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The Materiality and Measurement of Physical Climate Risk: Evidence from Form 8-K

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The Materiality and Measurement of Physical Climate Risk: Evidence from Form 8-K

Glen Gostlow¹

Abstract

Pricing firm-level exposure to physical risk, such as hurricanes, wildfires and floods, poses large informational challenges to investors and policymakers. This leads to difficulties in estimating how the market is pricing climate risk. This paper explores whether Form 8-K, a filing that allows firms to immediately report on unscheduled material events to shareholders, holds any relevant and latent information on physical risk. By utilising a simple textual approach, Form 8-K offers a way to identify material firm-level physical risk information related to severe weather and natural disasters. This paper also compares the measure to others in the literature. When compared to measures of keywords in annual reports, Form 8-K can detect *realised* and real-time physical risk from firms that predict they will be exposed. This allows for the validation of these less frequent and forward-looking measures. When compared to more frequent measures that utilise quarterly earnings call transcripts between managers and investors, Form 8-K identifies physical risk exposure that is not mentioned in the earnings calls. This is taken as evidence that Form 8-K may hold some latent real-time information on physical risk exposure.

JEL classification: G12, G14, Q54

Keywords: climate change, climate risk, physical risk, Form 8-K, materiality

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1 Introduction

A major aim of the empirical cross-sectional asset pricing literature is to explain why different assets earn different returns. An important assumption underpins these tests: expected returns are stable functions of characteristics, such as size, and not specific securities (Cochrane; 2011). Many theories thus attempt to explain *why* these characteristics are priced. For physical risk, the *why* is already answered: policymakers desire physical risk exposure to be priced given concerns that these risks are partially disclosed or misreported, leading to financial risks and the misallocation of capital across the economy (Hong et al.; 2019; Van Binsbergen and Opp; 2019). A question remains, however, whether they are in fact priced (IMF; 2020).

This paper explores whether Form 8-K has any utility as an instrument for the measurement of firm-level physical risk - a necessary step in understanding the pricing of this characteristic. Form 8-K is a broad form used to inform investors of specific events that are important to shareholders. It is also mandatory for publicly-listed firms in the United States to file an 8-K to the Securities & Exchange Commission (SEC) within four business days *after* certain triggering events and, in some cases, only if an event is deemed material to shareholders. Investors therefore have information on risks much quicker than the periodical annual or quarterly reports.

Information provided in Form 8-K must also be organised into topical categories. Of these, three existing categories are particularly encouraging for potential physical risk disclosure, known as Item 8.01 Other Events, Item 7.01 Regulation FD Disclosure², and Item 2.06 Material Impairments. The voluntary "disclose-when-material" nature of Form 8-K is a potentially novel way to detect point-in-time material physical risk and is the focus of this paper.

²Regulation FD Disclosure stands for Regulation Fair Disclosure.

Determining materiality is a key hurdle to overcome in the extant literature. US securities law defines materiality as any matter in which there is a substantial likelihood that the disclosure of the omitted fact would have been viewed by the "reasonable investor" as having significantly altered the "total mix" of information (Powell Jr; 1975). The "reasonable investor" is knowledgeable, 'though not necessarily prudent or conservative, or even sophisticated or savvy, but one who is presumed to have information available in the public domain and, importantly, one that invests principally to make money. They are neither an ostrich, hiding their head in the sand from relevant information, nor a child, unable to understand the facts and risks of investing' (Hansen; 2011, p.502). Firm managers are thus mandated to disclose information that is deemed relevant to the "reasonable investor" and have to defend their omission of facts in court under this definition (Wasim; 2019). These features offer an avenue for Form 8-K to potentially be a useful source of information. For example, even in 1996, before the recent interest in so-called ESG³ investing, firms were releasing information on their exposure to severe weather through Form 8-K (see Figure 1).

A more frequent and immediate measure of physical risk is potentially useful for various reasons. If a physical risk measure exists that is able to identify firm-specific exposure on a given week or day, then physical risk can be matched with interesting variables such as daily returns and daily temperature anomalies. This would enable interesting research on how quickly financial markets respond to firm-specific natural disasters and how climate variables impact economic outcomes at a granular level.

Another use concerns the forward-looking physical risk measures given by firms and data providers that are, at best, at a quarterly frequency (Sautner et al.; 2020). There exists no measure to validate the claims made by these physical risk guidances. For example, firms may identify extreme weather risks in the Risk Factors section of the annual report (Form 10-K) but this guidance may be boilerplate and not provide relevant information to investors. Form 8-K could be used to understand if these claims are accurate.

³ESG stands for Environmental, Social, and Governance.

The usefulness of Form 8-K is also potentially relevant during extreme weather events. As firms are mandated to file an 8-K once they deem an event material, the filing provides a way to assess exposure in the face of no suitable direct disclosure outlet and the market potentially not pricing the risk. This would allow a body of evidence to be built on what firms and sectors are most exposed, how they communicate these risks to shareholders, and could be used in models that aim to predict risks (Campbell et al.; 2008).

Form 8-K is not, generally, a forward-looking measure, despite firms sometimes updating their quarterly guidance by filing an 8-K after new material events occur. Instead, it is more commonly an ex-post measure that appears very close to the event of interest and reveals the views of management and whether they deem the event material. This paper shows that this filing is distinct from other measures and provides an alternative way to think about physical risk disclosure and identification.

In this paper, the Thailand floods in 2011 are used to test the utility of Form 8-K. All 8-K filings are downloaded from U.S public firms with operations in Thailand during 2011 and an algorithm is used to parse the physical risk information. The main results are the following. When compared to annual measures of keywords in the Risk Factors section of the annual report (Kölbel et al.; 2020; Nagar and Schoenfeld; 2020), Form 8-K can detect *realised* and real-time physical risk from firms that predict they will be exposed. This allows for the validation of these less frequent and forward-looking measures. When compared to more frequent measures that utilise quarterly earnings call transcripts between managers and investors (Sautner et al.; 2020), Form 8-K identifies physical risk exposure that is not mentioned in the earnings calls. This is taken as evidence that these filings may hold latent information. This paper shows how physical risk can evolve over time and is picked up by disclosures in Form 8-K. This offers a potentially interesting data source for research that requires a firm-specific, timely, and material measure of physical risk.

To illuminate the structure of Form 8-K, consider the filing of *FedEx Corporation* (Figure 1). *FedEx* was founded in 1971 as a delivery services company. On 16th January 1996, the company informed investors that recent severe weather will reduce third quarter operating profit. The filing revealed that the firm was impacted by ‘recent severe weather, coupled with the impact of earlier storms’, that will ‘reduce the Registrant’s third quarter operating profit significantly below current consensus Wall Street estimates’. More recently in 2019, *PG&E*, a utility company founded in 1901, was described by the *Wall Street Journal* as the first ‘climate change bankruptcy’ after suffering \$30 billion in liability charges from 750 climate-related lawsuits. The firm used Form 8-K to inform investors of investigations by the California Department of Forestry and Fire Protection of the possible role of power lines in causing severe wildfires across Northern California.

This paper is situated in a diverse literature, but primarily contributes to the identification of firm-level physical risk. Current measures either utilise information that does not come directly from the firm, such as the relationship between stock returns and temperature, or capture physical risk exposure by assessing communication directly from the firm such as through their annual report. These methods are reviewed in Section 2.

Assessing communication directly from firms to identify physical risk exposure has gained traction in the literature and has been aided by advances in quantifying large amounts of textual information (Sautner et al.; 2020; Kölbl et al.; 2020). This interest is partly driven by the disagreement amongst third-party data vendors on the salience of specific environmental issues, making decision-making difficult for investors who use these signals (Berg et al.; 2020; Eccles et al.; 2019).

Firm communication is also valuable since concerns exist about the materiality of physical risk. It is inappropriate to expect firms and investors to price-in financially immaterial events unless risks become material through other channels such as investor and stakeholder preferences (Pastor et al.; 2019; Rogers and Serafeim; 2019). Because materiality is a legal concept, firm filings are a useful source of information to understand a manager's view on material risks. This has spawned new textual approaches to quantify firm filings since information direct from firms provides investors with 'material, comparable, and consistent information they need to make investment and voting decisions' (SEC; 2020; Loughran and McDonald; 2016). This paper consequently also utilises advances in textual analysis to assess a large amount of 8-K filings in a simple manner, thus contributing to the literature on textual analysis and climate risk.

The remainder of this paper is structured as follows. Section 2 summarises current measures of firm-level physical risk whilst Section 3 details the legal structure of Form 8-K. Section 4 provides a methodology to detect physical risk from 8-K filings whilst Section 5 provides the context, data, and results for a use-case using the 2011 Thailand floods. Section 6 concludes.

2 Current Measures of Firm-level Physical Risk

There is a lack of research on assessing the empirical pricing of physical risk in the Fama and French (1996) tradition. This is partly due to the data limitations in attributing physical risk exposure to a specific firm which is a necessary step before forming sorted-portfolios. Some approaches have been proposed, however, in the literature that either focus on economic outcomes or returns. For example, temperature observations can be matched to firm-level sales (Addoum et al.; 2020), and climate change news (Engle et al.; 2020) or a measure of heat stress (Griffin et al.; 2019) can be matched to asset returns. Since the underlying causes of asset pricing anomalies are not fully understood (Fama and French; 1993), these approaches are similar in that they relate to firm-level characteristics.

Using return data requires no information on the geography of a firm because prices are expected to capture all relevant information (Fama; 1970). Abnormal returns then provide evidence that the firm is materially affected by new information that is unrelated to other systematic factors such as the market. For example, when returns co-vary with temperature this is evidence of exposure to temperature as a systematic risk factor (Kumar et al.; 2019).

However, matching temperature with sales *does* require a geographical variable such as the use of establishment-level data. The National Establishment Time-Series (NETS) dataset used by Addoum et al. (2020), for example, provides longitudinal establishment-level data on various dynamics of the U.S. economy. Addoum et al. (2020) use this data to assess how firm-level operation risk is affected by extreme temperatures.

Another common approach is to use headquarters as a proxy for the geography of the firm. For example, firms who are headquartered in small countries and gain the majority of their revenue from the same climatic zone can be linked to a specific temperature observation (Pankratz et al.; 2019). Tests can then be conducted on how revenue is impacted by changes in the weather.

Specific sectors can also be studied if firms' geographical footprint in a given sector are known to be close to their headquarters, such as in the agriculture industry (Hong et al.; 2019).

Measures of firm-level physical risk are provided by data vendors. Historical and forward-looking climate information can be used to estimate exposure and provide a single score for each firm. For example, for heat stress and extreme rainfall, *Four Twenty-Seven* use a baseline period of 1975-2005 and a projection period up to 2020-2040 to estimate physical risk exposure based on a current assessment of the firms assets. These scores are thus distinct from other measures because they not only match climate observations to firm outcomes but also forecast future exposure based on models of the climate system. Should a firm's geographical footprint change significantly after it has been assessed then its score would be a misleading signal. Consequently, assumptions can be made on the temporal evolution of a firms geographical footprint (Ginglinger and Moreau; 2019).

More generally in the asset pricing literature, researchers have recently examined the cross-section of expected returns using statistical learning and textual analysis techniques to tame the "factor zoo" (Cochrane; 2011). Lopez-Lira (2020), for example, quantify the textual disclosures in annual reports to extract the fundamental risks facing firms and find that portfolios sorted on these risks perform surprisingly well in explaining asset returns (see also Cohen et al. (2020)). These new techniques seek to answer the same essential question of other asset pricing techniques: where are the material risks in the economy?

Textual analysis can be used generally to quantify textual information from firms (Loughran and McDonald; 2011)⁴. This source of information can be useful since firms are mandated to disclose relevant information to shareholders, such as the factors that can make an offering in the firm speculative or risky. It can then be applied to specific issues such as physical risk.

⁴Earlier manual approaches include Doran and Quinn (2008) and Gamble et al. (1995).

For example, Nagar and Schoenfeld (2020) and Kölbel et al. (2020) measure the relative importance of key climate-related words in 10-K filings. Numerous advanced algorithms exist to parse this information but simpler algorithms have also been preferred for their replicability (Gentzkow et al.; 2019). This has spawned a diversity of approaches quantifying words in annual reports which are detailed in Figure 2.

Firms can also complete annual surveys on their physical risk exposure, such as through the annual *CDP* survey (Schiemann and Sakhel; 2019). For example, firms are asked to detail climate risks that have the potential to have a substantive financial or strategic impact on the firm. Because these surveys are voluntary, samples are likely to be biased towards larger firms that have the resources to complete them. For example, Dietz et al. (2018) find some evidence that larger firms score better in their *CDP* disclosure on transition risks.

Other textual measures include quarterly earnings calls and press releases, which can be measured for their share of climate-related words and the sentiment related to these words (Sautner et al.; 2020; McKnight and Linnenluecke; 2019). These measures take the share of the conversation devoted to physical risks as a proxy for exposure and then compare this measure to economic outcomes.

Overall, this paper also utilises recent techniques in textual analysis to understand firm-level risks. It does this by asking whether information in Form 8-K can aid in the identification of firm-specific physical risk, which could then be used to answer interesting future research questions such as whether physical risk is priced in the cross-section. To test this, a measure that is firm-specific, material, and time-varying is preferred to accurately capture a characteristic of interest.

A summary of the current techniques to identifying firm-level physical risk is given in Figure 2 and Figure 3.

3 Form 8-K

Form 8-K is interesting for various reasons. Since the Securities Exchange Act of 1934, regulated firms have been mandated to submit this filing to the Securities & Exchange Commission (SEC) within four business days of a triggering event and ensure the filing is made publicly available on the Electronic Data Gathering, Analysis, and Retrieval system (EDGAR). Non-US firms that are regulated under the SEC can file an equivalent form known as Form 6-K.

The aim of Form 8-K is to inform investors of potentially significant material events such as bankruptcy proceedings, significant acquisitions, or disruption to operations, and to keep investors up-to-date between periodical filings such as the quarterly and annual reports. It is consequently the most frequent filing made to the SEC. In 2004, in response to increased demand from investors for real-time information, the SEC shortened the filing period of Form 8-K and simplified the events to be disclosed in order to make the form as streamlined as possible (Benston; 1973; Lerman and Livnat; 2010).

Firms submit Form 8-K using a common and standardised structure. As well as dictating the visual appearance of the form, this structure formalises triggering events into 31 SEC topics. However, not all topics are considered mandatory. For example, Item 8.01 Other Events⁵ is only filed when the firm deems information "important" and Item 7.01 Regulation FD Disclosure⁶ is only filed when the firm believes a shareholder may "trade on the information". Item 2.06 Material Impairments is, however, mandatory when there is a "material charge for impairment under generally accepted accounting principles".

⁵The SEC states that "the registrant may, at its option, disclose under this Item 8.01 any events, with respect to which information is not otherwise called for by this form, that the registrant deems of importance to security holders".

⁶Regulation FD Disclosure stands for Regulation Fair Disclosure and is aimed at mandating the disclosure of information that could be used by insiders or is difficult to obtain. The SEC acknowledged concerns that mandating disclosure under Regulation FD may "chill" issuer disclosure as firms would find it difficult to determine when disclosure of information would be material and subject to the regulation. Firms may then cease communications with the "outside world" altogether. Regulation FD therefore only applies to any holder of the issuer's securities under circumstances in which it is reasonably foreseeable that the security holder will trade on the basis of the information.

The legal structure of Form 8-K provides an interesting avenue for disclosure and the detection of physical risk. Generally, the common threshold for disclosure under principle-based regimes such as those used in the United States and Europe uses the definition of materiality similar to that set out in *TSC Industries v. Northway* (Powell Jr; 1975). This case rules that disclosure is material, and thus mandatory, if there is a 'substantial likelihood that the disclosure of the omitted fact would have been viewed by the reasonable shareholder as having significantly altered the 'total mix' of information available'. The definition of the "reasonable investor" is therefore vital (Wasim; 2019). They are generally characterised as 'knowledgeable though not necessarily prudent or conservative, or even sophisticated or savvy, but one who is presumed to have information available in the public domain and, importantly, one that invests principally to make money' (Hansen; 2011, p.502).

As an example, in Item 8.01 Other Events, firms may disclose material information to ensure they meet the requirement of providing material and up-to-date information to the market. This may include physical risks the firm deems material. Firms may also reveal information through other channels such as conferences and investor calls, which are then disclosed in Item 7.01 Regulation FD Disclosure as it mandates the release of private information simultaneously to the wider market. Additionally, Item 2.06 Material Impairments requires firms to disclose impairments such as when a facility has been inundated during a flooding event. These three topics are particularly useful for the potential identification of physical risk (Figure 4).

The question remains whether Form 8-K is also economically relevant. Ben-Rephael et al. (2019) find significant abnormal attention to Form 8-K on the filing and event dates whilst Zhao (2017) and McMullin et al. (2019) find that an increase in information disclosed in Form 8-K improves the price formation process. Yet, Campbell et al. (2020) find that the price formation process occurs before the filing date, implying investors have access to other sources of salient information.

The textual information found in other filings, such as the Risk Factors section of Form 10-K, is generally economically relevant to investors (Campbell et al.; 2014; Ross; 2019; Lopez-Lira; 2020). However, these filings are becoming longer which has led to fears of boilerplate, especially for forward-looking risk identification (Kravet and Muslu; 2013; Cazier et al.; 2018). Cohen et al. (2020) show that prices are "lazy" to small changes in text given in these filings, implying investors are inattentive to the increased information they are provided with.

Identifying the value-relevance of filings in the context of physical risk has, however, seldom been studied. Kölbel et al. (2020) show that a forward-looking measure based on textual disclosures in the annual report, Form 10-K, has no impact on credit-default-swap spreads whilst Zhang and Zhu (2020) identify a textual measure of physical risk in Form 10-K that is associated with increased bond yield spreads. Nagar and Schoenfeld (2020) and Berkman et al. (2019) count the number of climate-relevant words in Form 10-K and find their proxy for climate risk is associated with lower expected returns.

Overall, it remains an open question whether Form 8-K shares the same characteristics as other filings or sources of physical risk information - or whether Form 8-K holds relevant information on physical risk. Yet, the legal structure of Form 8-K provides an interesting avenue for disclosure and the detection of physical risk: the filing is made frequently, is only mandatory when a manager deems a risk material, and provides information and guidance about events relatively quickly.

4 Methodology

This section details how we might go about identifying firm-level physical risk exposure in Form 8-K. The process is detailed in Figure 5 and consists of five steps.

Step 1

Form 8-Ks are downloaded from the US Securities & Exchange Commission's (SEC) Electronic Data Gathering, Analysis, and Retrieval (EDGAR) system⁷.

Step 2

The raw texts are turned into a corpus, defined as a collection of written texts with document-level variables, before being analysed⁸. The imported texts are also cleaned. Specific tokens, the most basic unit in textual analysis consisting of characters or letters, are removed to clean the corpus:

```
<.*?>|&#\d+;
```

The common character string ''' is also replaced with '''.⁷

Step 3

To extract the specific part of the 8-K filing that includes information on physical risk exposure, tags are identified that indicate the start and end of the key paragraph. This is possible since all filings are submitted to the SEC in a standardised format and made available through the EDGAR system. An algorithm searches for patterns in the corpus that match a regular expression (regex) and splits the corpus at each of these tags.

⁷This can be done in R: <https://cran.r-project.org/web/packages/edgar/edgar.pdf>

⁸Specifically, the 8-K filings are imported into R using the 'readtext' package, which can read multiple file formats including text (TXT) files. Unlike many parsing algorithms which extract filings from EDGAR, it is not necessary to encode the documents to 'utf-8' using the 'edgar' and 'readtext' packages. The 'quanteda' package is used for its speed and accessibility as it is more efficient than other R and Python packages for textual analysis and remains open source (Benoit et al.; 2018).

The end and beginning of a filing are also considered tags so that there is a split *between* the filings as well as a split when a key tag occurs. To illustrate this step, it is possible to think of the corpus as a book of all of the 8-K filings joined together. The algorithm searches through the book for tags and splits the book into many segments based on these tags.

Knowing what the tags should be is the key input into the algorithm. They must be flexible enough to capture subtle differences in spelling or formatting whilst remaining stringent enough to specifically capture the real tags. For example, some firms write "Item 8.01 Other Events" whilst others include a period and write "Item 8.01. Other Events". Regular expression matching allows for this flexibility by searching for a fluid string pattern. As Figure 6 shows, the key tags are the SEC topic that is specified by the firm, the signature of the executive, and the beginning and end of the filing. The two segments in this case are then extracted as separate documents with the tag saved as a document-level variable.

Some firms may also include a 'Forward-Looking Statement' before the signature in order to satisfy the requirements of the Private Securities Litigation Reform Act of 1995. This requires a cautionary statement when speculative comments are made in the 8-K filing. Because of this, 'Forward-Looking Statement' and 'Forward Looking Statement' are included as tags.

Six tags (given in Step 3 of Figure 5) are identified in the corpus using case-insensitive regex patterns:

```
2\\.06\\..*\\s*Material Impairments
7\\.01\\..*\\s*Regulation FD Disclosure
8\\.01\\..*\\s*Other Events
SIGNATURES
Forward Looking Statement
Forward-Looking Statement
```


Step 4

Some extracted segments do not contain information on physical risk but are required to be extracted in order to clean the corpus. For example, the second segment in Figure 6 between ‘Signature’ and the end of the filing contains no useful information. The segments have document-level variables which reveal which tag is within the segment. For example, the first segment in Figure 6 has a document-level variable called ‘ITEM 5. OTHER EVENTS’. Using this information, a corpus subset is created by removing unnecessary segments:

SIGNATURES

Forward Looking Statement

Forward-Looking Statement

Step 5

The remaining corpus consists only of the key paragraphs within the 8-K filings that may potentially mention physical risk. The researcher can then conduct textual analysis on these texts, such as by utilising a dictionary method, topic modelling, or an advanced algorithm such as BERT (Devlin et al.; 2018; Kölbl et al.; 2020).

Mentioning physical risk in Form 8-K is a suitable proxy for exposure since firms make this filing in response to an event. For physical risk, this event is usually always negative. A firm does not benefit from disclosing the fact they are unaffected from a risk. It can also be costly for them to do so. Instead, the filing helps to inform investors and shareholders of material changes to the firm, such that any litigation under the definition of materiality is minimised (Wasim; 2019; Skinner; 1994). Form 8-K is therefore a potential measure of exposure about the *realisation* of risks posed to the firm.

5 Identifying Physical Risk During the 2011 Thailand Floods

5.1 Context and data

This section utilises the methodology to understand if it is possible to detect exposure to severe weather and natural disasters. To do so, the focus is limited to the 2011 Thailand floods that occurred between July 2011 and January 2012 during the monsoon season.

The Thai floods led to economic losses totalling \$42 billion and ranked as the largest economic loss ever from a freshwater flood disaster (Gale and Saunders; 2013). The economic impact was particularly large for the private sector due to the clustering of manufacturing industries in the area (Perwaiz; 2015) and provides an ideal setting to test the utility of Form 8-K. For example, did any firms file an 8-K to inform investors they had been impacted by the flooding?

The impact of the flooding led to a 'hard disk drive supply shortage' which 'negatively impacted...revenue[s] as customers reduced inventories across the supply chain' (*Intel Corp*, Form 10-K Annual Report, p.23). After an earthquake in Japan in March 2011, many firms relocated to Thailand and joined the majority of international firms that are located in the Chao Phraya River Basin (Figure 7). This area consequently flooded in July 2011 (Swiss Re; 2012).

U.S-regulated firms with facilities in Thailand in 2011 are identified regardless of whether their facilities are in the Chao Phraya River Basin by using Orbis⁹ which provides a BvD ID and a ISIN code for each subsidiary/branch and its relation to a parent company. The sample is limited to firms with operations in Thailand in order to reduce the sample size and provide more detail on how the method can be utilised. This paper therefore focuses on depth-of-study rather than breadth. Future work could utilise a wide-ranging and general measure from Form 8-K.

⁹A special request was made to access the data for 2011.

In reality, firms with no operations in Thailand could also be affected through their supplier relationships (Pankratz and Schiller; 2019).

Parents companies are matched to a Central Index Key (CIK) code from Compustat. The list of CIK codes are then used to scrape the Electronic Data Gathering, Analysis, and Retrieval (EDGAR) system used by the SEC for all 8-K filings made by firms in 2011 Q3 and Q4¹⁰. The final sample consists of 1,506 8-Ks filed between July 2011 and December 2011 by 249 firms, which averages approximately 6 filings per firm. Noticeably, the semiconductor and hardware sectors, as part of the IT industry, are most represented and corroborate the findings of Perwaiz (2015) that these firms cluster in the region (Figure 8).

5.2 Results

Only some SEC topics in Form 8-K are relevant for physical risk disclosure. These include Item 8.01 Other Events, Item 7.01 Regulation FD Disclosure, and Item 2.06 Material Impairments. Each filing in the sample is split based on regular expression matching of the tags "SIGNATURES", "Forward Looking Statement"¹¹, "Other Events", "Regulation FD Disclosure", and "Material Impairments".

Of the 1,506 8-K filings that are initially downloaded, 1,043 are removed because they do not contain any of the relevant SEC topics. The remaining 463 filings are known as *potential physical risk filings* because they may hold information on exposure. Figure 9 shows the cumulative number of these filings made between July 2011 and January 2012.

¹⁰Specifically, this is done using the R package 'edgar'.

¹¹"Forward-Looking Statement" is also matched.

Form 8-K is the most commonly filed form to the SEC, and Figure 9 shows a steady rate of submission from firms. The next step in the process is to understand the information in the *potential physical risk filings*. To do this, Figure 10 shows a timeline of the physical risk disclosures made by firms in Thailand during this period.

The first 8-K disclosure concerning the floods was released on 11th October 2011 by *Hutchinson Technology Co* as the firm released two relevant 8-Ks topics on the same day, disclosing their ‘assembly operations in Ayutthaya, Thailand have been temporarily suspended due to rising floodwaters in the industrial park where our plant is located’. A press release on the 11th October 2011 triggered another 8-K filing and provided ‘an update on the status of our assembly operations in Thailand’.

On 12th October 2011, *Western Digital Corp* filed an 8-K triggered by a ‘press release regarding the impact of the severe flooding in Thailand on its operations’. On the same day, *ON Semiconductor Corporation* disclosed a ‘press release regarding the recent flooding in Thailand and the resulting impact on operations’.

On 13th October 2011, *Benchmark Electronics, Inc.* announced the ‘temporary closing of its Thailand facility due to flooding’.

Four days later on 17th October 2011, *Western Digital Corp* gave an update on ‘the impact of the severe flooding in Thailand on its operations’.

On 18th October 2011, *Benchmark Electronics, Inc.* disclosed an update on the impact of the Thailand flooding on its facility.

On 20th October 2011, *Western Digital Corp* informed the market it had held an investment community conference call 'to discuss its financial results for the first fiscal quarter ended September 30, 2011' and 'the impact of the flooding in Thailand'.

A day later, *ON Semiconductor Corporation* disclosed that their 'SANYO Semiconductor division's manufacturing operations in Thailand, including buildings and equipment located at the Rojana Industrial Park in Ayutthaya, Thailand have been severely damaged by the flood'. They added that 'based on currently available information and given the extent of the potential damage, the Company believes it will be unable to re-start probe, assembly and test operations at the Rojana Industrial Park for an indefinite period'. The company also provided an 'update on the impact to its business from the continued flooding in Thailand'.

On 24th October 2011, *Emerson Electric Co.* filed a 3-month summary of orders in which they stated that 'during the past several weeks, many areas in Thailand sustained massive damage from flooding'. They stated they were 'executing contingency plans, and working with suppliers and customers to minimize the impact of supply disruptions'.

On 28th October 2011, *Benchmark Electronics, Inc.* stated 'the Company's previously announced suspension of its operations in Ayudhaya continues to be in effect. Local officials have estimated that the flooding will continue through the middle of November 2011, at which time they will begin to pump water from the industrial park'. They added 'the Company's Thailand facilities are among its largest, generating 20-25% of the Company's revenue. As a result, the impact on revenue and operations will be significant for the next several fiscal quarters', whilst 'the uncertainties of the impact of the Thailand flooding on the Company's operations make it challenging to provide guidance'.

On 2nd November 2011, *Emerson Electric Co.* provided additional information on 'the impact of the flooding in Thailand on Emerson's business'. They stated 'the resulting supply disruption, primarily

affecting the Process Management segment, is currently estimated to impact first quarter sales by approximately \$300-\$400 million, but any impact on the full year is expected to be minimal’.

On 21st December 2011, the same company provided a 3-month summary of operations, in which it disclosed the ‘previously communicated Thailand flooding impact of \$300 to \$400 million in sales – will put heavy pressure on first quarter results’.

Finally, on 23rd December 2011, *Benchmark Electronics, Inc.* disclosed that ‘its Ayudhaya, Thailand facility that was closed due to flooding had reopened’.

Figure 11 plots how the filings that do mention the flooding compare to the *potential physical risk filings*. It is clear that reporting of physical risk impacts only began in October 2011, with firms such as *Benchmark Electronics, Inc.* reopening their facilities months later in December 2011. Firms began by stating they are aware of flooding and then stated they have become aware of the impact on facilities. As the flooding continues, firms such as *Emerson Electric Co.* begin relating the impact to sales and attempt to provide guidance to the market.

5.3 Comparison to other measures

How does Form 8-K compare to other measures in the extant literature? A key question is whether firms in Thailand in 2011 acknowledged the possibility that physical risk could impact business operations. Forward-looking predictions of physical risk exposure are not specifically mandated despite being advocated by the European Commission (EU-TEG; 2019) and the Task-force on Climate-related Financial Disclosure (TCFD; 2017). However, existing disclosure regulations may already cover these risks and firms should be disclosing them Hinman (2019). This has led the SEC to issue guidance on climate change disclosure in 2010 (SEC; 2010).

To test how forward-looking measures compare to Form 8-K, the Item 1A Risk Factors section of the annual report, Form 10-K, is used. This is because firms must disclose risks to investors that may make the firm speculative or risky. This section of the annual report thus frequently mentions physical risk and has already been quantified in this way (Nagar and Schoenfeld; 2020; Kölbel et al.; 2020).

The 10-K for each firm that is filed immediately prior to the floods is downloaded. This is done by scraping the 10-Ks from the EDGAR system and using regular expression matching to identify relevant parts of the filing in a similar fashion to the 8-K analysis. The regex pattern searches for text that starts with 'Item 1A' and ends with 'Item':

```
(?<=Item[$~$a-zA-Z\n] 1A) (. *?) (?=Item)
```

This identifies the true Item 1A Risk Factors section and also the table of contents reference. Only the longest section which is matched to the regex pattern is kept, which removes the table of contents pattern match. All characters are turned to lowercase, digits are removed, and unnecessary signs are removed using the regex pattern:

```
\b\d+(?:\.\d+)?\s+
```

Diverse language is used to explain physical risk. Firms may use the phrases 'natural and manmade disasters', 'extreme weather', 'environmental hazards', 'environmental disaster', 'severe weather', and 'natural causes'¹². Many of these phrases can be captured by searching for 'environmental', 'weather', and 'natural' at the the risk of capturing irrelevant phrases such as 'environmental technology'. For this paper, a dictionary method is used, given in Figure 12, to proxy for physical risk exposure in Form 10-K.

¹²Other terms include 'natural calamities', 'natural catastrophic events', 'natural events', and 'weather emergencies'.

The latest 10-K filing prior to the flooding provides, in essence, all the information an investor may have directly from the firm to judge future physical risk exposure. The percentage of firms which mention a term from the physical risk dictionary in the sample of firms prior to the flood with subsidiaries in Thailand is approximately 55% (Figure 13). Consequently, using this measure, not all firms deem themselves exposed.

Form 8-K can be viewed as the *realisation* of a physical risk event. This is polar to Form 10-K which is a predictive measure. This tension can then be compared directly by assessing whether firms accurately predicted their exposure by fact-checking the 10-K measures¹³.

Matching firms that made a 10-K and a 8-K filing results in 236 firm-disclosure observations. Figure 14 shows a confusion matrix for the forward-looking physical risk measure identified in Form 10-K and their subsequent realisation during the flooding as revealed in Form 8-K. For the 102 firms that do *not* mention physical risk in their Risk Factors section, none of them experience a material impact during the flooding - implying their ability to predict risks is high.

For the 129 firms that do identify physical risk as a reason why the firm may be speculative or risky, 5 firms, or 3% of this particular sample in Thailand, then file an 8-K to disclose they have been affected by the flooding.

It is difficult to disentangle the real reason for such firm disclosure. The results are consistent with (a) firms accurately predicting their future exposure, (b) firms mentioning physical risk despite not being affected (i.e. boilerplate), and (c) firms mentioning physical risk as a precautionary measure and being lucky. This latter case may be due to managers finding it difficult to predict the climate system.

¹³Evidence on the efficacy of manager's ability to identify risks has been well-studied in the accounting literature. Whilst some find that managers do not remove stale risks (Cazier et al.; 2018), others find that managers do update their risk factors (Campbell et al.; 2014; Cohen et al.; 2020).

Firms consequently mention physical risk as a potential source of risk even if an event does not occur in the specific time-frame of the annual report. A manager therefore trades-off two matters: the risk of not being protected in litigation cases because their language is too generic (Wasim; 2019) versus informing the market of material physical risks despite not being able to quantify the probability of exposure.

These results are also consistent with the concerns of the SEC about mandating climate disclosure that then becomes 'stale' or uninformative to investors (Hinman; 2019). If physical risk disclosure is mandatory, investors may have no way of distinguishing between firms if they all include boilerplate statements acknowledging physical risk events may occur.

Another measure from the extant literature utilises earnings call transcripts, which quantifies words to create three distinct measures of physical risk (Sautner et al.; 2020): exposure, sentiment, and risk. Exposure is measured as the frequency of physical risk bi-grams scaled by the total number of bi-grams given in the transcript. Sentiment is measured in a similar way but conditioned on the presence of positive and negative tone words (Loughran and McDonald; 2011). Risk is measured as the frequency of physical risk bi-grams that appear in the same sentence as the words 'risk' and 'uncertainty'.

To compare the 8-K measure to these earnings call transcript scores, firms in the total Thailand sample are matched to the measures provided by Sautner et al. (2020). This results in 120 individual firms in the sample.

Figure 15 measures the average score for each measure and plots them across time relative to the start of the flooding (approximately 2011 Q3). The exposure and risk measures from Sautner et al. (2020) increase in the second quarter of 2011 with sentiment decreasing. All three measures then increase from the third quarter of 2011. An increase in sentiment implies a positive sentiment, whereas an increase in exposure and risk implies more bi-grams are spent discussing physical risk in the earnings transcripts.

In the full dataset provided by Sautner et al. (2020) that includes over 10,000 firms from 34 countries, physical risk exposure and risk are generally low during 2011 (not shown). However, sentiment falls throughout 2011.

The Sautner et al. (2020) measures are decomposed more fully by plotting them for all firms in Thailand against the days in which an 8-K filing is made (Figure 16). The 8-K measure provides a daily measure of physical risk that are deemed material by managers as opposed to the transcript measure which quantifies the share of calls devoted to physical risk. Figure 16 shows the precise time in which the physical risk event began to impact firms. The exposure and risk measures increase by approximately 0.025 between 2011 Q2 and 2011 Q4.

Firms deemed exposed by the 8-K measure are then matched to the earnings call transcript measures. Interestingly, the three measures, risk, exposure, and sentiment, are all zero between 2011 Q1 and 2012 Q4 for these firms, implying no discussions were made in the calls by the firm or by investors (not shown). The 8-K measure is, however, able to identify a measure of physical risk exposure for these firms.

This section has therefore shown preliminary evidence that the 8-K measure can provide timely signals of firm-specific physical risk that differs from those currently available in the extant literature.

6 Conclusion

This paper explores the utility of a new measure of firm-level physical risk using textual information found in Form 8-K. For firms regulated in the US, this filing offers a distinct source of information on physical risk that is timely, firm-specific, and material.

The measure is distinct from others in the extant literature. When compared to predictive measures found in annual reports, Form 8-K can detect *realised* and real-time physical risk from firms that predict they will be exposed. The measure can also validate the claims made by firms who state they are not exposed to physical risk. When compared to more frequent measures that utilise earnings call transcripts, the measure detects physical risk that is missed by algorithms that search for climate-related bi-grams in the text of transcripts. Overall, physical risk detected in Form 8-K offers a measure that can be filed throughout the year, is specific to a firm, and passes a materiality threshold.

The measure opens up interesting future research avenues. First, Form 8-K provides a ‘manager’s view’ of materiality that can be compared to others in the field. For example, it can be compared to the Sustainability Accounting Standards Board materiality map (Khan et al.; 2016) and to material risk perceptions disclosed in annual reports (Matsumura et al.; 2018). An interesting study would consider how managers communicate their view of materiality and whether this corresponds to the views of stakeholders (Rogers and Serafeim; 2019).

Second, there exists mixed evidence on the economic relevance of Form 8-K (Campbell et al.; 2020). However, some disclosures, and the frequency at which they are made, are salient to investors (McMullin et al.; 2019; Feuerriegel and Pröllochs; 2018; Zhao; 2017). Interesting work could assess how value-relevant physical risk disclosures in Form 8-K are to investors.

The identification of firm-level physical risk is challenging. Despite not being a long-term forward-looking measure, this paper shows that Form 8-K can still be a useful source of information on latent physical risks, especially given the lack of alternatives in the literature, and could be used to answer interesting future research questions on the topic of physical risk and market efficiency.

Figures

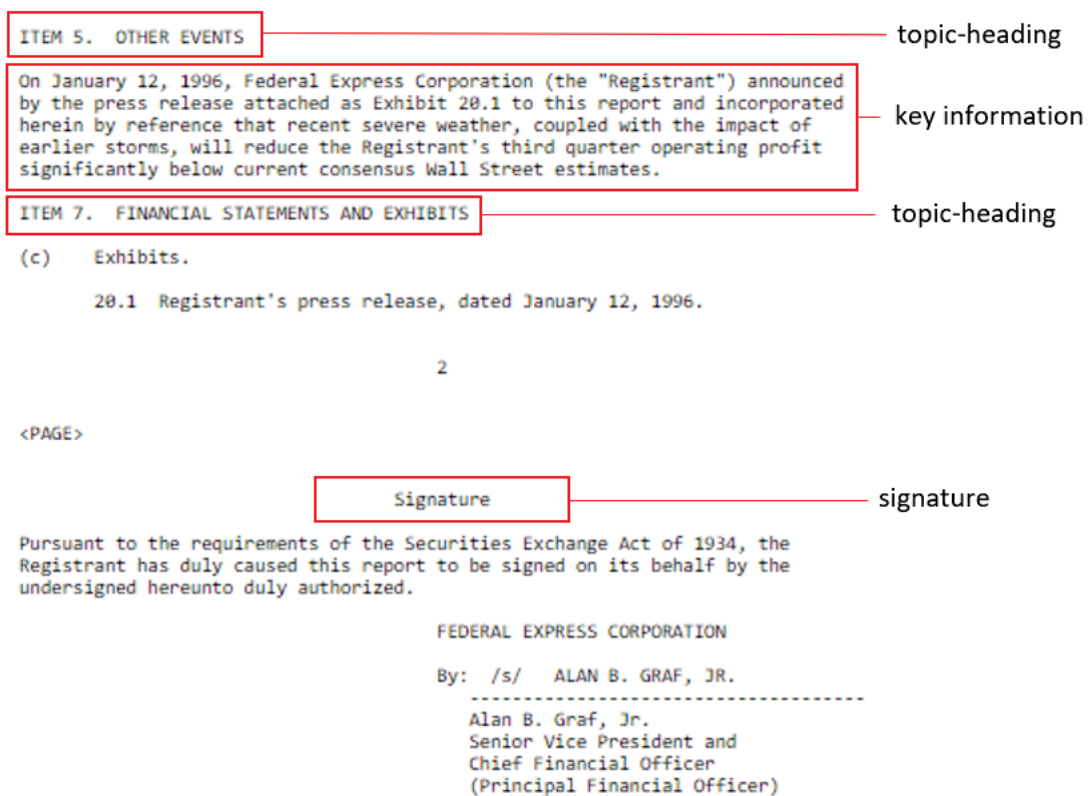


Figure 1: **Form 8-K filed by FedEx Corporation** - This figure shows the Form 8-K filed by *FedEx* on 16th January 1996 and made publicly available from the Securities & Exchange Commission's (SEC) Electronic Data Gathering, Analysis, and Retrieval (EDGAR) system. Filings can be viewed and downloaded in a txt format for all regulated firms from 1993 to the present day. The standardised format of the 8-K filing means that the SEC topic-heading, manager's signature, and key information are clearly displayed and can be used to extract the physical risk information.

Identification	Frequency	Authors	Method
Annual reports	yearly	Kölbel et al. (2020)	BERT (Devlin et al.; 2018) algorithm to quantify relative importance of climate risk words in Item 1A Risk Factors of Form 10-K.
	yearly	Nagar and Schoenfeld (2020)	In the full 10-K filing, count the occurrence of: (1) <i>weather</i> (2) <i>weather</i> used as verb (3) <i>weather</i> used as verb and nearest noun is weather-related. Exposure equals (1) - [(2) - (3)].
	yearly	Zhang and Zhu (2020)	Binary and continuous variables if <i>weather</i> appears in the full 10-K filing.
	yearly	Berkman et al. (2019)	Length and relevance of climate disclosures in Form 10-K from Ceres/CookESG.
Earnings calls	quarterly	Sautner et al. (2020)	Bi-grams algorithm by King et al. (2017) on keywords used in calls.
	quarterly	Li et al. (2020)	Pattern-based sequence recognition algorithm to detect keywords in calls.
Press releases	daily	McKnight and Linnenluecke (2019)	Press releases from <i>Factiva's PR Newswire</i> .
Surveys	yearly	Schiemann and Sakhel (2019)	Physical risk submissions made to <i>CDP</i> .
Proprietary models	yearly	<i>eRevalue</i> in Schiemann and Hoepner (2020)	Algorithm to identify environmental topics from firm filings.

Figure 2: **Firm-level physical risk measures from firm disclosures** - These measures rely on a firm's own assessment of their exposure, communicated through channels such as filings made to the regulator, press releases, and voluntary surveys.

Identification	Frequency	Authors	Method
Headquarters	monthly	Zhang and Zhu (2020)	Regress returns on a precipitation measure from the US National Climatic Data Center.
	daily	Griffin et al. (2019)	Match firms geographically to extreme high surface temperature days.
	daily	Pankratz et al. (2019)	Regress revenue and operating income of local firms on number of extreme temperature days.
Establishments	daily	Addoum et al. (2020)	Regress establishment-level log of sales on average and extreme temperature exposure.
Beta	monthly	Kumar et al. (2019)	Regress returns on abnormal US temperature changes. Exposure is measured as absolute beta.
	monthly	Zhang and Zhu (2020)	Match headquarters to a precipitation measure. Regress returns on the precipitation measure. Exposure equals 1 if at least one month's beta is statistically significant.
Surveys	yearly	Khan et al. (2016)	Match industry-specific guidance on materiality from the Sustainability Accounting Standards Board to data from MSCI.
News articles	monthly	Engle et al. (2020)	Regress returns on climate change news from the Wall Street Journal.
Proprietary models	once	<i>Four Twenty-Seven</i> in Gostlow (2020)	Regress returns on portfolios sorted on physical risk scores.
	once	<i>Carbone 4</i> in Ginglinger and Moreau (2019)	A Climate Risk Impact Screening score that measures forward-looking climate risks.

Figure 3: **Firm-level physical risk measures using climate and economic observations not provided directly by firms** - These measures rely on an external proxy for physical risk exposure, such as temperature readings matched to the location of a firm, the correlation between stock returns and temperature, and the views of industry specialists.

Topic	Item	Item Name	Mandatory
8 Other Events	8.01	Other Events	No (voluntary)
7 Regulation FD Disclosure	7.01	Regulation FD Disclosure	Yes (semi-voluntary)
2 Financial Information	2.06	Material Impairments	Yes

Figure 4: **Topics for physical risk detection in Form 8-K** - Three 8-K filing topics potentially hold information on physical risk exposure. Item 8.01 Other Events is voluntary because it is only required if the firm deems an event material to a reasonable investor. Item 7.01 Regulation FD Disclosure is semi-voluntary because it depends on whether private information was released by the firm and is likely to be used to trade on the basis of the information. Item 2.06 Material Impairments is mandatory because once an impairment has occurred, the firm must disclose it to investors.

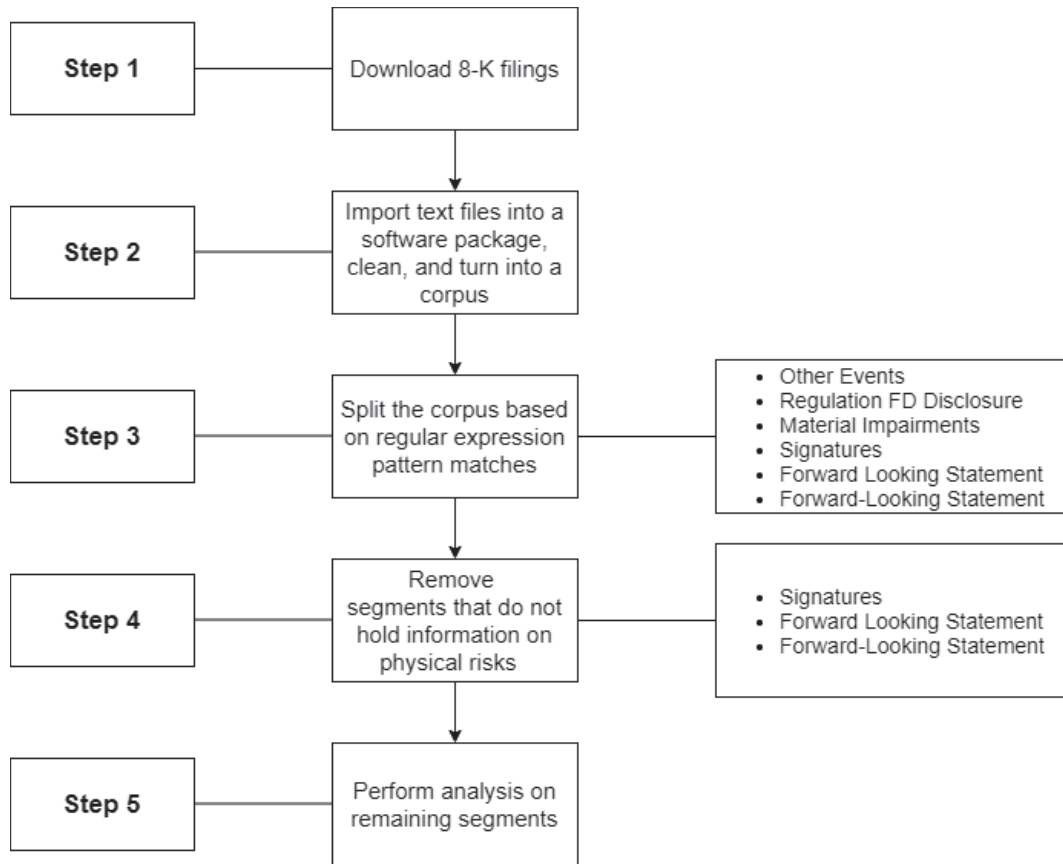


Figure 5: **Schematic to detect physical risk exposure from Form 8-K** - This figure shows the approximate steps necessary to parse Form 8-K for physical risk information. Advanced textual analysis techniques can be used in Step 5, such as utilising topic models. In this paper, filings are manually read in Step 5 to provide the full content of the filings that may be missed using other techniques.

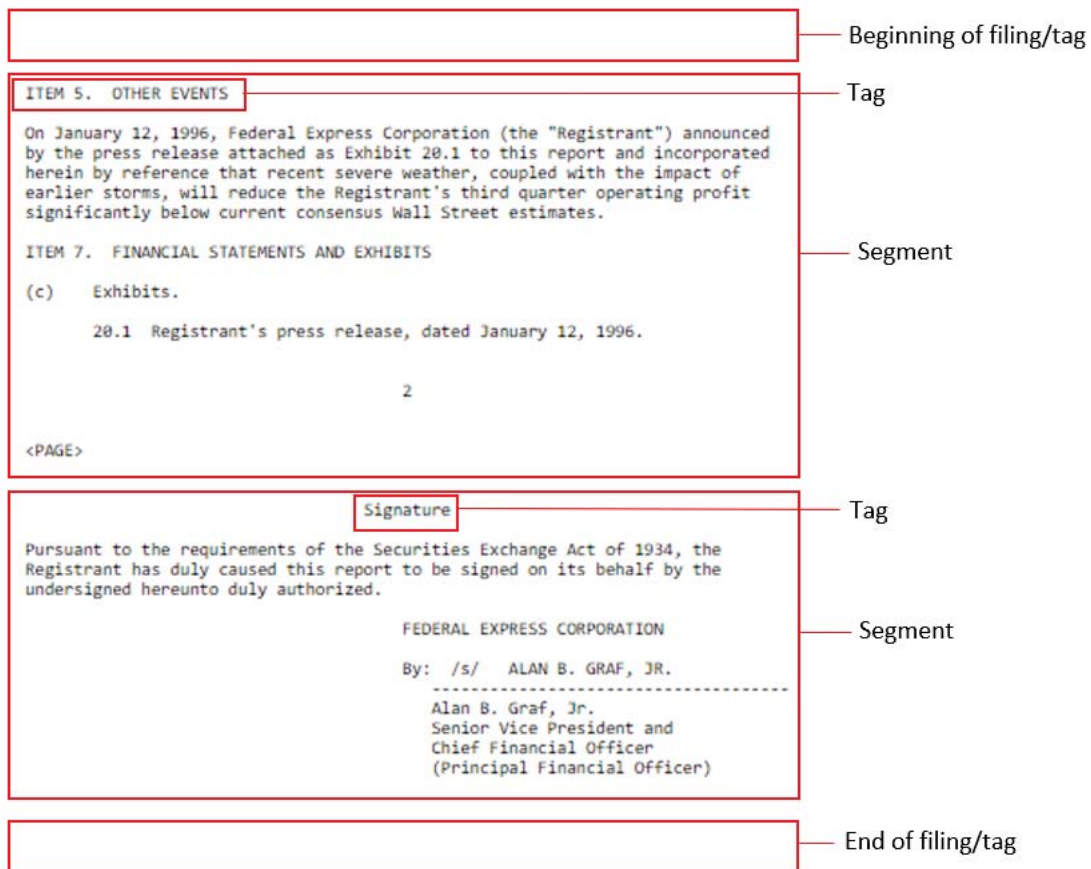


Figure 6: **Regular expression matching based on key tags** - Regular expressions can match character strings found in a text to a pre-specified pattern-string. All Form 8-Ks share a common structure that includes the SEC topic and the signature from an executive. Exploiting this commonality allows the filing to be split into segments to keep only segments of interest by using a regular expression. In this example, the first segment is valuable because the firm discloses physical risk in this paragraph. The second segment is not valuable since it includes a boilerplate statement on the Securities Exchange Act of 1934 and the executives signature. In this step, the segments are identified and ready for processing in Step 4.



Figure 7: **The extent of the Thailand flood** - The map of the flooding in 2011 is provided by Swiss Re (2012). The Chao Phraya River Basin flooded around July 2011 during the monsoon season after severe rainfall.

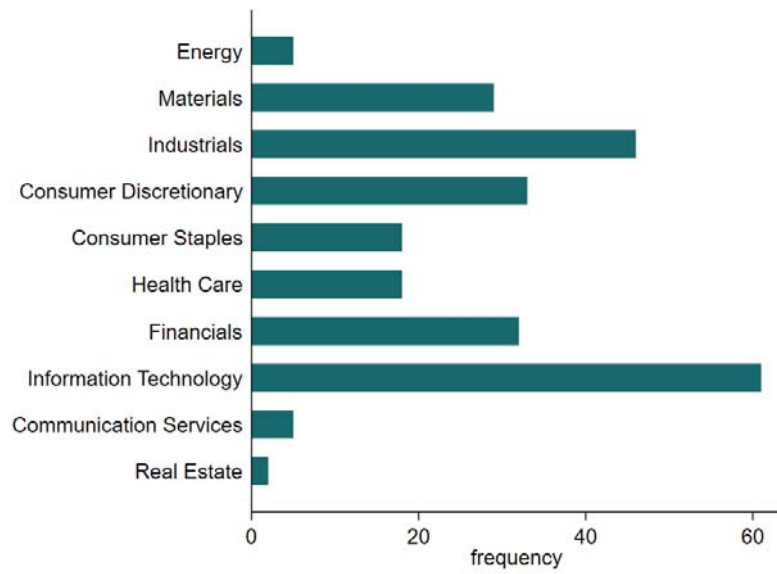


Figure 8: **US-regulated public firms with facilities in Thailand by GICS industry** - This figure shows the distribution of US industries present in Thailand in 2011. The semiconductor and hardware sectors, as part of the IT industry, are most represented (Perwaiz; 2015).

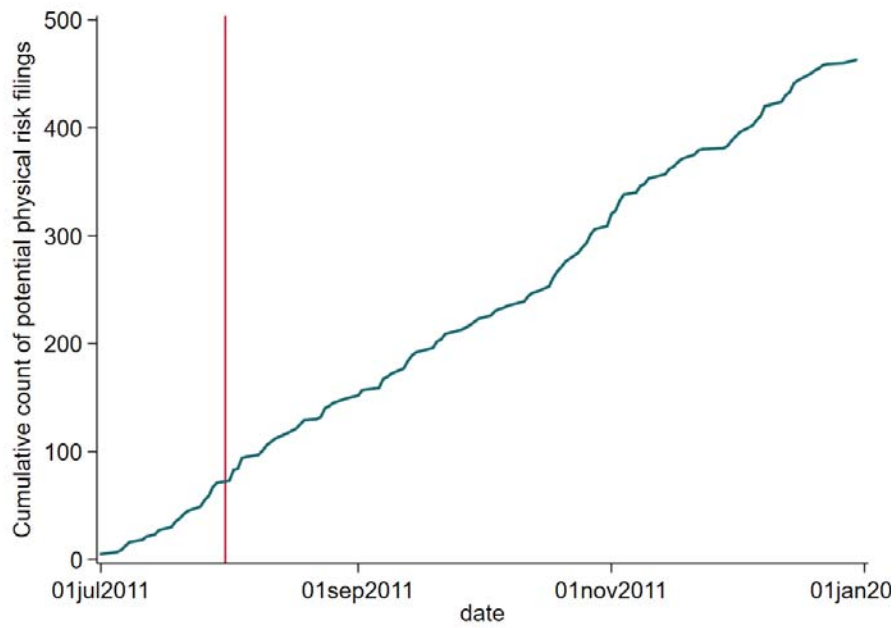


Figure 9: **Potential physical risk filings** - Potential physical risk filings are 8-K filings that are filed under the SEC topics Item 8.01 Other Events, Item 7.01 Regulation FD Disclosure, and Item 2.06 Material Impairment. The vertical red line shows the beginning of the Thailand flooding (31st July 2011). However, as it shall be shown, most impacted firms begin filing Form 8-K in October 2011 once the flooding had become more serious.

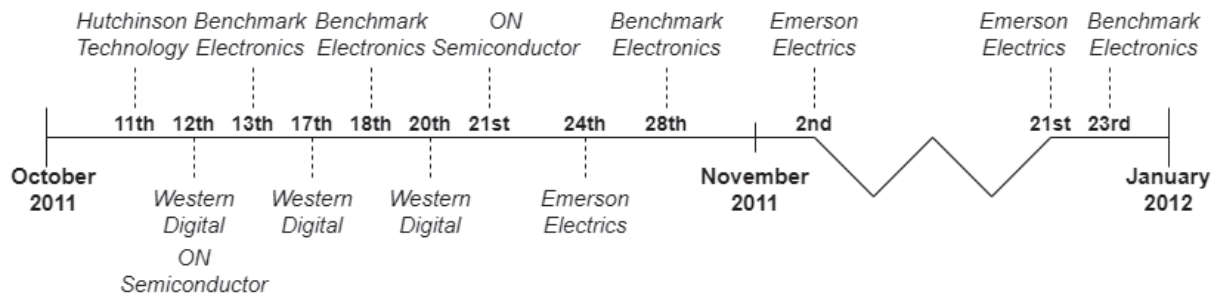


Figure 10: **Timeline of physical risk exposure revealed in Form 8-K** - The timeline shows the 8-K filings made by firms during the Thailand floods in 2011 that revealed they had been impacted by the flooding. Most filings are made in October 2011.

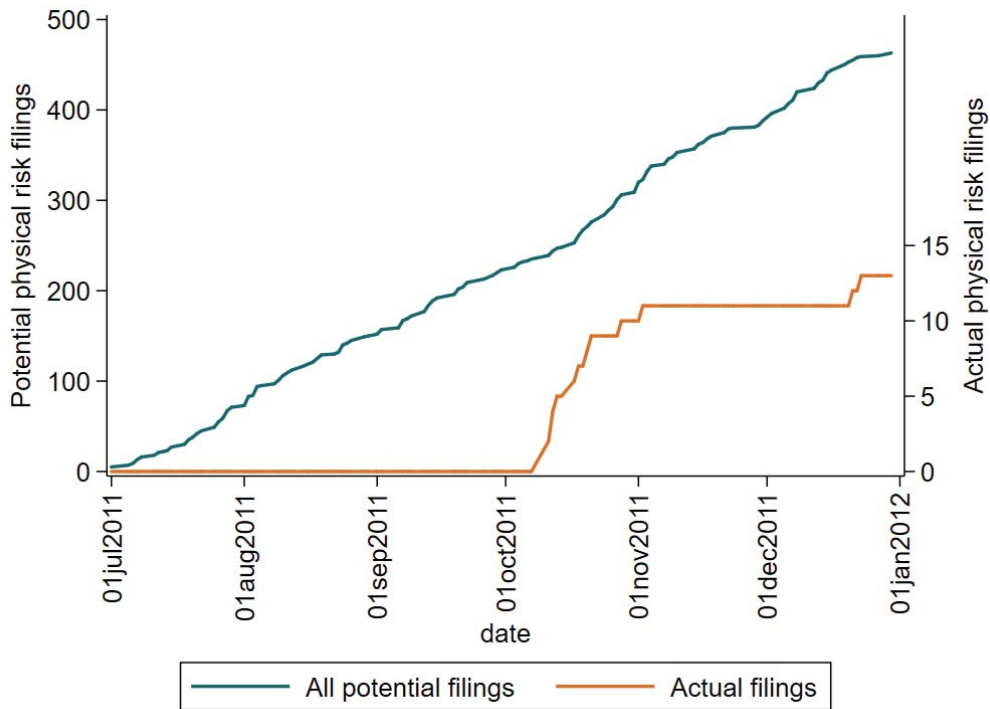


Figure 11: **Potential versus actual physical risk 8-K filings** - Potential physical risk filings are those 8-K filings that are identified as being one of the SEC topics other events, regulation fair disclosure, or material impairments. All other SEC topics filed under Form 8-K are inappropriate and do not mention physical risk. Of these potential physical risk filings, only a small percentage mention physical risk. These are termed *actual* physical risk filings. During the Thailand flooding, physical risk through Form 8-K began to be disclosed in October 2011.

environmental	monsoon	typhoon
flood	natural	weather
hurricane	tsunami	wildfire

Figure 12: **Physical risk dictionary** - A custom physical risk dictionary is used to detect physical risk in the Item 1A Risk Factors section of Form 10-K (the annual report).

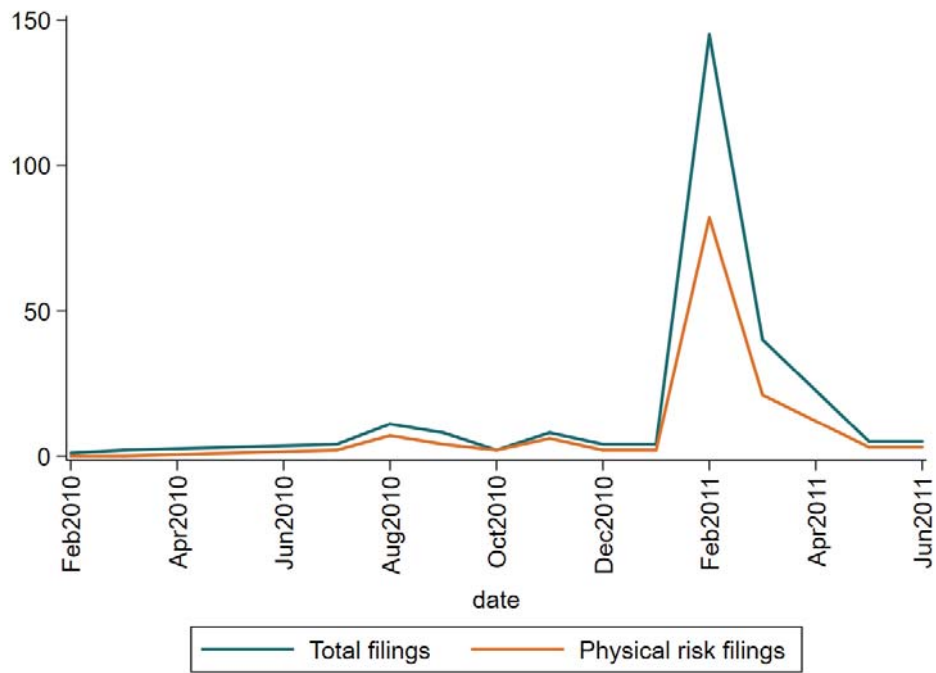


Figure 13: **Physical risk disclosed in Form 10-K before the flood** - Item 1A Risk Factors is a section in the annual report, Form 10-K, where firms are mandated to disclose risks that make them speculative or risky. Searching for physical risk terms in this section prior to the Thailand floods shows what percentage of firms identify themselves as being exposed.

		Form 8-K	
		no risk	risk
Form 10-K	no risk	102	0
	risk	129	5

Figure 14: **Confusion matrix for physical risk in the 8-K and predicted physical risk in the 10-K** - Form 8-K can be viewed as the *realisation* of a physical risk event. Conversely, the Item 1A Risk Factors section in Form 10-K is a predictive measure of future risk. To test how accurate these predictions are, the rows in this figure split the 10-Ks between those that mention physical risk (*risk*) and those that do not (*no risk*). The columns show the 8-Ks filed by the matched firms. The confusion matrix therefore shows that of the 102 firms that *did not* mention physical risk in Form 10-K, zero were impacted during the flooding - the predictions were accurate. For the 129 firms that *did* mention physical risk in their 10-K, 5 were impacted by the flooding.

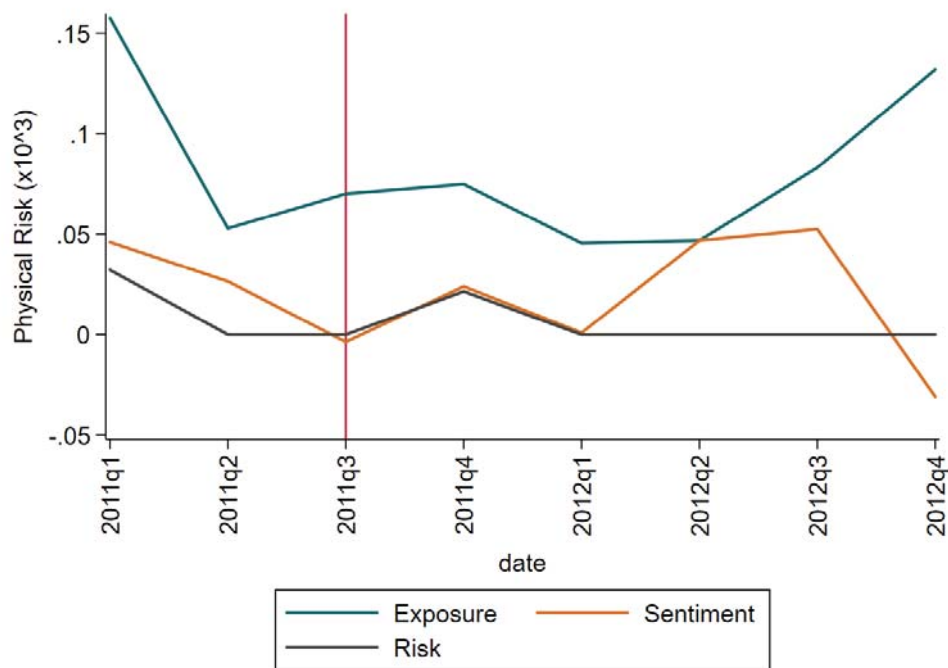


Figure 15: **Physical risk exposure for firms in Thailand using quarterly earnings transcripts** - Measures on quarterly earnings call transcripts are provided by Sautner et al. (2020). In 2011 Q2, the exposure and risk measures increase slightly whilst sentiment decreases. At the approximate time of the flooding, the sentiment measure becomes positive. The vertical red line shows the approximate start date of the Thailand flooding.

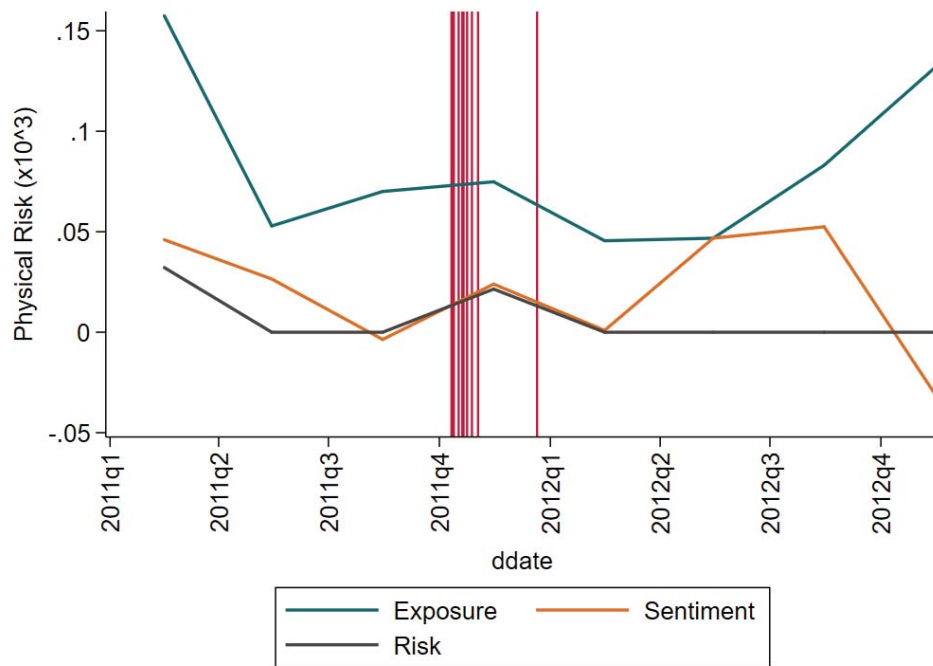


Figure 16: **Physical risk exposure: earnings call transcripts and Form 8-K** - The average exposure, sentiment, and risk scores for firms in the Thailand sample are taken from data provided by Sautner et al. (2020). The red lines show when a 8-K filing is made by a firm that mentions physical risk.

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