017 which had constantly over 500 tweets per week is contrasted by much lower tweet numbers starting from 2018 onwards. Climate change tweets show a few peaks which are discussed in detail in the section on event detection.

Greta published a total of 1,314 tweets between June 2018 and January 2020. With an average of 15.28 tweets per week, she published less than the average corporate account (15.57 tweets). Still, Greta's tweets lead to a much higher visibility and response rate with 21,033 favorites and 3.625 retweets on average per tweet, compared to 26 favorites and 8 retweets for corporate

tweets. Observing Greta's tweeting behavior over time on a weekly basis, reveals two extreme peaks with 50 tweets or more (*Figure 4*). The first one represents week 11/2019 (50 tweets), when Greta's first global climate strike took place in over 110 countries (BBC News, 2020). The second peak marks week 38/2019 (68 tweets) and week 39/2019 (tweets 89). In week

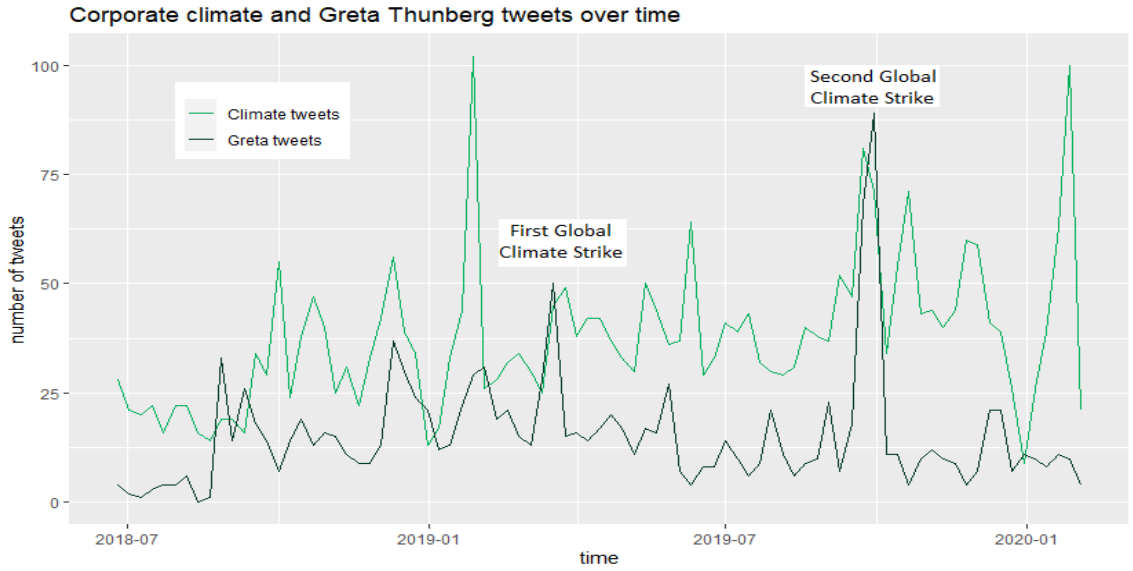

Figure 4: Corporate climate and Greta Thunberg tweets

39/2019, the second and largest global climate strike took place. Only on that day, Greta tweeted 45 times. During these two weeks, she was constantly present in the news and public interest was extremely high (tagesschau.de, 2019a). This shows that Greta's tweeting behavior is linked to and influenced by her actions.

We calculated a Pearson's test, conducting the r rank correlation coefficient among corporate total and climate change tweets and Greta Thunberg tweets (*Appendix 10*). It was investigated whether companies are more likely to post tweets in a week in which Greta is actively tweeting. All tweets lead to positive correlations. Though correlation values are generally small, they are larger for corporations' climate tweets and significant overall. The relation between total tweets and climate change tweets is not significant, which suggests different processes and motivations, as we would expect. Interestingly, a significant positive correlation exists between corporate climate change tweet occurrence and tweets by Greta, as suggested above in *Figure 4*. This is a first evidence for a possible relation between Greta Thunberg's tweets and the

corporate climate change related tweeting behavior further explored in the regression analyses.

Top words *Appendix 11* shows the 25 most frequently used words for companies and for Greta Thunberg. Wordclouds provide a first insight into the topics companies tweet about. For companies the most used words concern their products, name or CEO. Companies seem to speak positively about their business frequently mentioning *technology*, *innovation* and *future*. When companies talk about climate change, tweet content shifts, though company names and products remain overly present. Climate change tweets focus on *sustainability* and the *environment*. Still, words like *electric*, *green* and *solution* seem to represent product strategies to actively combat climate change. Nevertheless, there is sparely any intersection with Greta Thunberg. Greta uses more words of a strike- and climate-related vocabulary indicating her role in organizing climate protests. Words in common are *climate*, *future*, *global*, and *world*, although the latter three do not suggest any climate change context. Greta protests, but does not outline how to solve the climate emergency, while the companies want to show their positive impact in the guise of solutions to improve their reputation.This analysis did not identify that the climate change related topics companies tweet about are influenced by Greta Thunberg. However, Greta's tweet content is linked to her actions.

Event detection The relative distribution of climate change tweets (*Appendix 12*) shows an upward trend between 2016 and 2020 which might proceed in the future. At the beginning of 2020 climate change tweets were more salient, even though in absolute numbers they were less, as the number of overall tweets lies far below the 2019 level.

Subsequently, out of a total of 217 weeks, the 20 weeks with a relative proportion of over 10% of climate change tweets were examined (*Appendix 13)*. The goal was to detect whether external climate change news triggered peaks higher than any asymmetric fluctuations caused by individual company factors. An alternative hypothesis would consider internal events such as the launch of a climate-friendly products or a shift in the communication strategy as the cause.

To find external sources, the terms *climate change* and *Greta Thunberg* were searched for in the given week. The first peak, in week 17/2016, seems clearly caused by the Paris Climate Agreement being signed on 22.04.2016 (UN News, 2016). In 2017, peaks occur simultaneously with many events in the US. First, together with a donation to the UN's Green Climate Fund (BBC News, 2017) under President Barack Obama, later, in response to the *United States Climate Alliance*, a coalition of businesses against climate change (Financial Times, 2017), which emerged as a reaction to the withdrawal from the Paris Climate Agreement under the governance of President Donald Trump (Time, 2017).

The peaks in 2018, occur with international events. The first peak represents the WEF at which global business and political leaders met to discuss social, political, and environmental issues (United Nations Development Programme, 2020) while climate activists and scientists attracted attention protesting for climate action (Deutsche Welle, 2018). In the same week, the Doomsday Clock, representing the man-made threat to civilization, was advanced with climate change being cited as one of the reasons (The Guardian, 2018). Another peak covers Earthday on April 22, 2018 which, originated as a political campaign in the USA, is used worldwide to draw attention to environmental protection (National Geographic, 2018). The last peak, in week 49/2018, is the first one to reflect the presence of Greta Thunberg, less than six months after her first tweet. She was invited to speak at the 24th Conference of the Parties (COP24) to the UN's Framework Convention on Climate Change in Katowice (Fridaysforfuture.org, 2020).

The peaks in 2019 coincide with Greta's actions. The first one occurred while Greta was attending the WEF, the following while she was meeting with the Pope (ABC News, 2019). At an industry conference attended by Greta Thunberg, the chief executive from Oil&Gas UK confirmed the importance of Greta's advice on climate change action (BBC News, 2019). The peaks in week 38/2019 and week 39/2019 coincide with the absolute peaks of Greta's tweets, triggered by the global climate strike (Tagesschau.de, 2019a) and Greta's speech at the UN

General Assembly, New York (Fridaysforfutre.org, 2020). The next peak coincides with the nomination of Greta Thunberg for the Nobel Peace Prize (The Guardian, 2020). Some peaks in the last quarter of 2019 did not directly relate to international events around the person Greta Thunberg. However, she maintained a high presence in the news, striking in Canada against the local oil industry (Deutsche Welle, 2019), and being mentioned in New Zealand to be influential on their elections (Noted, 2019). Greta has shaped the language used to discuss climate change with her frequently tweeted term *climate emergency* being selected word of the year by the Oxford dictionary (marketwatch.com, 2019). The last peak in 2019 marks Black Friday, which the German Environment Agency promoted as a *Buy nothing day* (Umwelt Bundesamt, 2019). By 2020, Greta had established a reputation for relevance on climate issues. She argued that bushfires in Australia were a consequence of poor environmental protection (Daily Mail, 2020). In week 2/2020, Greta tried to actively influence the decision making of the DAX30 company Siemens, through direct interaction on Twitter (Die Welt, 2020). The week after, Blackrock, the largest investor cooperation, that holds shares of all DAX30 companies, demanded more climate protection from its investees (Deutsche Welle, 2020). Week 4/2020 marks the annual meeting of the WEF at which Greta Thunberg encountered with Donald Trump. With the topic *Stakeholders for a Cohesive and Sustainable World* for the first time, several teenage climate activists were invited after in 2019, Greta Thunberg had been the only teenager attending (WEF, 2020). This represents another evidence of Greta's impact.

Most peaks were associated with global events corresponding both to the global business activity of the companies and the worldwide recognition of Greta Thunberg. The analysis of events suggests that Greta Thunberg influenced the corporate climate change related tweeting behavior. Especially for 2019, we were able to assign most peaks to an event linked to Greta Thunberg and Greta's opinion was of great relevance whenever climate change was discussed. This can be interpreted as an indicator towards a Greta Thunberg effect, with her not only

influencing corporate climate change tweets but giving salience to climate issues.

Sentiment analysis

Polarity and Emotion *Appendix 14* displays descriptive statistics of the sentiment of the total DAX30 tweet body per day and calculated polarity and emotion values. Total tweets show four times more *positive* sentiment (79.99%) than *negative* (20.01%). The three most common feelings expressed are *trust* (29.29%), *anticipation* (23.86%), and *joy* (16.41%). The least expressed feelings are *disgust* (3.15%), *anger* (5.16%), and *sadness* (7.05%). *Disgust* occurs on the fewest days, with 205 out of 1492 days on which it is not expressed. The standard deviation for all sentiments is close to the mean.

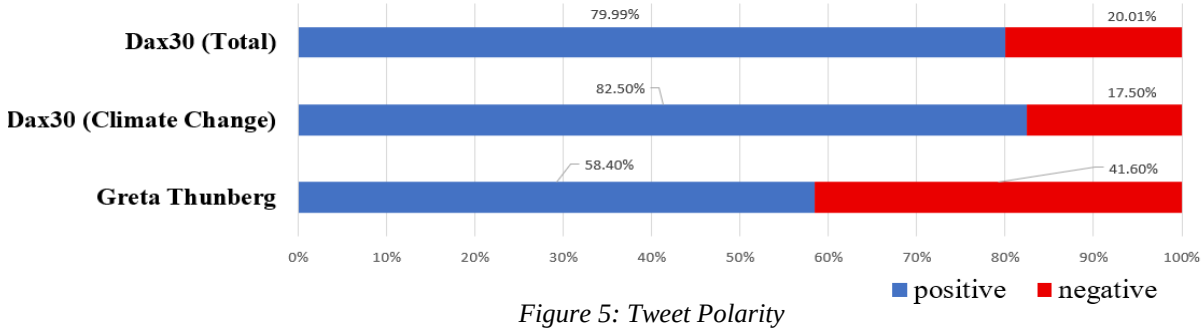

Figure 5: Tweet Polarity

Appendix 15 provides an overview of the sentiment of DAX30 climate change tweets per day. Climate tweets show over four times more *positive* sentiment (82.50%) than *negative* (17.50%). The three most common feelings expressed are *trust* (31.28%), *anticipation* (21.88%), and *joy* (17.40%). The least expressed feelings are *disgust* (3.56%), *anger* (4.86%), and *sadness* (5.40%). Climate tweets are more positive than total tweets. On average they have 1.55 indicators for positivity per tweet. However, even if the percentage of negativity is less, there are more indicators of negativity per tweet (0.33). In climate change tweets there are on average 0.83 indicators, in total tweets only 0.56, which indicates that the overall polarity and emotion density is higher in climate change tweets (4.55 vs. 3.19). The standard deviation is consistently higher than the mean value reflecting more variation in tweet sentiments of climate change tweets than total tweets. Climate change tweets seem to be more reactive and sensible to external events. *Appendix 16* displays details about the sentiment of tweets from Greta

Thunberg. Her tweets indicate more *positive* (58.40%) than *negative* sentiment (41.60%). However, the polarity is much more balanced. This represents her constant criticism and protest. The three most common feelings in her tweets are *trust* (26.28%), *anticipation* (16.47%), and *anger* (14.35%). She can show *trust* towards the network of *Fridays for future* but *anger* addressing business and political leaders. Her future-oriented speech leads to high *anticipation* values. The least expressed feelings are *disgust* (4.20%), *sadness* (7.40%), and *surprise* (4.76%). In general, Greta's tweets present a more balanced picture of sentiments and emotions articulated (*Appendix 17*) Her polarity value is more negative than for companies (*Figure 5*). Greta's overall polarity and emotion density were below corporate tweets (2.89) what can be caused by sharing pictures and hyperlinks but also shorter tweet length.

Regression To analyze whether a relation between corporate tweets and Greta's tweets exist, in a first stage we calculated a Pearson's test and in a second a linear regression. The results of the Pearson's test between climate tweet sentiments and Greta's sentiments showed positive and significant correlations between most variables (*Appendix 18*). This led to calculate regression values for climate and non-climate tweets (*Appendix 19 and 20*). All relations of the dependent variable (*Climate tweets*/ *Non climate Tweets*) are positive. Non-climate tweets show a significant and negative trend over time while climate tweets show a significant and positive time trend which is in-line with *Appendix 12*. We identified a significant positive relation between Greta's tweeting behavior and corporate climate change tweets. Companies react to a positive tweet by Greta with more positive tweets then they do for negative tweets by Greta. Companies generally publish significantly more positive tweets reflected in the intercept being higher. It would need to be explored whether companies react to negative tweets of Greta also with non-negative tweets. Greta's sentiment with the highest effect on climate tweets is trust. As expected, the results for *Greta t-1*, which show the corporate response to Greta's tweets of the previous week, are less significant. Reactions in social media are instant, and the intervals

of one week already cover the reaction time of firms. The results reject the Null hypothesis.

Conclusion

The rise of Greta Thunberg has significantly affected the contemporary discussion about climate change, yet this is the first study to evaluate the effect Greta had on corporate tweeting behavior. We examined the volume and sentiment of climate and non-climate tweets of 28 German companies and Greta Thunberg. Scraping data directly from Twitter allowed to portrait a stakeholder perspective and since tweets are posted as an immediate response to internal or external events, to show development over time.

In line with previous research (Greiwe & Schönbohm, 2011), we find that the increasing importance of climate change issues is reflected in the tweeting behavior. While non-climate tweets show a declining trend, climate change tweets are increasing significantly over time without any seasonal pattern observable. However, among companies, the number of tweets varies considerably for both total and climate change tweets. The content of climate change tweets differs from the general tweets of companies, but also from the tweets of Greta Thunberg. Greta's tweets are linked to and influenced by her climate strikes. In contrast, companies want to show a positive impact in the guise of solutions to improve their reputation. We were not able to detect a significant correlation between the ocurrence of total tweets and climate change tweets, so there seem to be different motivations for their publication. Climate-change tweets show greater variance in sentiment and thus seem to be more sensitive and reactive to external events, while non-climte change tweets seem to be more homogeneous. Most of the peaks in the relative amount of climate change tweets have been triggered by or coincide with international news featuring Greta Thunberg. Previous studies found a negative sentiment for the public discussion on climate change (Dahal et al., 2019). This is the first analysis to discover that corporate climate change tweets show overall a positive sentiment.

Furthermore, we identified a significant positive relation between Greta's tweeting behavior and corporate climate change tweets. We found that companies react to a positive tweet from Greta with significantly more positive tweets than they would for a negative sentiment. In conclusion, the evidence from this work project supports the idea of a Greta Thunberg effect such that it impacts the tweeting behavior of companies, in both its volume and sentiment. The results of this study contribute to the knowledge about corporate twitter use and the role of climate activists as opinion leaders. Moreover, it identifies existing gaps in the research about climate change discussion in social media.

We recommend companies to use a corporate twitter account to drive positive reputation, inform stakeholders in a comprehensive way about important business activities, and reflect the efforts on climate change action. Some companies, e.g. in the chemical industry, provide best practices for broad climate change communication on Twitter which can be used as a benchmark. Beyond the sentiment analysis, subjective stakeholder perception might differentiate from the objective emotional message. Lexicon-based methods for sentiment analysis are limited to the emotional value in a different context. The results do not include subjective skepticism or lack of trust in self-reported climate change initiatives. Even though climate change communication alters the reputation of a company, it remains unclear to what extent tweets reflect environmental practices. The dataset scraped from Twitter provides a basis for further research. We claim the necessity to investigate which effect, if any, Greta Thunberg's tweets and corporate climate tweets have on the stock market to assess how investors evaluate the power of stakeholders. Therefore, abnormal returns in price and variations in trading volume should be examined. Further, a topic modeling analysis on company level is required to reveal whether companies tweet about their own environmental achievements or general news. Future studies should examine also the stakeholder audience addressed by tweets through the creation of a relational network of followers for each account.

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Appendix

List of abbreviations

API	Application Programming Interface
CSR	Corporate Social Responsibility
COP24	24th Conference of the Parties
ESG	Environmental, Social and Governance
IPCC	International Panel on Climate Change
NGO	Non-governmental Organization
UN	United Nations
US	United States of America
WEF	World Economic Forum

Appendix 1: List of abbreviations

Company overview: DAX30 companies (alphabetical order)

	Company	Industry	Twitter account	Sales in million EUR	No. of employees	Total tweets	Climate change tweets	Relative climate change tweets
1	ADIDAS	Clothing	@adidas	21,915	57,016	10,782	100	0.93%
2	ALLIANZ	Insurance	@Allianz	130,557	142,460	2,385	387	16.23%
3	BASF	Chemicals	@BASF	62,675	122,404	3,289	601	18.27%
4	BMW	Manufacturing	@BMW	97,480	134,682	2,313	122	5.27%
5	BAYER	Pharmaceuticals and chemicals	@Bayer	39,586	110,838	4,413	260	5.89%
6	BEIERSDORF	Consumer goods and chemicals	@Beiersdorf_AG	7,223	20,059	230	19	8.26%
7	CONTINENTAL	Manufacturing	@Conti_Industry	44,404	243,226	1,799	75	4.17%
8	COVESTRO	Chemicals	@covestro	14,616	16,770	3,485	1,023	29.35%
9	DAIMLER	Manufacturing	@Daimler	167,362	298,683	8,456	791	9.35%
10	DEUTSCHE POST	Logistics	@DeutschePostDHL	61,550	547,459	9,277	391	4.21%
11	DEUTSCHE BOERSE	Securities	@DeutscheBoerse	2,780	5,964	2,535	120	4.73%
12	DEUTSCHE BANK	Banking	@DeutscheBank	25,320	91,463	5,133	418	8.14%
13	DEUTSCHE TELEKOM	Communications	@deutschetelekom	75,660	215,675	8,164	*	*
14	E.ON	Energy	@EON_SE_en	30,253	43,302	3,719	195	5.24%
15	FRESEN.MED.CARE	Medical and healthcare	@FMC_AG	16,547	118,308	361	8	2.22%
16	FRESENIUS	Medical care	@Fresenius	33,530	276,750	892	2	0.22%
17	HEIDELBERG CEMENT	Building	@the_hc_group	18,075	57,939	**	**	**
18	HENKEL	Consumer goods and chemicals	@Henkel	19,899	53,450	1,605	320	19.94%
19	INFINEON	Semiconductors	@Infineon	7,599	40,100	1,768	62	3.51%
20	LINDE	Industrial gases	@Lindeplc	13,139	58,000	1,007	88	8.74%
21	LUFTHANSA	Transport and aviation	@lufthansa	35,844	135,534	7,317	97	1.33%
22	MERCK	Pharmaceuticals and medical care	@merckgroup	14,836	51,713	3,486	112	3.21%
23	MTU AERO ENGINES	Aerospace	@MTUaeroeng	4,567	9,733	84	1	1.19%
24	MUENCHNER RUECK	Insurance	@MunichRe	49,064	41,410	2,880	178	6.18%
25	RWE	Energy	@RWE_AG	13,388	17,748	3,292	50	1.52%
26	SAP	Software	@SAP	24,708	96,498	9,652	327	3.39%
27	SIEMENS	Industrial and electronics	@Siemens	83,044	379,000	3,296	329	9.98%
28	VOLKSWAGEN	Manufacturing	@VWGroup	235,849	302,554	1,354	3	0.22%
29	VONOVIA	Real estate	@Vonovia_SE	6,502	9,923	1,758	133	7.57%
30	WIRECARD	Financial technology	@wirecard	2,016	4,989	4,814	45	0.93%

* no tweets published

** tweets not included in data

Statista (2019)

Data sample

	Datetime	Username	Text	Hashtags	Retweets	Favorites
1	2019-09-28 17:43:25	GretaThunberg	I have moved on from this climate thing... From now on I will be doing death metal only!!	NA	57046	422491
2	2019-09-28 17:00:59	GretaThunberg	Early numbers confirm at least 7 million people joined the #weekforfuture climate strikes! Thank you everyone, especially the local organisers! The #weekforfuture is one of the biggest global demonstrations in history. This is just the beginning! #climatestrike #fridaysforfuture	#weekforfuture #weekforfuture #climatestrike #fridaysforfuture	15321	75481
3	2019-09-28 14:14:09	GretaThunberg	Valparaiso, Chile. #ClimateStrike #FridaysForFuture	#ClimateStrike #FridaysForFuture	2533	16249
4	2019-09-28 12:45:02	GretaThunberg	Over 1 million people on #ClimateStrike in Italy! #FridaysForFuture	#ClimateStrike #FridaysForFuture	7994	51882
5	2019-09-28 12:41:03	GretaThunberg	Madrid! 150â€™000 on #ClimateStrike #FridaysForFuture	#ClimateStrike #FridaysForFuture	1514	10241

Appendix 3: Sample of tweets in the dataset

Data Cleaning

Restriction	Examples	Rationale	Source
Punctuation	*, ; .*	no sentiment value	Mohammad and Turney (2010)
Digits	*1, 2, 3*	no sentiment value	Mohammad and Turney (2010)
List of English stop words	*a, example, itself, since, what (SMART lexicon)*	no sentiment value	Mohammad and Turney (2010)
Twitter specific stop words	*https, www* (hyperlinks); *amp* (= &)	no sentiment value	Muhammad et al. (2016)
List of German stop words	*der, die, das, ein, eine* (articles)	no or wrong sentiment value in English	self identified
List of Swedish stop words	*det, vi, de* (pronuns); *att, som, och*	no or wrong sentiment value in English	self identified

Exclusion of stop words reduced the total of 2,174,564 to 1,156,402 words for corporate tweets and 24,613 to 11,628 for tweets by Greta Thunberg.

Appendix 4: Data Cleaning Process

Climate lexicon

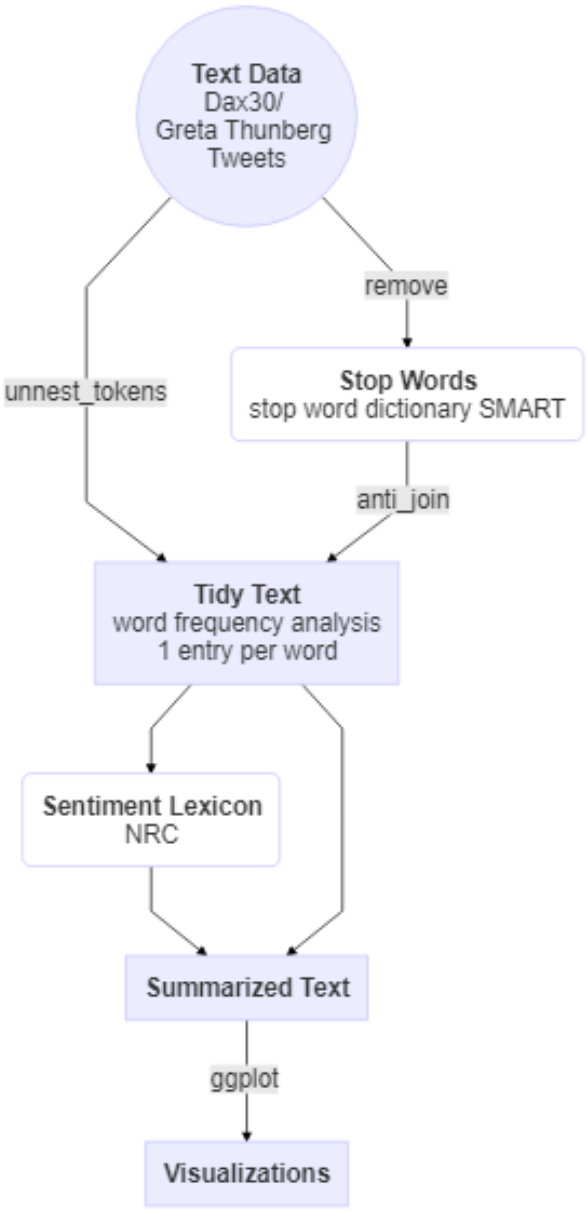
Words*	Rationale	Source
carbon, climate, environment, fossil, global warming, green, oceans,	The taxonomy was included only partly as it is extremely focused on climate change consequences instead of preventing actions	*Taxonomy for studying Climate Change tweets*, UN Global Pulse (2015)
cop24, cop25, davos, ipcc, wef, world economic forum	Inspired but updated list of climate summits and events.	*Taxonomy for studying Climate Change tweets*, UN Global Pulse (2015)
sustainable, sustainability	Terms covering environmental reporting topics.	Branco and Rodrigues (2008); Kilian and Hennigs
greta thunberg, fridays for future	To include tweets directly linked to Greta Thunberg.	self-identified
circular, earth, earthday, plastic, recycle, renewable	Further words which were found in a sample of tweets concerning climate change.	self-identified

* tweet texts were transformed in lower case to avoid case sensitivity in the lexicon

Appendix 5: Self-developed climate lexicon

$$RelativeClimateTweet_t = \frac{ClimateCount_t}{TotalCount_t}$$

Appendix 6: Formula for normalization of climate change tweets for event detection

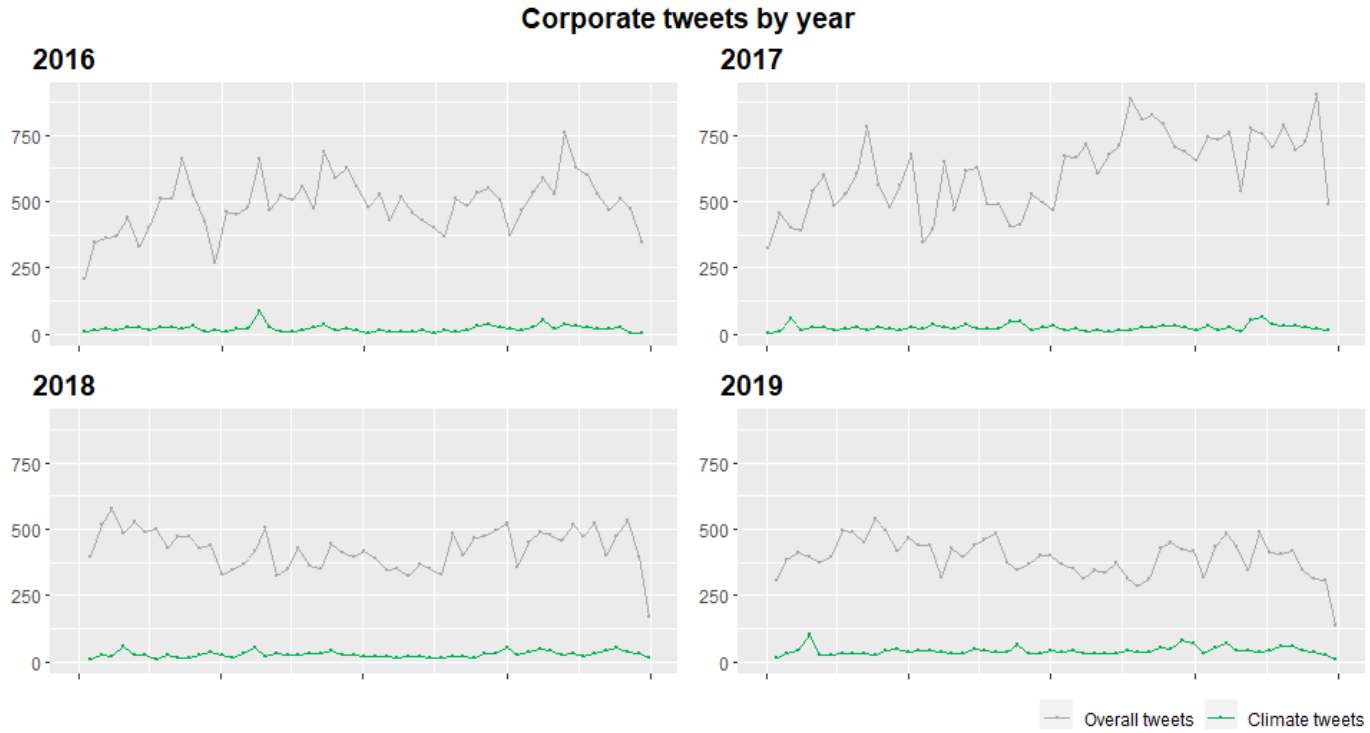


Appendix 7: Sentiment Analysis Overview following www.tidytextmining.com/sentiment.html

Overview of Variables

Variable	*Measurement*
Total tweets	Entirety of corporate tweets
Climate tweet	Corporate tweet classified as climate change related by self developed dictionary
Non climate tweet	Corporate tweet not classified as climate change related by self developed dictionary
Greta	Tweets from Greta Thunberg
WeekNo	Number of the week (with 1 being the first week of observation)
ClimateCount	Number of Climate tweets
NonClimaCount	Number of Non climate tweets
TotalCount	Number of Total tweets; Sum of NonClimatCount and Climate Count
GretaCount	Number of Greta tweets
GretaCount.lag	Number of Greta tweets lagged by one week (t-1)
RelativeClimateTweet	Percentage of the Climate tweets to Total tweets

Appendix 8: Overview of Variables



Appendix 9: Corporate tweets over time (aggregated by week)

Pearson Correlation: Tweet Volume

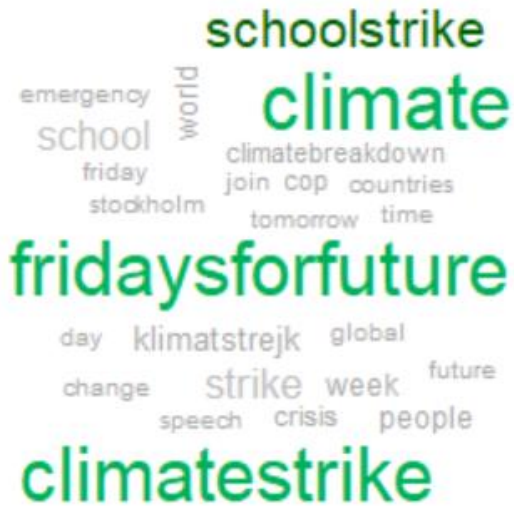
	TotalCount	*ClimateCount*	*NonClimaCount*	*GretaCount*
TotalCount				
ClimateCount	0.21			
NonClimaCount	0.98***	0.00		
GretaCount	0.24*	0.32**	0.18	
GreatCount.lag	0.21*	0.25*	0.16	0.46***

** p < 0.10; ** p < 0.05; *** p < 0.01*

Appendix 10: Pearson correlation of corporate and Greta Thunberg tweets

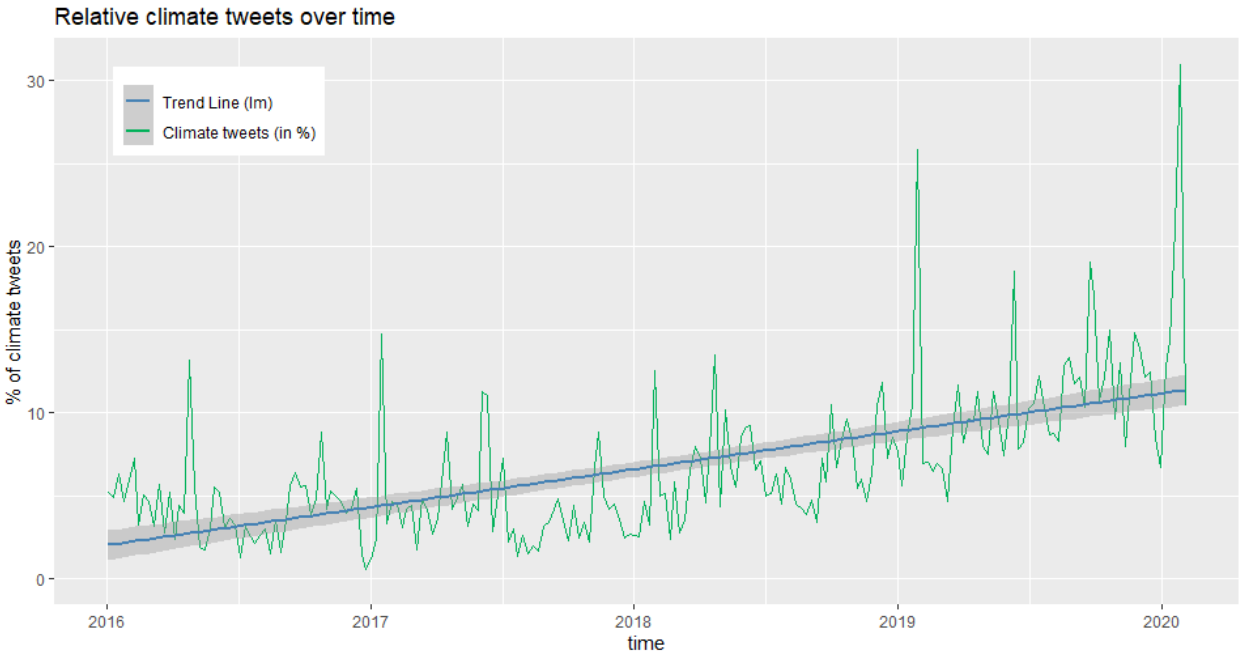
Top words DAX30 (Total tweets)

Top words DAX30 (Clima tweets)



Top words Greta Thunberg

Appendix 11: Wordclouds: 25 most frequently used words



Appendix 12: Relative Climate change tweets over time

Event detection: Weeks with percentage of climate change tweets over 10 %

Week	Year	Startdate	Climate change tweets	Total tweets	Relative climate change tweets	Selected event
17	2016	18.04.2016	82	634	12.93%	Paris Climate Agreement
3	2017	09.01.2017	59	402	14.68%	US donates to UN's Green Climate Fund
23	2017	29.05.2017	46	416	11.06%	Business coalition against climate change (United States Climate Alliance)
24	2017	05.06.2017	46	431	10.67%	Business coalition against climate change (United States Climate Alliance)
4	2018	22.01.2018	60	490	12.24%	Climate protests at WEF
16	2018	16.04.2018	42	398	10.55%	Earthday
49	**2018**	**03.12.2018**	**57**	**551**	**10.34%**	**Greta Thunberg at COP24**
4	**2019**	**21.01.2019**	**100**	**496**	**20.16%**	**Greta Thunberg af WEF**
12	**2019**	**18.03.2019**	**56**	**512**	**10.94%**	**Greta Thunberg meeting Pope**
23	**2019**	**03.06.2019**	**67**	**500**	**13.40%**	**Greta Thunberg at oil and gas industry conference**
38	**2019**	**16.09.2019**	**76**	**537**	**14.15%**	**Greta Thunberg´s global climate strike**
39	**2019**	**23.09.2019**	**78**	**498**	**15.66%**	**Greta Thunberg at UN General Assembly, New York**
41	**2019**	**07.10.2019**	**53**	**529**	**10.02%**	**Greta Thunberg nominated for Nobel Peace Prize**
42	**2019**	**14.10.2019**	**72**	**658**	**10.94%**	**Greta Thunberg effect on New Zealands elections**
47	**2019**	**18.11.2019**	**61**	**542**	**11.25%**	**Greta Thunberg´s word 'climate emergency': Word of the year**
48	2019	25.11.2019	60	532	11.28%	Black Friday vs Buy nothing day
1	2020	30.12.2019	18	175	10.29%	Australian bushfires, Greta blames lack of action
2	**2020**	**06.01.2020**	**43**	**348**	**12.36%**	**Greta Thunberg trying to influence Siemens**
3	2020	13.01.2020	45	388	11.60%	Blackrock requires more climate change action
4	**2020**	**20.01.2020**	**117**	**567**	**20.63%**	**Greta Thunberg af WEF**

Bold *entries influenced by Greta Thunberg*

Appendix 13: Event Overview

Sentiment: Dax30 (Total)

	positive	*negative*	*trust*	*surprise*	*joy*	*anticipation*	*sadness*	*fear*	*disgust*	*anger*
Minimum	2	0	0	0	0	0	0	0	0	0
Mean	70	18	38	9	21	31	9	10	4	7
Maximum	261	65	122	49	122	110	33	40	20	29
Standard deviation	39.82	10.40	22.04	6.01	13.28	17.60	6.00	6.66	3.43	4.61
Observations	1,492	1,492	1,492	1,492	1,492	1,492	1,492	1,492	1,492	1,492
Null observations	0	17	1	39	7	3	62	41	205	82
Sum	104,576	26,161	56,454	13,884	31,616	45,973	13,592	15,168	6,076	9,949
Polarity/Emotion probability	**79.99%**	**20.01%**	**29.29%**	**7.20%**	**16.41%**	**23.86%**	**7.05%**	**7.87%**	**3.15%**	**5.16%**
Average per tweet	1.03	0.26	0.56	0.14	0.31	0.45	0.13	0.15	0.06	0.10

Number of polarity values: *130,737*
Number of emotion values: *192,712*
Number of tweets: *101,382*

Appendix 14: Sentiment Analysis: Basic statistics for total DAX30 tweets (per day)

Sentiment: Dax30 (Climate change)

	positive	*negative*	*trust*	*surprise*	*joy*	*anticipation*	*sadness*	*fear*	*disgust*	*anger*
Minimum	0	0	0	0	0	0	0	0	0	0
Mean	7	1	3	1	2	2	1	1	0	1
Maximum	77	20	40	9	36	28	14	18	7	9
Standard deviation	7.33	2.00	4.35	1.17	2.54	3.22	1.11	1.78	0.86	0.97
Observations	1,492	1,492	1,492	1,492	1,492	1,492	1,492	1,492	1,492	1,492
Null observations	324	696	440	884	566	526	986	832	1,121	993
Sum	9,723	2,063	5,218	1,124	2,903	3,650	901	1,480	594	811
Polarity/Emotion probability	**82.50%**	**17.50%**	**31.28%**	**6.74%**	**17.40%**	**21.88%**	**5.40%**	**8.87%**	**3.56%**	**4.86%**
Average per tweet	1.55	0.33	0.83	0.18	0.46	0.58	0.14	0.24	0.09	0.13

Number of polarity values: *11,786*
Number of emotion values: *16,681*
Number of tweets: *6,256*

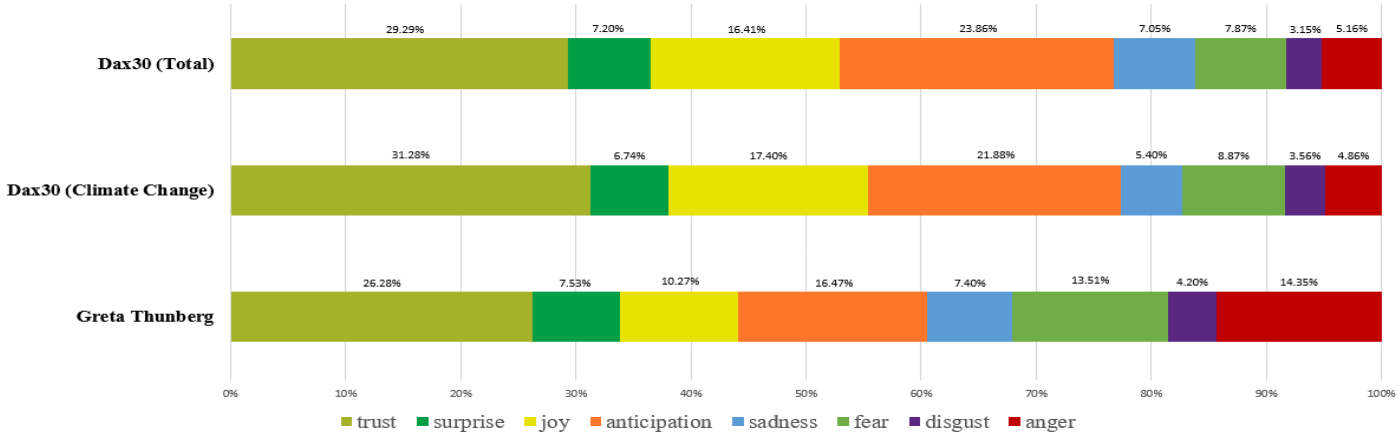
Appendix 15: Sentiment Analysis: Basic statistics for climate DAX30 tweets (per day)

Sentiment: Greta Thunberg

	positive	*negative*	*trust*	*surprise*	*joy*	*anticipation*	*sadness*	*fear*	*disgust*	*anger*
Minimum	0	0	0	0	0	0	0	0	0	0
Mean	2	2	2	1	1	1	0	1	1	1
Maximum	16	9	11	6	6	8	6	6	6	9
Standard deviation	2.30	1.66	1.68	0.85	1.00	1.36	0.88	1.22	0.60	1.10
Observations	362	362	362	362	362	362	362	362	362	362
Null observations	76	87	76	236	201	161	241	186	283	143
Sum	817	582	632	181	247	396	178	325	101	345
Polarity/Emotion probability	**58.40%**	**41.60%**	**26.28%**	**7.53%**	**10.27%**	**16.47%**	**7.40%**	**13.51%**	**4.20%**	**14.35%**
Average per tweet	0.62	0.44	0.48	0.14	0.19	0.30	0.14	0.25	0.08	0.26

Number of polarity values: *1,399*
Number of emotion values: *2,405*
Number of tweets: *1,314*

Appendix 16: Sentiment Analysis: Basic statistics for Greta Thunberg tweets (per day)



Appendix 17: Emotional values

	positive_D30	negative_D30	trust_D30	surprise_D30	joy_D30	anticipation_D30	sadness_D30	fear_D30	disgust_D30	anger_D30	positive_G	negative_G	trust_G	surprise_G	joy_G	anticipation_G	sadness_G	fear_G	disgust_G
positive_D30																			
negative_D30	0.86***																		
trust_D30	0.95***	0.83***																	
surprise_D30	0.75***	0.74***	0.70***																
joy_D30	0.89***	0.72***	0.87***	0.78***															
anticipation_D30	0.94***	0.85***	0.89***	0.74***	0.84***														
sadness_D30	0.74***	0.89***	0.71***	0.65***	0.60***	0.78***													
fear_D30	0.76***	0.75***	0.82***	0.56***	0.61***	0.77***	0.69***												
disgust_D30	0.57***	0.69***	0.60***	0.58***	0.57***	0.55***	0.60***	0.51***											
anger_D30	0.79***	0.87***	0.77***	0.68***	0.63***	0.79***	0.74***	0.75***	0.59***										
positive_G	0.64***	0.46***	0.60***	0.42***	0.57***	0.60***	0.37**	0.39***	0.29*	0.41***									
negative_G	0.63***	0.48***	0.51***	0.49***	0.58***	0.54***	0.38***	0.27*	0.22	0.41***	0.72***								
trust_G	0.56***	0.38***	0.55***	0.44***	0.50***	0.47***	0.27*	0.40***	0.22	0.34**	0.85***	0.66***							
surprise_G	0.45***	0.33**	0.36**	0.32**	0.34**	0.42***	0.27*	0.27*	0.10	0.30**	0.68***	0.68***	0.64***						
joy_G	0.42***	0.28*	0.38***	0.27*	0.36**	0.37***	0.21	0.22	0.16	0.23*	0.73***	0.47***	0.71***	0.68***					
anticipation_G	0.59***	0.36**	0.51***	0.40***	0.54***	0.50***	0.28*	0.28*	0.17	0.35**	0.85***	0.76***	0.74***	0.73***	0.74***				
sadness_G	0.58***	0.45***	0.49***	0.43***	0.50***	0.57***	0.38***	0.30**	0.11	0.40***	0.64***	0.84***	0.60***	0.72***	0.47***	0.65***			
fear_G	0.59***	0.41***	0.60***	0.52***	0.58***	0.52***	0.31**	0.49***	0.18	0.35**	0.64***	0.70***	0.71***	0.62***	0.51***	0.67***	0.72***		
disgust_G	0.41***	0.33**	0.32**	0.34**	0.48***	0.34**	0.18	0.07	0.17	0.24*	0.44***	0.57***	0.32**	0.39***	0.40***	0.52***	0.50***	0.48***	
anger_G	0.59***	0.47***	0.50***	0.44***	0.54***	0.49***	0.35**	0.27*	0.21	0.43***	0.75***	0.86***	0.75***	0.55***	0.52***	0.76***	0.66***	0.64***	0.52***

Appendix 18: Pearson correlation DAX30 climate (D30) and Greta Thunberg (G) sentiment (per week)

Climate Tweets - Greta

	Count	*Positive*	*Negative*	*Trust*	*Surprise*	*Joy*	*Anticipation*	*Sadness*	*Fear*	*Disgust*	*Anger*
Intercept	21.463***	19.5234***	3.73471*	8.12048	5.493823***	11.00580***	9.11636***	1.60922	3.241525	2.14975**	1.64706
	(4.9332)	(7.1171)	(2.02901)	(4.90403)	(1.128787)	(2.25269)	(3.28957)	(0.99371)	(2.191132)	(0.82768)	(1.02097)
Independent variable (Greta)	0.3482**	2.4425***	0.65697***	1.82015***	0.604574**	1.07809***	1.43502***	0.56388***	1.111999***	0.25106	0.4097***
	(0.133)	(0.3915)	(0.16459)	(0.36818)	(0.239187)	(0.38399)	(0.35308)	(0.20676)	(0.248948)	(0.20905)	(0.11862)
WeekNo	0.2751***	0.2457*	0.05637	0.15592*	0.004686	0.03459	0.11181*	0.03917*	-0.007465	0.01164	0.02122
	(0.0811)	(0.1334)	(0.03863)	(0.08415)	(0.022114)	(0.04212)	(0.06455)	(0.01976)	(0.041691)	(0.01549)	(0.0194)
Observations	72	72	72	72	72	72	72	72	72	72	72
R-squared	0.1913	0.421	0.2479	0.3053	0.0929	0.1234	0.2699	0.1835	0.2244	0.02963	0.1835
Adjusted R-squared	0.1685	0.4047	0.2267	0.2857	0.06735	0.09871	0.2493	0.1605	0.2025	0.002299	0.1605
F-test	8.395	25.81	11.7	15.6	3.636	4.997	13.12	7.979	10.27	1.084	7.978

** p < 0.10; ** p < 0.05; *** p < 0.01*

Std. error in parentheses

Climate Tweets - Greta_lagged (1 week)

	Count	*Positive*	*Negative*	*Trust*	*Surprise*	*Joy*	*Anticipation*	*Sadness*	*Fear*	*Disgust*	*Anger*
Intercept	22.3388***	19.2227*	5.50202*	11.99211*	4.81438***	13.66451***	10.30065**	1.11458	3.04691	2.5628***	2.72305*
	(5.0129)	(10.4191)	(2.94345)	(6.40123)	(1.3368)	(2.75158)	(4.41758)	(1.25045)	(2.64467)	(0.89824)	(1.38194)
Independent variable (Greta_lag	0.3017**	0.9985**	0.0644	0.72305*	0.4083*	-0.22362	0.22763	0.24715	0.56087**	-0.12108	-0.01537
	(0.1357)	(0.4647)	(0.18376)	(1.733)	(0.24062)	(0.40095)	(0.38235)	(0.21335)	(0.26886)	(0.2132)	(0.1307)
WeekNo	0.2742***	0.5795***	0.11037**	0.26202***	0.02866	0.06146	0.21505***	0.06483***	0.04387	0.01323	0.03851*
	(0.0822)	(0.1617)	(0.04435)	(0.09755)	(0.02248)	(0.04478)	(0.07091)	(0.02075)	(0.0458)	(0.01603)	(0.02172)
Observations											
R-squared	0.1709	0.1725	0.08468	0.1122	0.05283	0.03534	0.1163	0.1235	0.0664	0.01624	0.0489
Adjusted R-squared	0.1476	0.1489	0.05853	0.08679	0.02577	0.007778	0.09103	0.09841	0.03972	-0.01186	0.02173
F-test	7.319	7.297	3.238	4.421	1.952	1.282	4.605	4.929	2.489	0.5779	1.8

** p < 0.10; ** p < 0.05; *** p < 0.01*

Std. error in parentheses

Non Climate Tweets - Greta

	Count	*Positive*	*Negative*	*Trust*	*Surprise*	*Joy*	*Anticipation*	*Sadness*	*Fear*	*Disgust*	*Anger*
Intercept	456.8938***	613.7199***	144.9217***	313.3989***	93.56564***	190.516***	272.9208***	72.40138***	83.20163***	42.71864***	58.99341***
	(19.5893)	(26.4992)	(7.6279)	(17.3046)	(1.01243)	(8.9531)	(11.5193)	(4.41962)	(4.97747)	(2.99299)	(3.60171)
Independent variable (Greta)	0.5917	4.1142***	0.7003	3.5873***	0.06247	1.7818	1.1612	1.63214*	0.98262*	0.09978	0.24178
	(0.5282)	(1.4576)	(0.6187)	(1.2992)	(0.0936)	(1.5261)	(1.2364)	(0.91959)	(0.56552)	(0.75596)	(0.41846)
WeekNo	-2.1921***	-1.6571***	-0.1444	-0.7576**	-0.35919***	-0.6317***	-0.7908***	0.13266	-0.27573***	-0.20415***	-0.24622***
	(0.322)	(0.4966)	(0.1452)	(0.2969)	(0.0936)	(0.1674)	(0.226)	(0.08789)	(0.09471)	(0.05601)	(0.06844)
Observations											
R-squared	0.411	0.1771	0.02427	0.1481	0.1819	0.1684	0.1472	0.09765	0.1215	0.1579	0.1552
Adjusted R-squared	0.3944	0.1539	-0.003214	0.1241	0.1588	0.145	0.1232	0.07223	0.09671	0.1342	0.1314
F-test	24.77	7.638	0.883	6.173	7.891	7.191	6.128	3.842	4.908	6.656	6.522

** p < 0.10; ** p < 0.05; *** p < 0.01*

Std. error in parentheses

Non Climate Tweets - Greta_lagged (1 week)

	Count	*Positive*	*Negative*	*Trust*	*Surprise*	*Joy*	*Anticipation*	*Sadness*	*Fear*	*Disgust*	*Anger*
Intercept	456.2666***	602.8158***	143.0805***	307.8069***	91.90281***	180.8456***	265.115***	69.92215***	82.05659***	42.6796***	60.8828***
	(19.6457)	(31.4731)	(9.46416)	(19.1906)	(5.36533)	(9.9475)	(13.3064)	(5.09161)	(5.40425)	(3.133)	(4.4296)
Independent variable (Greta_lag	0.6204	1.9361	0.211544	2.3546*	0.23152	2.8382*	1.0237	0.68145	0.50837	-0.2759	-0.2801
	(0.5318)	(1.4036)	(0.590847)	(1.2506)	(0.96575)	(1.4495)	(1.1517)	(0.86871)	(0.5494)	(0.7436)	(0.4189)
WeekNo	-2.1865***	-0.8608*	-0.007537	-0.3796	-0.32111***	-0.4718***	-0.5772***	0.24234***	-0.20155**	-0.1871***	-0.2317***
	(0.3222)	(0.4883)	(0.142611)	(0.2925)	(0.09021)	(1.4495)	(0.2136)	(0.08451)	(0.09359)	(0.0559)	(0.0696)
Observations											
R-squared	0.4119	0.08585	0.002323	0.08254	0.1603	0.1759	0.1222	0.1051	0.07719	0.138	0.1379
Adjusted R-squared	0.3953	0.05973	0.9218	0.05632	0.1363	0.1523	0.09717	0.07956	0.05083	0.1134	0.1132
F-test	24.86	3.287	0.08149	3.149	6.68	7.47	4.874	4.112	2.928	5.605	5.597

** p < 0.10; ** p < 0.05; *** p < 0.01*

Std. error in parentheses