UNIVERSITÀ CATTOLICA del Sacro Cuore

**DIPARTIMENTO DI POLITICA ECONOMICA**

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*Abstract*

Transition to a climate-neutral society is expected to generate disruptive changes and influence the investors and consumers' perception. According to the Task Force on Climate-related Disclosures, firms that compose the polluting sectors might be vulnerable to reputation risk. In this work, we investigated the effect of climate-related announcements of listed companies on their equity performance. Focusing on the major historical greenhouse gas equivalents emitters, we studied the effect of companies' climate-related social media activity on their daily abnormal returns in general and during climate-related events. Results suggest that climate-related announcements expose firms to abnormally negative returns. Sensitive external events and political rallies coincided with negative stock returns within investor's expectations.

Keywords: Transition Risk; Reputation risk; Events Analysis; Text Analysis; Efficient Markets
JEL: G32, G41, Q54
Abbreviations: Greenhouse Gasses (GHG), Abnormal Returns (AR), Stock Returns (SR)

## *1. Introduction*

According to the Task Force on Climate-Related Disclosure (TCFD), climate change carries several risk factors for financial activity: liability from lawsuits, enforcement of strict regulations, paradigmatic shifts in energy sectors, and changes in investors' and consumers' perceptions of firms' reputation (Task Force on Climate-related Financial Disclosures 2017). The 2009 Basel II framework first defined reputation risk as to the loss of financial performance or debt financing due to the deterioration of consumers or investors' expectations (Basel Committee 2009). In relation to the climate-related reputation risk, the TCFD has highlighted three plausible sources: market shifts driven by changing customer's preferences, dis-investment, and sector stigmatization. This last one is particularly relevant for a limited number of firms operating in highly polluting sectors such as energy, utilities, transport and materials.

Climate-related reputation risk could thus be a source of systemic risk for investors dealing with companies operating in these sectors. Heede (2014) traced the accumulated emissions related to organizations' economic activity before the industrial age (1854) up to 2014 and suggested that more than 70% of total greenhouse gas atmospheric stock can be related to the activity of just 90 organizations. The 2017 "Major Report" (Griffin and Heede 2017) confirms this result, and even media like The Guardian[1] and CNBC[2] highlighted the responsibility of such" Majors" in driving the temperature shifts. In addition, political organizations involved in environmental activism have pursued a stigmatization strategy against such companies to haste the global disinvestment from historical polluters (Günther and Ferns 2017). Among the greatest historical polluters, many companies are listed on financial markets and use social media accounts as part of their communication strategy. This allows studying the relationship between companies' climate-related narrative and short term returns on financial markets. We engaged the issue under the assumption that an untimely climate-related narrative deteriorates the companies' reputation leading to lower-than-expected equity returns, at least in the very short term.

Financial markets require a premium to firms in carbon intensive sectors because those firms are the most exposed to transition risk. By screening companies according to their GHG emissions, investors take portfolio decisions that impact firms' financial performance (Bolton and Kacperczyk 2020; Ilhan, Sautner, and Vilkov 2020). The presence of a carbon premium suggests investors' awareness of carbon risk (Jung, Herbohn, and Clarkson 2018) and that such a risk is considered in medium-term portfolio strategies. However, investor's perception of risk is influenced by communication activities concerning official announcements (Barakat, Ashby, and Fenn 2018a) and daily media communication strategies (Barakat et al. 2019). Different studies found evidence that mainstream media sentiment can influence stock prices (Behrendt and Schmidt 2018; Strauß, Vliegenthart, and Verhoeven 2018; Vanstone, Gepp, and Harris 2019), suggesting that, when news arrive into the market, the media strategy can affect the way this news is capitalized into the stock prices. The analysis of monetary policy announcements has already evidenced how the communication tone of central bankers' speeches can influence stock prices (Masawi, Bhattacharya, and Boulter 2014). Such evidence also extends to climate change-related communications, as Engle et al. (2020) show about climate change innovation in firms.

The relation between social expectation, corporate image and financial performances is expressed by the legitimacy and reputation isomorphism. Reputation refers the positioning of corporate activity in comparison to competitors (Bitektine 2011; Czinkota, Kaufmann, and Basile 2014). Legitimacy on the other hand is a state of congruence towards laws, rules and social norms (Parsons 1956, 1960; Weber 1978). When the minimum standard is violated, corporate status is affected too: illegitimate acts or communications could tarnish corporate reputation. Legitimate acts or communications are reflected in a better positioning of firms with respect to others. Therefore, the corporate image with respect to carbon reputation could be reflected in

[1] https://www.theguardian.com/sustainable-business/2017/jul/10/100-fossil-fuel-companies-investors-responsible-71-global-emissions-cdp-study-climate-change

[2] https://www.cnbc.com/2017/07/10/just-100-firms-attributable-for-71-percent-of-global-emissions-report-says.html

financial performances. There are several channels that serve the purpose of improving corporate image regarding climate change.

Non-mandatory disclosure, mainstream news, or social media activity constitute a relevant information source for investors, accordingly. Concerning non-mandatory disclosure, the results in Elijido-Ten (2017) and S. Y. Lee and Choi (2019) support this view indicating that investors and consumers price the acknowledgement of climate risk. Besides, green-washing practices are systematically linked to sub-optimal performances (Cooper, Raman, and Yin 2018). Concerning media information, it is becoming a common approach to leverage social network data to understand the effect of media communication strategies on financial markets (Affuso and Lahtinen 2019; Fan, Talavera, and Tran 2020; Naeem et al. 2020; Sebastian and Isa 2020). Among these media, Twitter probably the most used, especially when sentiment analysis is conducted systematically for multiple firms using text mining (Karami et al. 2020). In financial analysis, tweets represent a non-mandatory communication form used for understanding the issuer's sentiment and eventually predicting volatility and performances of financial instruments (Albarrak et al. 2020; Behrendt and Schmidt 2018; Diaz-Rainey et al. 2021; Naeem et al. 2020; Paniagua, Rivelles, and Sapena 2019; Sóti et al. 2020).

Companies' non-mandatory communication may be of relevance when it turns to their environmental impact. Communication is oriented to legitimacy creation, that is, information disclosure aimed at explaining organization's behavior in relation to actions taken to fulfil their social contract. Legitimacy is fundamental for many companies, enabling the social recognition of business objectives and even the survival in jumpy and turbulent moments (Schiopoiu Burlea and Popa 2013; Suchman 1995). In other words, a firm must be legitimate to have a positively impacting corporate activity (Galán-Valdivieso et al. 2019). The stigmatization of the Majors is an attempt to counter their legitimacy narration or, as some say," myth-making" (Ferns, Amaeshi, and Lambert 2019).

Legitimacy construction via social media narration is more effective during periods of great attention on climate-related topics. Sensitive events influence the perspective of investors and modify the reception of communication and announcements: this effect could be reflected in financial performances (Au Yong and Laing 2021; Chahine and Malhotra 2018; Diaz-Rainey et al. 2021; H. Lee, Abdar, and Yen 2018). The use of Twitter-based event analysis has become popular for analyzing the financial impact of relevant documentation disclosure, as in the case of the negative effect of the United States' withdrawal of the Paris treaty (Berkman, Jona, and Soderstrom 2019; Diaz-Rainey et al. 2021), or extreme weather events (Chang, Hsu, and McAleer 2018). These results imply that financial markets used information efficiently, or in other words, according to the efficient market hypothesis (Rogova and Aprelkova 2020).
This study aims to assess the financial effect of climate reputation risk on the major polluters. We linked proxies of exposure to such risk to abnormalities in daily equity price variations. Under a weak form of the efficient market hypothesis, abnormalities are expected to fall near zero with a constant variance. We derived three types of dummy variables as proxies and used them as main variables to isolate unexpected financial performances. The target variable is therefore the daily abnormal returns covering the period between Jan 2017 to Dec 2019. Abnormal returns compare most polluting company's returns with the SP500 returns, which serves as a broad benchmark. In that way, the empirical approach allows isolating the sector stigmatization effect. It is possible to disentangle the financial effect of company's attempts to construct their legitimacy through social media interactions and assess if the effect is larger during events drawing social media attention. Two events that attracted not only social, but also mainstream media attention considerably. These are the Greta Thunberg Speech at COP24 and the first climate strike.

The study is structured as such. Section 2 reviews the relevant literature and presents the three research hypotheses. The empirical approach is discussed in Section 3. Section 4 describes and summarizes the data used. Empirical model results are presented in Section5 and discussed in Section 6. Section 7 concludes the work.

## *2. Research hypothesis*

Climate reputation risk focuses on the changes in perception regarding involvement in emissions, abatement strategies, or drastic changes in the regulation system (Task Force on Climate-related Financial Disclosures 2017). Risk emerging from damaged climate reputation is characterized by three factors while considering financial markets as capable to use efficiently information. The first factor is risk exposure. If investors respond to sector stigmatization systematically, exposure to climate transition risk should affect stock returns abnormally when compared to the benchmark (Engle et al. 2020; Rogova and Aprelkova 2020). While social media use has become common among companies around the world, for companies in stigmatized sectors, social media use concerning climate-related topics may signal reputation risk exposure (Albarrak, Elnahass, and Salama 2019; Bank, Yazar, and Sivri 2019). Accordingly, daily social media interaction by companies in stigmatized sectors can signal transition risk exposure and generate anomalies in the financial markets. The first null hypothesis relates the ineffectiveness of climate related communication to financial performances, while the alternative is the effectiveness. The variable used to test this hypothesis is derived by text from Twitter accounts.

The second factor is the happening of specific events that trigger public attention on social media, among other channels. Evidence suggests some specific events can be relevant signals for financial markets and generate short term anomalies like, for instance, the pullout of the US government from the Paris Agreement in 2016 (Berkman, Jona, and Soderstrom 2019; Fan, Talavera, and Tran 2020; Ilhan, Sautner, and Vilkov 2020). Climate-sensitive events are events capable of drawing public attention to climate change, its impact and causes and, indirectly, the responsibility of major polluters (Ilhan, Sautner, and Vilkov 2020). Accordingly, such events may alter the normal course of transactions leading to abnormal returns for stigmatized companies. This second hypothesis is tested empirically using event dummy variables in an event-study fashion to explain the occurrence of abnormal returns.

The third factor is the change in investor's perception of company's exposure to climate reputation risk during climate-sensitive events. Attempts to create legitimacy from major polluters, in fact, may appear particularly inappropriate during climate-sensitive events that point to their responsibility (Behrendt and Schmidt 2018; Ferns, Amaeshi, and Lambert 2019). Investors may thus evaluate the social media presence of exposed companies during and immediately after climate-sensitive events differently. This third hypothesis is tested by including the interaction between social media presence metrics and event dummy variables.

## *3. Empirical Methods*

This section presents the methodological approach of the paper. The assumption we outlined in the introduction relies on the existence of a link between unexpected financial performances, climate-related communication and overall sentiment surrounding the issue. The target variable is the firm specific Abnormal Returns (AR). The independent variables comprehend communication-related, general events and interactions. The estimation is split in four main rounds to avoid collinearity and isolate all effects:

$$
\begin{aligned}
(a)\ AR_{i,t} &= \gamma_0 + \gamma_1 CRTA^{5}_{i,t} + \gamma_2 GRETA^{5}_{i,t} + \gamma_3 Climate\ Strike^{5}_{i,t} + \varepsilon_{i,t} \\
(b)\ AR_{i,t} &= \gamma_0 + \gamma_1 CRTA^{10}_{i,t} + \gamma_2 GRETA^{10}_{i,t} + \gamma_3 Climate\ Strike^{10}_{i,t} + \varepsilon_{i,t} \\
(c)\ AR_{i,t} &= \gamma_0 + \gamma_1 CRTA^{15}_{i,t} + \gamma_2 GRETA^{15}_{i,t} + \gamma_3 Climate\ Strike^{15}_{i,t} + \varepsilon_{i,t} \\
(d)\ AR_{i,t} &= \gamma_0 + \gamma_1 CRTA^{15} + \gamma_2 GRETA^{15} + \gamma_3 Climate\ Strike^{15} + \gamma_4 CRTA^{15} x GRETA^{15} \\
&\quad + \gamma_5 CRTA^{15} x Climate\ Strike^{15} + \varepsilon_{i,t}
\end{aligned}
\tag{1}
$$

CRTA refers to the climate related Twitter Activity, while GRETA and Climate Strike to the dummies of the selected events. Changes in reputation are reflected in the perception of investors, especially when comparing a firm to a benchmark. According to the efficient market hypothesis, the distance between the observed stock returns and their expectations is normally distributed around mean zero and constant variance. We tested

therefore for null hypothesis of $\gamma_0$ equal zero. Expectations are determined by the variation of the benchmark. These distances from zero are called abnormalities and under the null hypothesis, they should be uncorrelated to any information. If these observations are systematically related to climate-related communication, it means that financial markets priced an unexpected information. This is the market pricing of reputation changes due to legitimacy building. The first step to determine abnormalities in trading is to explain changes in stock prices and the determination of expectations.

$$SR_{i,t} = \frac{P_{i,t} - P_{i,t-1}}{P_{i,t-1}} \quad (2)$$

Stock returns (SR) seldom diverge from their benchmark market returns (Fama and French 1992; Malkiel and Fama 1970). SR of a firm "i" in the day "t" are measured as the stock prices variation over time (equation 2). When investors use information efficiently, events may affect the SR, but their systematic effect should disappear within days (Naeem et al. 2020; Strong 1989).

$$SR_{i,t} = \alpha_i + \beta_i SR_{m,t} + \epsilon_{i,t} \quad (3)$$

The relation between observed SR and a benchmark ($SR_{m,t}$) determines expectations according to two parameters as reported in Equation (3). Such equation is estimated at firm level. The market alpha $\alpha_i$ is a measure of the active return on an investment compared to the benchmark. The market beta $\beta_i$ indicates how the SR moves on average with respect to the benchmark.

Estimates and statistical significance of each firm is presented in the appendix. We used as reference the S&P500 where a large number (370) of listed companies which are included into the index voluntary disclosed information about their emission policy (IEA 2020). After the estimation of market alpha and beta for each firm, it is possible to calculate the expectations as predictions of the SR. As previously stated, the distances between observed SR are called AR expectations should fall within a normal distribution.

$$ARi,t = SRi,t - E(SRi,t \mid SRm,t) \quad (4)$$

As presented in equation 4, AR are calculated using expected values. The precision of these expectations is determined by a confidence interval. Abnormalities within this confidence interval are not used within this analysis; on the other hands, AR that fall outside two standard deviations outside the expectations' confidence intervals are considered. The abnormal returns collected in equation 1 will reflect this characteristic.

The right hand of equation 1 includes variables which represent information regarding firms' communication, climate, and sentiment. The period of daily abnormalities required a source of information that could be synthesized daily. Social media represented a viable option for several reason. The first relate the possibility to model information at firm-specific level daily. Secondly, corporate announcements via social media could influence corporate reputation (Becker and Lee 2019; Zheng, Liu, and Davison 2018). Among the social media, Twitter activity has been used to control legitimacy of announcement regarding green transition (Albarrak, Elnahass, and Salama 2019; Lyon and Montgomery 2013). Several studies have found evidence that corporate communication on Twitter (and the information embedded in it) affects financial performances (Fan, Talavera, and Tran 2020; Naeem et al. 2020; Paniagua, Rivelles, and Sapena 2019; Strauß, Vliegenthart, and Verhoeven 2018; Vanstone, Gepp, and Harris 2019). At first, it is important to assume that investors are aware about how much companies could be considered responsible for climate change. Investors are therefore capable to discern the legitimacy of sustainability and climate related communication of firms. In this respect, the works by Heede (2017; 2014) identified major pollutants and received substantial attention in academia but also substantial mainstream media coverage. Such a wide coverage presumably affected investors' awareness and all companies in the sample could be considered as subject to sector stigmatization. Thus, climate responsibility

could be a relevant standard for investors: communication could affect the status i.e., the reputation and cause abnormalities in financial performances. Twitter accounts provided the raw source for indicators of daily announcements, communication regarding Climate change of the major historical polluters.

A daily measure of company interaction on climate-related issues has been constructed applying text mining algorithms. Once a Twitter account has been associates with a company in the sample, all the tweets for the period have been downloaded and catalogued on a daily basis to generate a daily text for each company. Such a text has further been cleaned from irrelevant speech elements or text signs, such as emoticons and matched with the IPCC glossary to identify climate-related tweets (Beattie 2020). The results are equivalent to a plain set of a couples of words, called bigrams. Term Frequency (tf) refers to the count of each bigram used in a daily collection of tweets and is computed as the sum of the days in which at least one bigram is matched with the IPCC glossary over the total number of bigrams ($B_{i,t}$) in one day of activity of the firm (equation 5). Unfortunately, the tf indicator provides a weightless dimension unless the intrinsic relevance of the term, that is the bigram use the other documents, is considered. For this reason, tf is weighted by its inverse distance frequency (idf, equations set 5) to produce a Climate Narration index of "$N_{i,t}$" (equation 5), which is zero by definition if company i in day t did not produce tweets with bigrams matching the IPCC vocabulary. The climate narration is measured with the tf-idf, i.e term frequency multiplied by inverse document frequency. It is possible to trace the level of use of climate-related terminology. A similar approach has been employed for political risk and firms' activity of lobbying (Hassan et al. 2019).

$$
\begin{aligned}
tf_{i,t} &= \frac{1}{B_{i,t}} \sum_{\forall b_{i,t}} I\left[\left(1: b_{i,t} \in W\right) \cap \left(0: 1: b_{i,t} \notin W\right)\right] \\
idf_b &= -ln\left\{\frac{\sum_{\forall b} I[(1: \tau \supset b) \cap (0)\,]}{B}\right\} \\
N_{i,t} &= \sum_{\forall b_{i,t}} tf_{i,t} * idf_b
\end{aligned}
\tag{5}
$$

To keep the measure simple and its interpretation meaningful, the variable used in the regression model transforms the Climate Narration index N into a binary variable. It is referred as Climate-Related Twitter Activity (CRTA in equation 1) with non-zero values if company $i$ in day $t$ has tweeted about climate-related topics. Multiple variants of this variable have also been created to account for prolonged effects on the target variables, assigning non-zero values to observations in the next 5, 10 and 15 days, respectively. The perception over the theme of climate change is also driven by global events, capable of shaping the investor's perspective of individual. Political events are known to have massive impact on individual's perspective and investors alike. For instance, the election results in 2016 in USA affected positively brown assets (Berkman, Jona, and Soderstrom 2019; Fan, Talavera, and Tran 2020; Ilhan, Sautner, and Vilkov 2020). Among the potentially relevant events, two are considered here. One is the Greta Thunberg' speech over climate change on December 4$^{th}$ 2018. The other event is the Climate Strike on September 20$^{th}$ 2019, especially the one in New York (Global climate strike 2019). The choice of the events was driven by the impact on YouTube views for the former and for the significant presence on academic and journalistic channels for the second (Global climate strike 2019; Schiermeier et al. 2019). A Boolean indicator equal to 1 after Greta Speech (referred to as GRETA in equation 1) and after the Climate Strike. These events carry a time-specific event that is equal to all firm. They are treated similarly to the previous Boolean Indicator with delays of 5, 10, and 15 days. Under the null hypothesis of the weak version of the efficient market hypothesis, the effect of events should be statistically insignificant.

Figure 1 presents all the panel observation together for the Climate Narration index N (above) and the CRTA indicator (below). From the analysis of both panels, it is possible to appreciate an increasing frequency of term use, especially after signing the Paris Agreement on November 4th, 2016 (the first red vertical line from the left). The two additional red vertical lines represent the Greta COP24 Speech and the first climate Strike, respectively on December 4, 2018 and September 20, 2019.

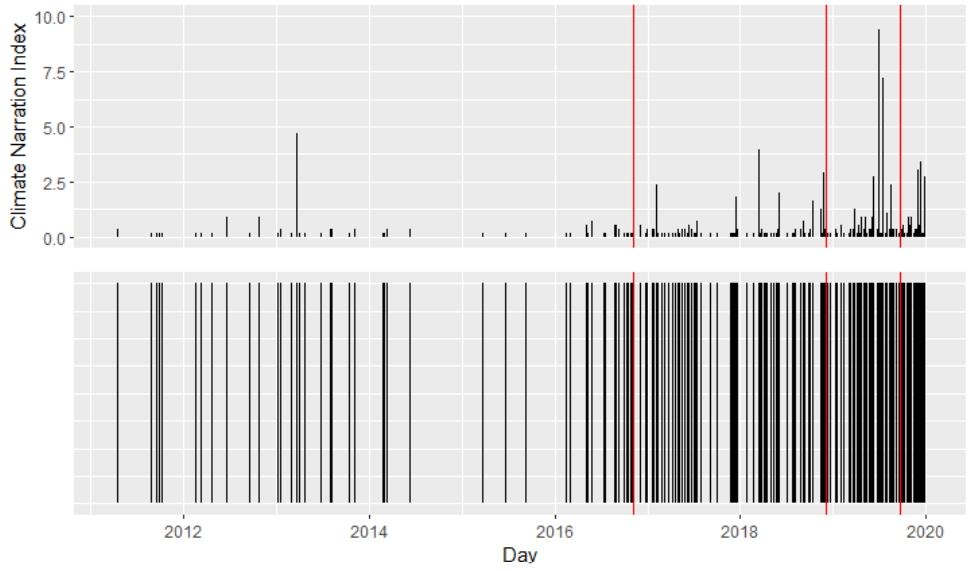


*Figure 1: Events (below) and Climate Narration index N in % (above)*

In figure 1, it is possible to see the increased levels of Climate Narration index N. After 2018 again, there is surge in terms of daily use. It is possible that the building of legitimacy was affected by these global events, hence, affecting investor's choices. Thus, we added an interaction specific to each firm that published a Tweet within the period of these two occasions. The dummy is again equal to 1 whenever a Tweet contains a climate change reference within 5, 10, and 15 days of a sensitive event. Therefore the model contains a systematic risk component driven by sensitive events and one non-systematic determined by Twitter activity and in particular Twitter activity during sensitive events. CRTA, the Speech from Greta, the first Climate Strike, and interactions constitute the independent variables on the right side of model in equation 1.

## *4. Data*

According to the work of Heede (Griffin and Heede 2017; Heede 2014), most of the accumulated emissions are related to a collection of 90 organizations. Such collection should represent the most vulnerable ones to reputation risk according to legitimacy theory, and their actions and effort to tackle climate change should be immediately affecting market preference. For this reason, the analysis in this work has been restricted to this sample. Some organizations, however, had to be excluded for two main reasons. The first reason is the inability to measure the target variable. Some of these organizations do not use floating equity or do not exist anymore. The latter is the case of USRR or the Polish government before 1991. The second reason prevents measuring the explanatory variables of interest. Some of these organizations do not use social networks in general and Twitter in particular. In some cases, they so but using a language different from English, a condition that prevents computing Twitter metrics given the impossibility to apply the same natural language processing algorithm to texts written in different languages. The resulting panel includes 40 organizations, 13 of which have never mentioned climate-related issues in their Twitter activity. These corporations represent together the 37.37% of total historical emissions from 1854. Heede' study considers the entire carbon footprint: within it there are reported the direct, indirect emissions and total amounts of CO2 equivalent emissions. ARs have been estimated according to equation 3 and are presented in figure 2. On the right side, all AR are collected in one picture, while on the right panel only selected firms are reported. The variables employed in the estimation of the model represented in equation 1 is summarized in table 1.

*Table 1: Summary Table*

| Static | N | Mean | St. Dev | Min | Pctl(25) | Pctl(75) | Max |
|---|---|---|---|---|---|---|---|
| $SR_{i,t}$ | 12064 | 0.0004 | 0.020 | -0.373 | -0.007 | 0.008 | 0.500 |
| $R_{m,t}$ | 12064 | 0.001 | 0.008 | -0.041 | -0.002 | 0.005 | 0.050 |
| $AR_{i,t}$ | 12064 | 0.0001 | 0.012 | -0.366 | -0.002 | 0.001 | 0.487 |

| Dummies | Values | Trigger | Persistence | Date |
|---|---|---|---|---|
| Twitter Activity[5] | [0,1] | Climate-related Twitter | 5 days after the tweet | |
| Twitter Activity[10] | [0,1] | | 10 days after the tweet | |
| Twitter Activity[15] | [0,1] | | 15 days after the tweet | |
| Greta Speech[5] | [0,1] | General Event | 5 days after the speech | December 4, 2018 |
| Greta Speech[10] | [0,1] | | 10 days after the speech | |
| Greta Speech[15] | [0,1] | | 15 days after the speech | |
| Climate Strike[5] | [0,1] | General Event | 5 days after the speech | September 20, 2019 |
| Climate Strike[10] | [0,1] | | 10 days after the speech | |
| Climate Strike[15] | [0,1] | | 15 days after the speech | |
| Tweet after Greta Speech[15] | [0,1] | | 15 days after the speech | |
| Tweet after Climate Strike[15] | [0,1] | | 15 days after the speech | |

On average, SR and Benchmark $R_{m,t}$ percentage variations are nearly null. They present, on the other hand, a standard deviation of respectively 2% and 0.8%. Maximum values for both are greatly above the 75 percentile: SR in of the panel presented a 50% increase, while benchmark returns $R_{m,t}$ at most 5%. We reported within table 3 in the Appendix the results for alpha and betas per each firm. While SR heterogeneity is expected to be randomly distributed, AR are calculated according to a firm-specific model. The effect of omitted variable of the market model are therefore embedded in the error term of equation 10. We also report the results of the Hausmann test to check for the statistical significance of fixed effects. Its purpose is to check the null hypothesis of random effects vs the alternative of fixed effects.

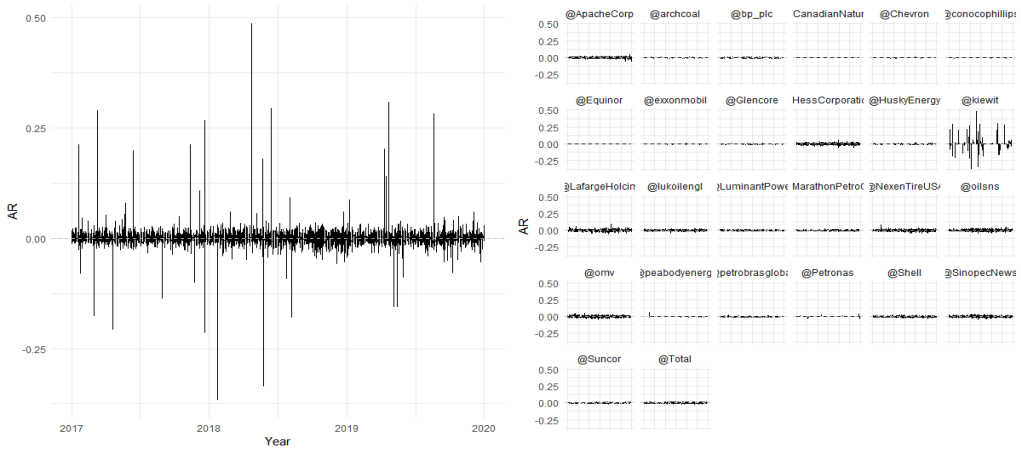


*Figure 2: Abnormal Returns estimated without event dynamics*

## *5. Results*

The estimates is reported in Table 2. We reported the days as 5 (a), 10 (b), 15 days (c), adding the interaction in (d). The model estimated reflect the relations between dummies of CRTA, selected events and the interaction between the two variables. The dependent variable reflects the AR outside the bound of two standard deviations of the daily expected returns in two years from above and below. This means that the estimates reflect abnormalities unexpectedly outside the bounds of predictability and well beyond the benchmark variation.

The results on the constant term do not allow the rejection of the null hypothesis of a constant equal to zero. Outbound AR registered a positive and persistent impact coming from CRTA. While the 5 days dummy is statistically insignificant, dummies for controlling at 10 and 15 days are positive with the estimates of 0.015 and 0.065 respectively. The selected events of Greta Speech and Climate strike had no statistically significant impact on AR at any timeframe considered. The dummy for 10 days after the Greta Speech is significant with -0.004 of value. There was no possibility to test shorter effects of interaction between general events and Twitter activity due to collinearity problems.

Along with estimation, a brief insight over selection models and robustness is provided. The F test is statistically significant, indicating that the null hypothesis of no statistical significance of the models is rejected for all cases. To consider potential selection bias and heterogeneity we applied fixed effects (FE) test of Hausman. The results provided the rejection of the null hypothesis of random effects all models.

The test for the third hypothesis required the estimation of a model with the addition of variable interaction between CRTA and the two sensitive events. AR during 5 days after the climate strike registered a negative impact of −1.3% while after Greta' Speech were improved by 0.1%. The proposed results display partial discordance with the initial hypothesis.

*Table 2: Regression results from Equation set (1)*

| | Abnormal Returns | | | |
|---|---|---|---|---|
| | (a) | (b) | (c) | (d) |
| Constant | 0.051 | 0.049 | 0.031 | 0.041 |
| | (0.146) | (0.141) | (0.133) | (0.160) |
| CRTA 5 | −0.011 | | | |
| | (0.009) | | | |
| CRTA 10 | | 0.015** | | |
| | | (0.005) | | |
| CRTA 15 | | | 0.065* | 0.063* |
| | | | (0.034) | (0.034) |
| GRETA speech 5 | −0.017 | | | |
| | (0.011) | | | |
| GRETA speech 10 | | −0.004*** | | |
| | | (0.0003) | | |
| GRETA speech 15 | | | −0.036 | −0.054 |
| | | | (0.025) | (0.067) |
| Climate Strike 5 | −0.119 | | | |
| | (0.085) | | | |
| Climate Strike 10 | | 0.033 | | |
| | | (0.037) | | |
| Climate Strike 15 | | | 0.15 | 0.21 |
| | | | (0.094) | (0.123) |
| Interaction with Greta | | | | 0.001** |
| | | | | (0.0004) |
| Interaction with Climate Strike | | | | −0.013** |
| | | | | (0.006) |
| Hausman | 10.223*** | 7.223*** | 12.223*** | 14.094*** |
| F test | 21.234*** | 23.234*** | 12.021*** | 23.543*** |

## *6. Discussion*

According to our results, firms using Twitter for climate-related communication show higher unexpected abnormal returns. This result does not necessarily counter our hypothesis settings. For instance, cited literature suggests that firms involved in green communication generally perceive higher SR than those that do not. Thus, the Twitter activity used by the Major Polluters does not induce negative unexpected returns. Furthermore, the selected sensitive events are uncorrelated to unexpected AR. To this study, there is no

evidence of sectorial stigmatization coming from the Greta Speech neither the Climate Strike. However, firms that were active on Twitter during the former events received unexpected AR (0.1%). They performed relatively worse during the climate strike (-1.3%). The market used efficiently the information generated by any potential climate sentiment, affecting single firms rather than the entire panel.

Overall, the estimation provided in the results underpinned hypotheses one and three. The sample of firms were unaffected systematically from the Greta Speech or the Climate strike, indicating the ineffectiveness (or even inexistence) of stigmatization deriving from the event. We consider this effect as a portrait of stigma as several firms avoid using Twitter for communication. Therefore, the dummies for Greta Speech and Climate strike would have systematically affected all firms. On the other hand, our results provide evidence for hypothesis three. While Twitter use regarding climate issues increases unexpected abnormal returns, it constitutes exposure to climate reputation risk. According to the event, talking about climate can generate unexpected negative returns. The explanation of the difference in sign could be related to the type of sentiment that was portrayed in news. The speech addressed political leaders and the establishment, rather than the Major polluters:

*"Since our leaders are behaving like children, we will have to take the responsibility they should have taken long ago … We have to understand what the older generation has dealt with us, what mess they have created that we have to clean up and live with. We have to make our voices heard."*

In the famous message, there was no connection to major polluters. No sentiment against the large polluters emerged. With what Rosen (2006) has called a sentiment "momentum", there would have been abnormal effects on financial performance. However, the Climate Strike was a wider and long-tailed event. For instance, it recorded the massive participation of young people, academics, and other personalities from cinema (Marris 2019; Schiermeier et al. 2019). Furthermore, some reporters have pushed the message that major polluters have unmet responsibility against the worldwide welfare (Yamin 2019). This might have generated enough sentiment momentum on social media against the major polluters included in our study. Firms without a Twitter account or silent during the Climate Strike faced no negative abnormal returns according to our findings. Exposed firms registered on the other hand the unexpected negative performance.

This study contemplated the negative effects of sensitive events. The timing agenda for sensitive events relating to climate change represents a possible" shock" policy for immediate damage control. The sentiment component is not new in this context. It is currently possible to monitor it via data analysis and test causality links. We addressed within the methodology the possibility of a selection bias and the probability of our panel being non-representative of a population of polluting firms. While these are not all historical polluting firms, these represent the greatest historical polluters. Therefore, even if it is a small population, this sample explains it at almost 40% of historical emissions. Reputation risk might greatly affect this small collection of firms. A very small number of agents generally controls recalling the Pareto Law of concentration, the majority of assets (and therefore their returns, effects, and emissions). This means that along with emissions, reputation risk should be perceived by a smaller group of firms rather than an entire sector homogeneously.

## *7. Conclusion*

The study involved a collection of firms responsible for the major historical CO2 emissions as reported by Heede (Heede 2014). Using text analysis, we recorded Twitter Use from the accounts of selected firms regarding climate risk and we considered such information as an indicator of exposure to climate reputation risk. Referring to Legitimacy Theory, we linked the violation of the legitimate use of the climate vocabulary to climate reputation risk.

Three main hypotheses drove this paper. The first focuses on the relation between climate-related Twitter activity and financial performances. According to our results, historical polluters narrating about climate

change do perceive better financial performance against those who do not. Therefore, financial markets positively price the communication of this subject, suggesting that it is legitimate for these firms to engage the issue of climate change.
The second hypothesis relates the impact on financial performances during the Greta speech in December 2018 at GOP 21 and the climate Strikes in 20-27 September 2019. According to our analysis, no abnormality was found. We consider this outcome as evidence against the presence of a stigma against major polluters generated by these two events. Finally, we treated the impact to firms that were active on Twitter narrating about climate during those events. This interaction relates to exposure to climate reputation risk and negative sentiment from investors. In other words, it represents a measure of unexpected financial performances from climate reputation risk. The results suggest that firms were susceptible to negative unexpected AR from the Climate Strike, but perceived limited unexpected positive AR from Greta's Speech.
In terms of narration, the first speech of Greta was directed at the political elites, not specifically the major polluters. Climate strikes on the other side referred to the way economy is constructed, underlying the structural impossibility of this economic system to sustain the transition. The call to reduce emission was rather direct and participation massive: the performance of major polluters was abnormally low two week afterwards. The results suggest that events might carry different effect of climate reputation risk. Nevertheless, the paper presented evidence of abnormalities in market efficiency related to reputation risk. Possible advancement might require the delineation of scenarios according to the presence of the negative effects of social media activity. A similar approach that allows for estimation for such dynamics is synthetic control: in terms of counterfactual determination does not differ from event analysis (Castro-Iragorri 2019).

Our approach determined the vulnerability of AR according to sensitive events. Firms engaged in social media activity perceived positive returns against those who did not. Twitter activity during the Climate Strike proved to be counterproductive. The reduction was 1.3% outside the expected AR of -1.3% equivalent to the standard deviation between 2017 and 2019. This means that these were unpredictable damages. According to our model and hypothesis testing, this loss emerged while the panel of firms persisted on Twitter activity during the sensitive event. The uncertainty is linked to climate reputation risk and reputation carries negative scenarios. Strategic use of such social media is a positive instrument as this study has estimated. If compared to mandatory non-financial disclosure, Social Media Activity does not present self-evident transition risks, however, illegitimate climate-related communication undermines financial performances. Furthermore, the sentiment surrounding certain events can boost a sentiment momentum against major polluters. In a complex world of information and social media, climate reputation risk represents a potential source of unpredictable operational risk.

## *8. Appendix*

The study over emissions per each organization was taken as previously stated by an article of Heede 2014. In it is compiled the accumulated emissions in scope 1, 2, and 3. The work presented above has employed a refined collection of the major 90 to capture the punishment of illegitimate use of climate-related words by the firm. Anchoring reputation to Twitter activity required to drop certain organizations. In table 3 the list is followed by the reasons for dropping down. Furthermore, the reference account of Twitter and the ticker from the financial market is added.

*Table 3: Major 90 and data cleaning*

| Entity | Scope1 | Scope2 | Scope3 | Total | Percent | Account | ticker | Reasons to Drop | Alpha | Beta |
|---|---|---|---|---|---|---|---|---|---|---|
| Former Soviet Union,* | 116.88 | 2.31 | 10.53 | 129.72 | 8.94% | | | No account | | |
| China (coal & cement) | 115.11 | 0 | 8.98 | 124.09 | 8.56% | | | No account | | |
| ChevronTexaco, USA | 46.28 | 1.48 | 3.34 | 51.1 | 3.52% | @Chevron | CVX | | 0.0001 | 0.963*** |
| ExxonMobil, USA | 41.6 | 1.54 | 3.53 | 46.67 | 3.21% | @exxonmobil | XOM | | -0.0004 | 0.897*** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Saudi Aramco, Saudi Arabia | 42.82 | 1.03 | 2.18 | 46.03 | 3.17% | | | No English | | |
| BP, UK | 32.51 | 1.02 | 2.31 | 35.84 | 2.47% | @bp plc | BP | | 0.000 | 0.952*** |
| Gazprom, Russian Federation | 25.09 | 2.13 | 4.92 | 32.14 | 2.22% | | | No English | | |
| Royal Dutch Shell, | 27.57 | 0.99 | 2.19 | 30.75 | 2.12% | @Shell | RDSA.AS | | 0.001 | 0.788*** |
| National Iranian Oil Company | 26.71 | 0.76 | 1.62 | 29.08 | 2.01% | | | No account | | |
| Poland (coal) | 24.66 | 0 | 2.09 | 26.75 | 1.84% | | | No account | | |
| Pemex, Mexico | 18.14 | 0.59 | 1.29 | 20.03 | 1.38% | | | No account | | |
| British Coal Corp., UK * | 17.74 | 0 | 1.5 | 19.25 | 1.33% | UK Coal | BP.L | | | |
| ConocoPhillips, USA | 14.7 | 0.67 | 1.5 | 16.87 | 1.16% | @conocophillips | COP | | 0.001 | 1.444*** |
| Petroleos de Venezuela | 14.77 | 0.44 | 0.95 | 16.16 | 1.11% | | | No English | | |
| Coal India | 14.28 | 0 | 1.21 | 15.49 | 1.07% | @CoalIndiaHQ | COALINDIA.NS | | 0.000 | 0.312*** |
| Peabody Energy, USA | 11.46 | 0 | 0.97 | 12.43 | 0.86% | @peabodyenergy | BTU | | -0.002** | 1.319*** |
| Total, France | 10.79 | 0.35 | 0.77 | 11.91 | 0.82% | @Total | FP.PA | | 0.000 | 0.767*** |
| Russian Federation (coal) | 10.36 | 0 | 0.88 | 11.24 | 0.78% | | | No account | | |
| PetroChina, China | 9.67 | 0.28 | 0.61 | 10.56 | 0.73% | | | No English | | |
| Kuwait Petroleum Corp. | 9.8 | 0.23 | 0.48 | 10.5 | 0.72% | | | No English | | |
| Abu Dhabi NOC, UAE | 8.84 | 0.26 | 0.57 | 9.67 | 0.67% | | | No finance | | |
| Sonatrach, Algeria | 7.96 | 0.4 | 0.91 | 9.26 | 0.64% | | | No English | | |
| Consol Energy, Inc., USA | 8.38 | 0 | 0.71 | 9.1 | 0.63% | @CONSOL Energy | CEIX | | 0.001 | 1.527*** |
| BHP Billiton, Australia | 6.97 | 0.06 | 0.58 | 7.61 | 0.52% | @bhp | BHP.AX | | 0.001 | 0.377*** |
| Czechoslovakia, (coal) * | 6.77 | 0 | 0.57 | 7.35 | 0.51% | | | No account | | |
| Anglo American, UK | 6.68 | 0 | 0.57 | 7.24 | 0.50% | @AngloAmerican | AAL.L | | 0.001 | 1.326*** |
| Iraq National Oil Company | 6.7 | 0.14 | 0.29 | 7.14 | 0.49% | | | No account | | |
| RWE, Germany | 6.31 | 0 | 0.54 | 6.84 | 0.47% | @RWE AG | RWE.DE | | 0.001** | 0.373*** |
| Pertamina, Indonesia | 6.16 | 0.21 | 0.46 | 6.83 | 0.47% | | | No English | | |
| Libya National Oil Corp. | 6.22 | 0.15 | 0.32 | 6.69 | 0.46% | | | No English | | |
| Nigerian National Petroleum | 6.06 | 0.15 | 0.33 | 6.54 | 0.45% | | | No Finance | | |
| Petrobras, Brazil | 5.49 | 0.16 | 0.34 | 5.99 | 0.41% | @petrobrasglobal | PBR | | 0.000 | 1.476*** |
| ENI, Italy | 5.2 | 0.24 | 0.54 | 5.97 | 0.41% | | | No English | | |
| Rio Tinto, UK | 5.5 | 0 | 0.47 | 5.96 | 0.41% | @RioTinto | RIO | | 0.001* | 1.055*** |
| Arch Coal, USA | 5.43 | 0 | 0.46 | 5.89 | 0.41% | @archcoal | ARCH | No Twitter | | |
| Petronas, Malaysia | 4.56 | 0.22 | 0.5 | 5.27 | 0.36% | @Petronas | PNADF | | 0.000 | 0.0212*** |
| Anadarko, USA | 4.56 | 0.18 | 0.46 | 5.2 | 0.36% | | | Truncated Serie | | |
| Occidental, USA | 4.63 | 0.09 | 0.34 | 5.06 | 0.35% | @OXY Petroleum | OXY | | -0.001* | 1.167*** |
| Kazakhstan (coal) | 4.09 | 0 | 0.35 | 4.44 | 0.31% | | | No Account | | |
| Statoil, Norway | 3.89 | 0.15 | 0.33 | 4.37 | 0.30% | @Equinor | EQNR | Truncated Serie | 0.000 | 1.261*** |
| Oil & Gas Corporation, India | 3.71 | 0.14 | 0.31 | 4.16 | 0.29% | @ONGC_ | ONGC.NS | | 0.000 | 0.381*** |
| Lukoil, Russian Federation | 3.6 | 0.09 | 0.19 | 3.87 | 0.27% | @lukoilengl | LUKOY | | 0.001* | 0.784*** |
| Sasol, South Africa | 3.24 | 0 | 0.27 | 3.52 | 0.24% | @SasolSA | SSL | | -0.001 | 1.331*** |
| Qatar Petroleum | 3 | 0.13 | 0.29 | 3.41 | 0.24% | | | No English | | |
| Repsol, Spain | 2.96 | 0.13 | 0.29 | 3.38 | 0.23% | | | No English | | |
| Ukraine (coal) | 3.11 | 0 | 0.26 | 3.37 | 0.23% | | | No Account | | |
| Marathon, USA | 2.64 | 0.11 | 0.24 | 2.99 | 0.21% | @MarathonPetroCo | MPC | | 0.000 | 1.206*** |
| Yukos, Russian Federation* | 2.69 | 0.06 | 0.12 | 2.86 | 0.20% | | | No account | | |
| North Korea (coal) | 2.58 | 0 | 0.22 | 2.8 | 0.19% | | | No account | | |
| Egyptian General Petroleum | 2.48 | 0.09 | 0.2 | 2.77 | 0.19% | | | No English | | |
| Rosneft, Russian Federation | 2.5 | 0.07 | 0.15 | 2.72 | 0.19% | | | No English | | |
| Petroleum Development Oman | 2.4 | 0.08 | 0.18 | 2.66 | 0.18% | | | No English | | |
| Hess, USA | 2.09 | 0.08 | 0.19 | 2.36 | 0.16% | @HessCorporation | HES | | 0.000 | 1.872*** |
| Xstrata, Switzerland | 2.05 | 0 | 0.17 | 2.22 | 0.15% | @Glencore | GLEN.L | | 0.000 | 1.276*** |
| Massey Energy, USA | 2.03 | 0 | 0.17 | 2.2 | 0.15% | @energy massey | MEE | | -0.003 | 1.121* |
| Alpha Natural Resources, USA | 1.98 | 0 | 0.17 | 2.15 | 0.15% | | | No account | | |
| Czech Republic & Slovakia | 1.84 | 0 | 0.16 | 2 | 0.14% | | | No account | | |
| Singareni Collieries, India | 1.74 | 0 | 0.15 | 1.88 | 0.13% | | | No finance | | |
| Ecopetrol, Colombia | 1.66 | 0.05 | 0.1 | 1.81 | 0.12% | | | No English | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sonangol, Angola | 1.69 | 0.03 | 0.07 | 1.79 | 0.12% | | | No English | | |
| Cyprus Amax, USA * | 1.61 | 0 | 0.14 | 1.75 | 0.12% | | | No Twitter | | |
| EnCana, Canada | 1.4 | 0.09 | 0.2 | 1.69 | 0.12% | | | No Twitter | | |
| Devon Energy, USA | 1.41 | 0.08 | 0.19 | 1.69 | 0.12% | @DevonEnergy | DVN | | -0.001* | 2.018*** |
| BG Group, UK | 1.24 | 0.09 | 0.21 | 1.54 | 0.11% | | | No finance | | |
| Sinopec, China | 1.41 | 0.04 | 0.08 | 1.53 | 0.11% | @SinopecNews | 0386.HK | | 0.000 | 0.518*** |
| Westmoreland Mining, USA | 1.41 | 0 | 0.12 | 1.53 | 0.11% | | | Bunkrupted | | |
| Suncor, Canada | 1.24 | 0.05 | 0.11 | 1.41 | 0.10% | @Suncor | SU.TO | | 0.000 | 0.987*** |
| Syrian Petroleum | 1.29 | 0.04 | 0.08 | 1.4 | 0.10% | | | No finance | | |
| Kiewit Mining, USA | 1.19 | 0 | 0.1 | 1.29 | 0.09% | @kiewit | KIRY | | 0.001 | 0.797*** |
| North American Coal, USA | 1.09 | 0 | 0.09 | 1.18 | 0.08% | @NACleanEnergy | NC | | 0.001 | 0.906*** |
| RAG, Germany | 1.05 | 0 | 0.09 | 1.14 | 0.08% | | | No English | | |
| China National Offshore Oil Co. | 1.03 | 0.03 | 0.06 | 1.12 | 0.08% | @oilsns | 0883.HK | | 0.001 | 0.639*** |
| Luminant, USA | 0.97 | 0 | 0.08 | 1.05 | 0.07% | @LuminantPower | VST | | 0.001 | 0.557*** |
| Lafarge, France | 1.04 | 0 | 0 | 1.04 | 0.07% | @LafargeHolcim | HCMLF | | 0.000 | 0.334*** |
| Holcim, Switzerland | 1.01 | 0 | 0 | 1.01 | 0.07% | | | lafarge | | |
| Canadian Natural Resources | 0.83 | 0.04 | 0.09 | 0.96 | 0.07% | @CanadianNatural | CNQ | | 0.000 | 1.483*** |
| Apache, USA | 0.81 | 0.04 | 0.1 | 0.95 | 0.07% | @ApacheCorp | APA | | -0.002** | 2.007*** |
| Bahrain Petroleum | 0.78 | 0.05 | 0.11 | 0.93 | 0.06% | | | closed | | |
| Talisman, Canada | 0.79 | 0.04 | 0.09 | 0.92 | 0.06% | | | No account | | |
| Murray Coal, USA | 0.73 | 0 | 0.06 | 0.8 | 0.05% | | | No account | | |
| UK Coal, UK | 0.73 | 0 | 0.06 | 0.79 | 0.05% | | | Merged UK | | |
| Husky Energy, Canada | 0.59 | 0.02 | 0.05 | 0.66 | 0.05% | @HuskyEnergy | HSE.TO | | 0.001 | 1.228*** |
| Nexen,** Canada | 0.59 | 0.02 | 0.04 | 0.65 | 0.04% | @NexenTireUSA | 005720.KS | | 0.000 | 0.249*** |
| HeidelbergCement, Germany | 0.59 | 0 | 0 | 0.59 | 0.04% | @the hc group | HEI.DE | | 0.000 | 0.698*** |
| Cemex, Mexico | 0.55 | 0 | 0 | 0.55 | 0.04% | | | No English | | |
| Polish Oil & Gas | 0.42 | 0.02 | 0.03 | 0.47 | 0.03% | | | No account | | |
| Italcimenti, Italy | 0.46 | 0 | 0 | 0.46 | 0.03% | | | No English | | |
| Murphy Oil, USA | 0.37 | 0.02 | 0.03 | 0.42 | 0.03% | @murphyouiii | MUR | | 0.000 | 1.884*** |
| Taiheiyo, Japan | 0.4 | 0 | 0 | 0.4 | 0.03% | | | No account | | |
| OMV Group, Austria | 0.3 | 0.01 | 0.03 | 0.35 | 0.02% | @omv | OMV.F | | 0.000 | 0.666*** |
| Total | 828.66 | 17.97 | 67.63 | 914.22 | 70.4% | | | | | |

## 8.1. Tweet Examples

**LafargeHolcim**

DidYouKnow (1) We lead in low-carbon construction with innovative cement and concrete products that allow for CO2 savings of up to 70% and an ambitious 2030 target aligned with the scenario of the Paris Agreement!
#ClimateAction #LHLowCarbonTransition
20/09/2019

**Suncor**

We're happy to see that Greta Thunberg visited Fort McMurray to speak to local
Indigenous communities about development in the region. Check out this story about her time with Mikisew Cree...
25/09/2019 (Climate Strike weeks 20-27)

**Equinor**

"Current climate actions far from enough to put the world on path to keep global warming well below 2 degrees," says our chief economist Ewaerness. What are your #EnergyPerspectives?
06/06/2019 (Climate Strike weeks 20-27)

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