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Abstract

We study the comprehension, mapping, and reporting of climate-related risks among firms listed on the NasdaqOMX stock exchange in Stockholm. Our study contains two parts: i) a study on the firms' external communication through their annual reports, sustainability reports and webpages, and ii) a follow-up survey addressed to each firm's management team. We find that firms are likely to engage in some form of mapping and reporting of climate-related risks. However, their comprehension of the nature of these risks, underlying problems, and what a climate transition implies varies across firms and industries. There are also substantial variations in the method employed to map and report climate-related risks. Our results further suggest that firms use the Task Force on Climate-related Financial Disclosures' recommendations (TCFD) on how to map and report climate risks as a learning tool to improve their climate-risk management. However, as a voluntary initiative it is insufficient to generate substantial change. Consequently, policymakers should focus on improving firms' comprehension of what constitutes a climate-risk, how to map such risks and how to report them. The mapping and reporting of climate-related risk may otherwise prove an inefficient tool to redirect and accelerate investments promoting a low-carbon and climate-resilient economy.

Key policy insights

- Public policies and private initiatives such as NFRD, EU Taxonomy for Sustainable Activities, and TCFD may contribute to redirect and accelerate investments promoting a low-carbon and climate-resilient economy. However, the success of these policies and initiatives requires improved comprehension of climate-related risks among firms.
- Although most firms map and report climate-related risks their comprehension of the nature of these risks, underlying problems, and what a climate transition implies varies across firms and industries. Policymakers must provide firms with additional guidance aimed at improving their comprehension of climate-related risks.

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- Firms need to, individually and jointly, revise their theoretical and empirical understandings of climate-risk management and especially the role climate-related risks play in this new setting. Here, the TCFD has played an important role, but as a voluntary initiative it proofs insufficient.

Keywords: climate policy; climate change; climate-risk management; climate-related risks; non-financial reporting; TCFD; NFRD
Jel-codes: M40; Q54; Q56; Q58

1. Introduction

Achieving a sustainable development is an important and urgent goal for society. Sustainability is a broad term covering environmental, social, and economic dimensions. Yet, the international agenda on sustainable development is at the present characterized by what could be called a climate-first strategy where the goal of reducing greenhouse gas emissions take center-stage. The is manifested by e.g., the UN's regular climate change conferences, including the Paris Agreement, as well as the EU and US Green Deals. These conferences and policy agendas have set the direction of travel. Public polices and private initiatives are now following at a rapid pace to fill the agenda with content.

One new strand of public policies and private initiatives is to require and encourage firms to map and report climate-related risks. Investors are increasingly concerned about financial losses caused by climate change (Bos and Gupta, 2019). Firms that do not openly provide information regarding their climate performance through their reporting encounter growing skepticism from investors and in turn higher cost of capital (Krasodomska and Cho, 2017; Fink, 2020). There is also increasing pressures from external groups such as non-governmental organizations and policymakers (Steger et. al., 2007; Rodriguez-Melo and Mansouri, 2011) partially aided by social-media campaigns (Sogari *et al.*, 2017). There is a growing body of public policies such as the European Union's (EU) Non-Financial Reporting Directive (NFRD), in 2021 renamed the Corporate Sustainability Reporting Directive (CSRD), and the EU Taxonomy for Sustainable Activities requiring firms to map and report climate-related risks. Initiatives such as the Task Force on Climate-Related Financial Disclosures (TCFD) have been set up to aid firms in the mapping and reporting of climate-related risks.

An important aim of improving non-financial reporting on climate-related risks is both to improve the firms' risk management and to redirect and accelerate investments from carbon intensive to carbon neutral activities. This increased focus on mapping and reporting of climate-related risk constitutes a new approach to tackling climate change, not least from a public-policy perspective, which previously relied primarily on pricing carbon emissions through a carbon tax or emission trading system. While pricing emissions is still important, mapping and reporting of climate-related risks are becoming increasingly important as a driver to highlight and manage risks as well as accelerate change.

In theory, mapping and reporting of climate-risks may appear simple. However, it is more difficult in practice. Climate-related risks are different compared to risks firms are used to deal with. Studies have shown that there is a lack of a common view of what constitutes a climate-

related risk, how to map them and to communicate the risks internationally and externally with stakeholders (Reinecke *et al.*, 2012; Valente, 2012; Kapitan *et. al.*, 2019). The risks mapped and reported thus varies from firm-to-firm (Helfaya *et al.*, 2019). This is problematic in view of the need to provide external stakeholders with value-relevant, credible and comparable measures of firm climate performance (Arvidsson, 2019).

Research has shown that climate-related risks are seldomly properly included in firm's and investors' decision-making processes (Johnson *et al.*, 2021). Mapping and reporting of climate-related risks have been found to provide a partially useful tool in identifying critical risks, adaptation options and investment priorities; aligning and integrating action with existing firm risk management (Street and Jude, 2019). These processes are assisted by recent public policies and private initiatives such as NFRD, CSRD, EU Taxonomy and TCFD which aim to help firms and investors in identifying and managing climate-related risks by providing a common framework and terminology to map and report these risks. As shown by O'Dwyer and Unerman (2020) there are major challenges for firms in realizing the potential of these public policies and private initiatives which calls for academic research studies providing solid evidence in helping to improve the practical impact of these policies and initiatives.

In this paper, we study the mapping and reporting of climate-related risks among listed firms on the Swedish NasdaqOMX stock exchange in Stockholm. Our overarching purpose is to explore whether the stream of public polices and private initiatives have influenced the firms' comprehension, mapping and reporting of climate-related risks. We pose four research questions; i) to what extent do firms map and report climate-related risks?, ii) what do firms comprehend to be a climate-related risk?, iii) do firms use a specific methodology to map and report climate-related risk?, and iv) do firms use the methodology suggested by TCFD, and/or the EU's reporting recommendations (NFRD)? These Swedish firms are interesting to study as Sweden is considered to be front-runner both at the national level in terms of climate policy (Anderson *et al.*, 2020; Karlsson, 2021), and at the firm level in terms of sustainability work and reporting (see Cahan *et al.*, 2016; KPMG, 2015; 2019).

The study contains two parts: *First*, we study the firms' external reporting climate-related risks through their annual reports and sustainability reports. *Second*, we conduct a survey addressed to the management teams including quantitative and qualitative questions related to climate-related risk. Our results show that mapping and reporting of climate-related risks are common, however, there are differences among industries based on their position in the value-chain. Despite the fact that mapping and reporting these risks appears to have become a common practice, most firms are still unfamiliar with how to set up this practice adequately.

There is a lack of a common comprehension of what constitutes a climate-related risk, how to map them and how report them. Most firms lack an understanding of what constitutes a transitional risk, and few firms considers climate-related risks that may occur in the long-run (10 years plus). However, there are signs of learning, and several firms use TCFD as a learning tool to improve their climate-risk management. These results accentuate the need to further support firms in order for the public policies and private initiatives to reach their intended outcome, i.e., redirecting and accelerating investments promoting a low-carbon and climate-resilient economy.

The rest of the paper has the following disposition. In Section 2 we discuss the background to non-financial reporting and the risks related to climate change. Section 3 presents the research methodology and the data. Section 4 contains the empirical results. Section 5 concludes the paper.

2. Background

2.1 Non-financial reporting

Although the Brundtland Report (UNWCED, 1987) already in 1987 highlighted the need to promote a global sustainable development, this urge was not extensively acknowledged in business society at the time (see Dierkes and Antal, 1986; Kolk, 2010; 2005). To assist in the process of integrating sustainability perspectives in the management of the firms, a multitude of voluntary guidelines, principles and frameworks have been developed over the last four decades (e.g., UN Global Compact, Global Reporting initiative (GRI). The International Integrated Reporting Framework, OECD Guidelines for Multinational Enterprises). Although the economy remains unsustainable, these aids have triggered firms to engage in sustainability reporting. Today, sustainability reporting is a global reporting practice (KPMG, 2015; 2019).

Unfortunately, the information in these reports, has for long been the object of skepticism and criticism. Investors and financial analysts claim that this information lacks value, relevance, comparability and credibility and that it is often totally useless for making financial decisions (Arvidsson, 2014; Cho *et al.*, 2015 Abhayawansa *et al.*, 2019). As Larry Fink (2020) argues in his letter to CEOs of the firms BlackRock invests in, those that do not openly report this information *"…and do not respond to stakeholders and address sustainability risks will encounter growing skepticism from the markets, and in turn, a higher cost of capital"*. Today, there is a greater understanding that risk translates into stranded assets and resources, as a low carbon economy makes certain assets worthless, or even turns them into liabilities (Bos and Gupta, 2019). For the last three years, climate and societal risks have dominated the global risk

agenda outlined at the World Economic Forum (2020). Financial market actors need to better understand the link between climate change and investment risk. These new types of risks are, thus, advancing to be critical factors in financial decision-making. Consequently, there is an increasing demand for information on firms' climate-related risks and sustainability performance.

It is in the light of this, the world's policy makers and regulators have realized that the ambitious goals of the Paris Agreement and the US and EU Green Deals, will not be reached through mere carbon pricing, but requires a considerable improvement of firms' climate-related reporting. *This* is the origin of the rapid development of public policies and private initiatives aimed at assisting in redirecting and accelerating investments promoting a low-carbon and climate-resilient economy. Over the last few years a range of new private and public initiatives have emerged that constitutes a new approach to combating climate change. The NFRD and the TCFD framework being two of the prominent.

The NFRD, or formally referred to as the EU directive (2014/95/EU) on non-financial information and diversity, has been transposed into national law in the European countries. From the financial year 2017, listed Swedish firms with more than 250 employees[3] are required to report on their achievements, among other things, related to environmental protection (EU Directive 2014/95). Although the NFRD is mandatory, it gives great flexibility to firms as to which information they should report and the EU Commission only provides guidelines as to which information the firm might wish to report on. The NFRD is now up for revision and on April, 21, 2021, a draft on the revised NFRD, renamed to CSRD was launched. The sentiment is that the CSRD will significantly enhance the scope of the existing and more flexible NFRD regarding how and what firms are mandated to report on related their sustainability endeavors (KMPG, 2021).

One of the most known public-private initiatives is the TCFD initiated by the previous governor of the Bank of England Mark Carney and the previous mayor of New York Mike Bloomberg. TCFD was created in 2015 to develop clear, consistent and comparable climate-related financial risk reporting. The objective with the TCFD is to contribute to greater understanding of climate risks and facilitate financing the transition to a more stable and sustainable economy. A widespread adoption of the TCFD framework will ensure that the effects of climate change become routinely considered in corporate and investment decisions.

[3] The Swedish government decided to mandate all firms with more than 250 instead of the EU's limit of 500 employees.

Adoption of these recommendations will also help firms better demonstrate responsibility and foresight in their consideration of climate issues. That will lead to smarter, more efficient allocation of capital, and help smooth the transition to a more sustainable, low-carbon economy.

2.2 Climate-related risks

Broadly speaking, firms face two types of risks related to climate change: physical risks and transition risks (Stern, 2013; Demaria and Rigot, 2020). Financial firms may also face a third risks, which is the mispricing of "green-assets" through so-called "green-washing" (Ehlers and Packer, 2017). For the firms included in our sample, the first two risks are of most importance. Physical risks are caused by higher temperatures increasing the incidence of extreme weather conditions and natural disasters, which in turn may affect the firm's own assets, cause damages to their customers or disrupt their supply chains (Barro, 2009, 2015). Transition risks relate to the human response to climate change. An uncoordinated and chaotic transition to a low carbon economy may cause substantial disruptions to the economic, social, political and technological environment that the firm faces (Carney, 2015). Again, these risks are not only directly related to the firm's own operations but include risks to the firm's entire economic eco-system as a major disruption in one part of the economy rapidly spreads through the value-chain to other sectors of the economy (Andersson, 2018; 2020).

The size of the physical risks and the transition risks depends on how well these risks are understood and dealt with within the firm. In the end, to what degree an individual firm, and society at large, is affected by these risks depend on the risk-management. Risks that are identified in advance and managed properly may not cause any major disruptions. The increased interest in climate-related risks among regulators in recent years is a sign that the climate risks are still poorly understood among most actors both in industry and on financial markets (see e.g., Swedish Finansinspektionen, 2016; Banque de France, 2015; European Systemic Risk Board, 2016).

The identification of climate-related risks is made more difficult by their complexity. Not only do firms have to identify risks related to their own firms they also need to consider their entire supply chain, and their suppliers' supply chains. The risks stretch over many different dimensions such as social, economic, political, and technological. Some risks are short-term, but most of them are more likely to occur in a distant future, which makes them harder to identify and model. One of the objectives with reporting guidelines such as the TCFD is to encourage firms to engage in mapping and managing of climate-related risks over many different dimension and time horizons (see above for details on TCFD). For example, firms are

actively encouraged to deploy scenario analysis to engage in strategic thinking about possible future pathways for the economy that lies more than ten years into the future and how it may affect the individual firm (TCFD, 2021). The EU's proposed directive on Corporate Sustainability Reporting (EU 2021) similarly proposes firms to map and report climate-related risks over different time horizons for their entire supply chain. The role of scenarios is not to forecast, or predict, the exact outcome as it is impossible to predict the distant future with any greater accuracy (Kay and King, 2020). Instead, scenarios are used to engage in strategic thinking to prepare for many different possible future outcomes (Peterson *et al.,* 2003). While forecasting often relies one main forecasted outcome, scenarios aim to explore multiple potential futures (TCFD, 2021).

Although climate-related risks are commonly perceived to be either physical or transitional, there is an additional risk related to the process of mapping and reporting of risks. The method firms use to map and report risks has an impact on their comprehension of climate-related risks and their climate-risk management. Their pre-comprehension also influences their choice of method and the implementation of it. Furthermore, this also affects stakeholders' perceptions of the climate-related risks the firm faces and their willingness to engage with the firm (Kapitan *et al.,* 2019). Different mapping and reporting methods may produce significantly different results (Santos *et al.,* 2019). This creates a so-called methodological risk on top of the physical and transitional risks. This methodological risk should not be underestimated since the mapping of climate-related risks is in its early stages and there is as yet no consensus on preferred modelling approaches (BIS, 2021).

3. Research design and methods

We study our four research questions using a *report study* on the firm's external communication through annual reports, sustainability reports and their webpages, and through a *survey* addressed to the management teams including qualitative and quantitative questions related to the firm's comprehension, mapping, and reporting of climate-related risks[4]. The combination of these two research methods enables us not only to review how firms communicate externally about their understanding and mapping process of climate-related risks but also to go behind the reports and explore how management teams *de facto* perceive and work with climate-related risks.

[4] The report and survey studies were conducted within the project Hållbara Bolag (Sustainable Businesses), a partnership with Dagens Industri and Aktuell Hållbarhet, of which professor Susanne Arvidsson is chairman.

3.1 Report study

We begin the analysis by studying the respective firm's external communication with stakeholders through their published yearly annual reports and sustainability reports for the financial year 2019, as well as the respective firm's webpages accessed during May of 2020. Here we use the English versions of the reports and webpages. To classify the communication, we created a checklist with items based on previous research. The checklist is designed to cover the areas of comprehension, mapping and reporting of climate-related risks. To ensure that the checklist included a relevant mix of items, the final list was discussed with corporate representatives with experiences from climate mitigation, corporate finance, investing, assurance and sustainable finance. In the analysis these items will be coded either 1 (the reports and/or webpages include information related to this item) or 0 (the reports and/or webpages do not include information related to this item). Coding procedures always raise subjectivity concerns. Therefore, the checklist was tested on five firms' reports and webpages by two senior researchers and six master students involved in the coding procedure – all within the field of sustainable finance. This test resulted in some minor adjustment of the checklist and the coding document. Furthermore, detailed coding instructions were structured, and coding reviews were conducted during the whole analysing procedure. These detailed coding instructions and coding reviews contributed to the robustness of the results.

3.2 Survey study

The report study is followed by an in-depth survey distributed to all firms' management teams during the summer of 2020. This part of the analysis is limited to the number of firms that reply to the survey. The response-rate was high, 65 percent, see Table 1, with variations across the industries from 55 percent of Consumer staples firms responding to 73 percent of industrial goods firms responding. Although the response rates were high, a potential concern is that the survey sample is biased with towards firms that are more likely to engage in mapping and reporting of climate risks. However, any such potential bias will be detected when comparing the results from the *survey* with the *report study*.

[Insert Table 1 about here]

The survey questions were designed to complement the *report study* and, thus, includes questions, which are worded such that they can be compared to the results from the *report-study*. The questions address the comprehension mapping, and reporting of climate-related

risks. All survey questions include three response options; "*yes"; "we are working on it" and "no"*. When appropriate the questionnaire includes open ended qualitative follow-up questions where the respondent is invited to elaborate on his/her answer. Most firms have included a written response, which provides important background information and helps us interpret the quantitative results.

The survey was distributed directly to the management team (CEO, CFO, Investor Manager and Head of Sustainability). To focus on the management team allows us to go behind the scenes and explore the mapping process of sustainability risks in Swedish companies. The survey was sent out electronically on June, 17, 2020, the month after the report-study was concluded. Due to summer holidays, deadline was set to August, 10, 2020. Three reminders were sent out during this period. Considering that English is the corporate language in most of the largest Swedish companies, the survey was in English. The final version of the survey is presented in Appendix 2.

3.3 Data sample

Our data sample consists of firms listed on the NasdaqOMX stock exchange in Stockholm. These firms are large and have a significant environmental and economic impact on society. Because they are large, they are likely to engage in mapping and reporting of climate-related risks either voluntarily (Stiller and Daub, 2007) and they are also required to follow EU's NFRD. We limit the sample to firms from four GICS industries with a major climate impact[5]: materials, industrial goods, consumer discretionary and consumer staples (see Table 2 and Appendix 1). In total we have a sample of 111 firms.

The four industries are clearly different. They are located at different places in the value chain. The material producing industry is an upstream sector that primarily sells to downstream firms in the industrial goods and consumer discretionary/staples industries. Consumer discretionary/staples sell mostly to households. The material industries is among the most carbon- and energy intensive industries in the economy while industrial goods, consumer discretionary/staples are less carbon intensive (Andersson, 2020). However, the latter industries supply chain is carbon intensive as they consume intermediate goods produces by the materials and agricultural industries. Their supply chains also tend to be more international compared to the materials industries in Sweden. Global sustainability risks are thus more important for these industries compared to the materials industries.

[5] GICS (Global Industry Classification Standard) developed by Morgan and Stanley Capital International and Standard and Poor's Dow Jones Index.

[Insert Table 2 about here]

4. Empirical results

4.1 Report study

Tables 3 and 4 presents the result form the *report study*. Table 3 presents studies whether firms map climate-related risks and which climate-related risks they map (physical and/or transitional). Table 4 studies whether the firms use a specific method to map risks, and whether this method includes scenario analysis. For each question two statistics are presented: first for the full population of firms, and second for those firms that also responded to the survey we distributed.

[Insert Table 3 about here]

The majority of firms, between 69 percent (consumer discretionary) and 100 percent (consumer staples) state that they are mapping sustainability risks in their reports. The percentage is higher among the firms that responded to the survey, which might indicate that the survey sample is potentially biased towards firms with active climate-risk management. It is also common for firms to report how they map climate-related risk, however, there are firms that do not disclose this information. Especially in the materials industry. Again, the firms that responded to the survey is more likely to disclose information on how the mapping of climate-related risks was conducted.

An interesting result is that firms are less likely to report that they are mapping climate-related risks in general compared to report that they map either physical or transitional climate risks. The high degree of specificity indicates that firms are aware of the different types of climate-related risks. The mapping of physical risks is more common compared to the mapping of transition-related risks among the industrial goods industries and the consumer durables industries. For materials, transition risks are more commonly mapped than the physical risks. The material industries are also likely to more directly be affected by a climate transition as their direct greenhouse gas emission levels are relatively high (Andersson, 2020). They also face few economic co-benefits from a decarbonization, which makes a decarbonization relatively costly (Åhman and Nilsson, 2015; Åhman *et al.*, 2017). In other words, the material industries are likely more negatively affected by climate transition. According to our results the firms are aware of the potential risks they face. The industrial goods sector and the consumer

discretionary, on the other hand, are less affected directly, but they are to a greater extent affected through their supply chains as they purchase most of the output from the material industry and turn it into products that are then sold to end consumers (Andersson, 2020). That only 21 percent of industrial goods firms and 45 percent of consumer discretionary firms consider transitional risks may leave them unprepared for future disruptive changes.

A majority of firms report how they have mapped climate-related risks, see Table 3. However, few firms follow the TCFD recommendations. For example, none of the consumer staple firms use the TCFD, although all firms in this industry map all types of climate-related risks. The most likely industry to follow the TCFD recommendations is the materials industry. This may explain why the materials industries are more likely to consider transitional risks compared to the industrial goods and consumer discretionary industries. This lack of a common mapping and reporting method has been raised in the literature as a major problem aggravating the credibility and comparability of this information, which is vital in credit and investment decision processes (see e.g., BIS, 2021).

Climate-related risks are rarely mapped and reported based on specific time horizons. Instead, firms report general risks without any specific time horizon applied to them. Less than 20 percent disclose risks that are either short-term or long-term in nature. The lack of a specific time horizon is also revealed by the small number of firms that present results from scenario analysis where future potential risks are explored. This result is in line with our previous findings that firms are less likely to consider transition related climate risks, which are most likely to occur in the future. Overall, these results indicate that firms view climate-related risks as short-term risks and do not to any greater extent consider potential disruptive long-term transitional risks.

[Insert Table 4 about here]

Although firms engage in climate risk mapping and reporting, it is important to consider to what extent the management team actively involved in the climate-risk management. The reaching of a successful integration of sustainability perspectives is argued to rest on the attention given and legitimacy granted by the top management team (TCFD, 2017; 2021). Unravelling the involvement of the management team from the report study is, however, difficult. Some insights can be gained by considering the following two factors; the share of a firm's employees that has been trained in the UN's sustainability development goals (SDGs), and the share of managers that are evaluated based on sustainability performance measures. Management of

climate-related risks appear to be a residual issue for most firms. Between 3 percent (consumer discretionary) and 57 percent (consumer staples) have been educated in the SDGs. Only between 14 percent (industrial goods) to 24 percent (consumer discretionary) of all firms evaluate managers based on their sustainability performance. The written responses to the survey questions suggest that financial performance still has greater impact on the renumeration than sustainability performance.

In summation, the *report study*, reveals that the material industry, with the highest carbon intensity, is most likely to actively consider climate-related risks. Consumer staples also score highly, which is potentially explained by high levels of pressures from consumers. The industrial goods and consumer discretionary industries are less likely to map climate-related risks. They are also less likely to follow a specific mapping and reporting method such as the TFCD. The level of comprehension of what climate-related risks are and how to map and report them varies among firms and industries but is generally judged to be low. Few firms separate between risks over different time horizons, and even fewer firms use scenarios to map and consider potential future risks. Finally, despite most firms indicating that they do map climate-related risks, the involvement of the management team in these processes appear to be low, which risks impairing the effectiveness of their climate-risk management.

4.2 Survey

Next, we turn to the results from our survey. The survey questions are related to the questions explored in the report study but also provides additional insights, both qualitatively and quantitatively. Differences in response pattern across industries are similar: the material goods, and the consumer staples industries stand out compared to industrial goods and consumer durables industries, see Tables 5 and 6. From the responses to the survey it appears that firms are engaged in more risk mapping compared to the information they disclose to their stakeholders. However, as was revealed by the *report study*, firms responding to the survey appear to be more likely to engage in risk mapping compared firms not responding the survey.

Unlike the *report study* firms respond that they are as likely to map transition risks as they are mapping physical risks. The mapping of transition risks is even slightly higher: 80 percent of all firms map short term risks or are working on mapping risks over this time horizon. As the time horizon increases, the likelihood of mapping risks is reduced. This result stand somewhat in contrast to the response that they are mapping transition risks as these are more likely to occur over the long term than the short term. (elaborate and include reference here or in conclusions?) Even the material industry and the consumer staples industry, which both tend to

be the most active in mapping risks, have a lower probability of mapping long term risks compared to the short- and medium-term risks.

From the results, it appears to be common to map risks both directly affecting the firm, but also indirect risks in the supply chain. However, the industrial goods industry stands out compared to the other industries with only 69 percent of all firms mapping these risks compared to 90 percent or more among the other industries. The combined "yes" and "working-on-it"-responses are lower for the industrial goods industry compared to the other industries.

[Insert Table 5 about here]

While most companies report mapping of climate-related risks, they are less likely to follow a specific mapping and reporting methodology. A minority of all companies' report based on the recommendations in NFRD or TCFD. However, a large share of the firms report that they are planning to start following them in the future ("working-on-it" response). The main outlier here is the consumer staples industry where 80 percent of companies respond that they do follow the TCFD recommendations already. However, there are only five firms in this industry. These results stand in contrast to the report study where we found a clear minority of firms disclosing that they used TCFD. This indicates that the firms are more likely to employ the framework than actually disclosing the results to stakeholders.

As outlined in the TCFD recommendations, scenario analysis is a key component to explore potential long-term disruptive physical and transitional risks. Roughly half of all firms use some form of scenario analysis and 15 to 30 percent plan to use scenarios in the future. The relatively low share of companies that uses scenarios at the moment suggest that scenario use is uncommon among industries in general. From the report study there is also some indication that it is more common to present one outcome of the scenario analysis rather than exploring multiple different scenarios. This lend credence to assume that scenarios are, more handled as a forecast than proper scenario analysis. This implies some learning gaps among these industries with substantial climate impact on the global economies. Furthermore, there are differences among firms in how scenarios are conducted, what the scenarios entail, and whom is involved in the process of creating and exploring the scenarios. Less than ten companies overall involve the board or the management of their firms in the creation of the scenarios.

[Insert Table 6 about here]

The written responses reveal that behind the quantitative answers lies different perspectives on what transformative risks implies. For some firms, transformation risks are linked to the concept of disruption, i.e., large sudden changes that disrupts the operations of the firm. These changes are most likely to occur over the long-term rather than the short-term. For other firms, transformative risks are tied to yearly or bi-annual risk assessments based on consumer surveys or observed changes in regulation. These perspectives are more connected to short-term market developments rather than long-term disruptions. Examples of the short-term perspective tends to highlight their mapping of ongoing changes in legislation and yearly consumer surveys. For example, one firm in the industrial goods industry writes:

"*[a]t the global level, we carry out bi-annual customer surveys to understand customer preferences. Locally, we continuously do customer surveys and other business intelligence to map risks and opportunities in the markets we operate in.*" (Industrial goods firm)

This is by no means a unique answer as other firms provide similar responses:

"*[m]arketing tracks consumer preferences by doing regular surveys in key markets*" (Consumer discretionary firm)

Yet, another firm writes:

"*[w]e listen to our "users" because the use of our products hopefully long-term*" (Consumer discretionary firm)

Firms with a longer-term perspective tend to be fewer, however, there are several examples of a more disruptive perspective:

"*[t]he climate-related risks and opportunities that we have identified have been classified according to the TCFD model, including physical risks as well as transition risks. … [the firm] has a risk in not being able to keep up with the demand for these products or fulfilling demands tenders, as environmental care and risk assessment ins mandatory in all public tenders and has the likelihood to impact our finances for the next 25 years*" (Industrial goods firm)

Most of the firms that indicate that they are working with disruptive risks has a focus on policy more than on consumer demand:

"*[f]or example, impact of potential/future regulatory changes is assessed to make sure we are prepared to adopt if necessary. It may be regulation such as CO2 tax, emissions factors for transport etc*"
(Consumer discretionary firm)

Another response reads:

"[e]*fforts are put to highlight the ongoing discussions on the political scene not only in the annual assessments but also in the recurring review meetings*"
(Industrial goods firm)

Firms with a long-term disruptive perspective are more likely to involve external partners in their risk assessment:

> "*[the firm] participates in various national and international industry organizations, as well as in other type of partnerships. The aim is to gain knowledge, and also to contribute actively to the development of areas where we have expertise and that are significant to our operations.*"
>
> (Consumer staples firm)

The different approach to understand transitional risks clearly demonstrate the varying degree of comprehension among firms of what a transitional risk is. From this result we can draw three tentative conclusions: *First*, many firms are still inexperienced in mapping and reporting climate-related risks. Their comprehension of the potential risks the firms faces from climate-change is still low. Based on the responses it is possible to divide the firms into two groups: firms with a low level of comprehension that mostly engage in short-term market research, and firms with a high level of comprehension engaged in scenario analysis of potential disruptive future economic, social, market and political changes that may affect the firm.

Second, the number of firms in the group of high level of comprehension is likely to grow over time as they continue to develop their mapping and reporting skills. Some firms have clearly come further in the learning process and are engaging in relatively advanced scenario analysis, often with external partners. *Third*, to increase the value of the mapping and reporting of climate-related risks, policy should focus on improving the comprehension of what climate-related risks are and how best to map and report those risks. Such a policy would speed up the learning processes among firms and increase the value of the mapping and reporting to make it more useful for stakeholders in various decision-making processes. At the moment, the value for stakeholders of individual firm's reporting is relatively low as the information disclosed have different interpretations depending on the reporting firm's own comprehension of climate-related risks.

According to our results, a share of the firms reports that they map and report climate-related risks. However, the varying level of comprehension indicates that the actual number of firms that are fully engaging in management of climate-related risks is lower. Although Swedish firms are considered front-runners on sustainability reporting (see Cahan *et al.*, 2016; KPMG, 2015; 2019), there is still room for improvements. The results that the TCFD may play an important role in driving improvements. For example, according to the responses, the adoption of the TCFD recommendations is a key driver towards scenario analysis. There is clearly an overlap between firms conducting mapping of long-term disruptive risks and using scenario

analysis, and vice versa. However, there are more firms which outlines their use of scenario analysis following the TCFD recommendations than there are firms mapping long-term transition risks. Several of those firms write that they are in the process of using scenarios or have just begun the processes using scenario analysis. Overall, it is likely that firms are going through a learning processes of how to map climate-related risks and implementing the TCFD recommendations and that the mapping of long-term disruptive transition risks will increase over time. Firms appear to view TCFD as a learning tool to improve their climate-risk management. This interpretation of the results is supported by some of the written responses. For example three firms, among several write,

"*[we] are working to understand our wider sustainability risk and opportunities for the business, through further developing our enterpirse risk management process. We will use the TCFD guidelines as part of this process"* (Industrial goods firm)

"[w]e have an ambitious ESG agenda and are constantly working with how to improve our pro-climate (and ESG) related activities… In this work and process development we use both EU guidelines and TCFD as guidelines and inputs" (Industrial goods firm)

"In our operations, we identified and implement mitigation actions we can take to address extreme weather risks. We are working to understand our wider sustainability risks and opportunities of the business, through further developing our enterprise risk management process. We will use TCFD guidelines as part of this process" (Industrial goods firm).

Overall, the written responses from the survey reveal fundamental difference in set-up regarding whom is responsible and involved in the firms' climate-risk management. Some firms opt for a centralized approach with high degree of board *involvement* while others have chosen a more decentralized approach where business units appear to mere *report* to a risk committee or similar without direct involvement of management team and board.

Conclusions

We study the comprehension, mapping and reporting of climate-related risks among listed firms on the NasdaqOMX stock exchange in Stockholm. We conduct both a study of the firms' external communication with stakeholders through their annual reports, sustainability reports and webpages, and a survey addressed to their respective management teams including quantitative and qualitative questions. Our results reveal that firms are highly likely to engage in some form of mapping and reporting of climate-related risks. The mapping covers both the respective firm and their supply chains. The firm's position in the value chain affects the likelihood of mapping and reporting these risks. Firms in industries with either a high direct carbon footprint such as the material industries, or industries facing strong consumer groups

such as consumer staples are more likely to map and report climate-related risks than the other industries. An additional finding is that there is little communality among firms and industries when it comes to *how* the mapping is done, *how* it is reported, and *whom* is responsible and involved in the mapping. The survey responses suggest that several firms fail to understand the difference between a transitional risk, which of course is a relatively new part of firm-risk management, and short-term market trends. Furthermore, several firms do not distinguish between short-term forecasts and long-term scenario planning. Most firms focus mostly on the short-term and do not consider potential long-term disruptive risks. There is also little evidence of climate-related risks being high up on the management's agenda. The primarily focus on short-term market trends indicates that firms are likely to underestimate the potential climate-related risks. Overall, their present risk management seems unprepared for facing potential future disruptions caused by climate change.

Our results further suggest that firms use TCFD as a learning tool to improve their comprehension, mapping, and reporting of climate-related risks. Firms that have adopted TCFD are more likely to engage in scenario planning, consider the long-run, and to collaborate with external partners to fully explore potential economic, social, and political risks to the firms posed by climate change. While policy makers may view the EU Taxonomy and the NFRD as important policies to drive decarbonization, firms tend to view these policies as learning tools. These policies should, thus, be designed to act as both a learning tool and driver for decarbonization.

It is important to understand that the implementation of completely new public policies and private initiatives creates a new learning environment where old lessons and learning processes may no longer suffice. This is especially true when it comes to climate change. Our results show that firms must individually and jointly, revise their theoretical and empirical understandings of firm-risk management and especially the role climate-related risks play in this new setting. Here, TCFD has played an important role, but as a voluntary initiative it is insufficient. Having laid the foundation, the next step is for policy makers to provide firms with additional guidance aimed at also improving their comprehension of the nature of the risks, underlying problems, and the concept of a climate transition. Mapping and reporting of climate-related risks will not become an efficient tool for decarbonization, among many others, to meet the ambitions of the Paris Agreement, the EU and US Green Deals unless greater attention is given to the firms' learning and comprehension of climate-related risks. This calls for future research attention and policy exploration.

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Appendix 1: Firms included in the study

Materials (N=18)	Industrial goods (N=56)		Consumer discretionary (N= 29)	Consumer staples (N=8)
Ahlstrom-Munksjö	ABB	Nordic Waterproofing	Besqab	AAK
Arctic Paper	Addtech	OEM International	Bilia	Axfood
Bergs Timber	Alfa Laval	Peab	Björn Borg	Cloetta
Billerud Korsnäs	Alimak	Projektengagemang Sweden	Bonava	Essity
Boliden	AQ Group	Saab	Boozt	ICA Gruppen
Endomines	Assa Abloy	Sandvik	Byggmax	Midsona
Granges	Atlas Copco	Serneke	Clas Ohlson	Scandi Standard
Hexpol	Balco	Sintercast	Duni	Swedish Match
Holmen	BE Group	Skanska	Dustin	
Josemaria Resources	Beijer Alma	SKF	Electra Gruppen	
Lucara Diamond	Beijer Ref	Svedberg i Dalstorp	Electrolux	
Lundin Gold	Bergman & Bevinge	Sweco	Fenix Outdoor	
Lundin Mining	Bufab	Systemair	H&M	
Profilgruppen	Cavotec	Trelleborg	Husqvarna	
Rottneros	Concentric	Troax	JM	
SCA	CTT Systems	VBG	Kabe	
SSAB	Duroc	Volvo	Mekonomen	
Stora Enso	Eltel	Xano Industri	Mips	
	Eolus Vind		New Wave	
	Fagerhult		Nilörngruppen	
	Ferronordic Machines		Nobia	
	FM Mattsson Mora		Odd Molly International	
	Garo		Oscar Properties Holding	
	Haldex		Qliro	
	Hexatronic		Retail and Brands	
	Indutrade		SSM	
	Instalco Intressenter		Strax	
	Inwido		Thule	
	Lifco		Venue Retail Group	
	Lindab International			
	Malmbergs Elektriska			
	Midway Holding			
	Momentum			
	Munters			
	NCC			
	Nederman Holding			
	Nibe Industrier			
	Nolato			

Appendix 2. Survey: Comprehension, mapping and reporting of climate-related risks

Please note: In the section below, the questions 1-24 adopts a broad sustainability focus, based on your most material sustainability aspects

1. Do you map different sustainability risks that emerge out of your operations and value-chain?

Yes
No
We are working on this right now

Please elaborate

2. If YES please discuss how your process for mapping sustainability risks is structured.

Please include relevant links and documents

3. Are you conducting the mapping for short term (2-3 years)?

Yes
No
We are working on this right now

Please elaborate

Please include relevant links and documents

4. Are you conducting the mapping for medium term (4-6 years)?

Yes
No
We are working on this right now

Please elaborate

Please include relevant links and documents

5. Are you conducting the mapping for long term (10+)?

Yes
No
We are working on this right now

Please elaborate

Please include relevant links and documents

6. Are you conducting the mapping without a specified time horizon?

Yes
No

Please elaborate and exemplify your answer

Please include relevant links and documents

7. Does your mapping include the identification and analysis of physical risks, for example weather-related, flooding and water stress and/or other physical conditions?

Yes
No
We are working on this right now

Please elaborate and exemplify your answer

Please include relevant links and documents

8. Does your mapping include the identification and analysis of transformation risks, for example changes in regulations and in consumer preferences?

Yes
No
We are working on this right now

Please elaborate and exemplify your answer

Please include relevant links and documents

9. Does your mapping include the identification and analysis of other sustainability risks (e.g. corruption, violation against human right, inequalities etc.)?

Yes
No
We are working on this right now

Please elaborate and exemplify your answer

Please include relevant links and documents

10. Do you conduct a sustainability risk mapping of you suppliers?

Yes
No
We are working on this right now

Please elaborate and exemplify your answer

Please include relevant links and documents

If YES, exemplify these risks and elaborate on why you focus on these

11. How are the outcomes of your mapping of sustainability risks used in the company (e.g. in various operations, business development, stakeholder engagement)?

Please elaborate and exemplify your answer

Please include relevant links and documents

12. Do you also map how different sustainability risks might affect your company? (*Note:* Here the focus is not on the impact of your company but instead how sustainability risks might affect your company)

Yes
No
We are working on this right now

Please elaborate and exemplify your answer

Please include relevant links and documents

13. What are the main advantages of mapping sustainability risks?

14. What are the main challenges in mapping sustainability risks?

15. Do you perform scenario analyses in relation to different sustainability areas? (*Note*: Scenario analysis is a process focused on analyzing future events by considering alternative possible outcomes).

Yes
No
We are working on this right now

Please elaborate

Please include relevant links and documents

16. If YES, in what areas related to sustainability do you perform these scenario analyses?

17. If YES, how does the process of your scenario analyses look like?

18. If YES, do you conduct the scenario analyses in-house or use external resources?

19. Please elaborate on the advantages and/or disadvantages with the chosen method used for conducting scenario analyses

20. If YES, what time horizon(s) do you have in your scenarios?

21. How are the outcomes of your scenario analyses used in the company (e.g. in various operations, business development, stakeholder engagement)?

22. What are the main advantages of conducting scenario analyses?

23. What are the main challenges in conducting scenario analyses?

24. Who are involved in the process of conducting scenario analyses?

Please note: In the section below, the questions 25-31 focus specifically on climate risks.

25. Do you integrate the EU Commission's non-binding **guidelines on non-financial reporting: Supplement on reporting climate-related information** (2019/C209-01) in your company (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019XC0620(01)&from=EN)?

Yes
No
We are working on this right now

Please elaborate on your answer

26. If YES, how and to what extent do you integrate these EU Commission's guidelines (2019/C209-01) in your company?

Please include relevant links and documents

27. Do you adopt the TCFD (The Task Force for Climate related Financial Disclosure https://www.fsb-tcfd.org/supporting-tcfd-recommendations/) framework (Governance, Strategy, Risk management and Metrics)?

Yes
No
We are working on this right now

Please elaborate and exemplify your answer

Please include relevant links and documents

28. Do you integrate the TCFD recommendations in your strategic processes or similar?

Yes
No
We are working on this right now

Please elaborate on your answer

29. If YES, please elaborate on how the TCFD is integrated in strategic processes or similar.

Please include relevant links and documents

30. What are the main advantages with the TCFD framework?

31. What are the main challenges with the TCFD framework?

GICS-industry	Number of firms (full sample)	Number of filled out surveys	Response rate
Materials	18	10	56 %
Industrial goods	56	41	73 %
Consumer discretionary	29	18	63 %
Consumer staples	8	4	55 %
Total number of companies	111	72	65%

Table 1. Response rates for the survey

GICS-industry	Description of corporate focus/operations	Number of firms (full sample)
Materials	Companies with operations related to chemicals, construction materials, containers and packaging, metals and mining, forestry products.	18
Industrial goods	Companies with operations related *to* capital goods, commercial & professional services, transportation services.	56
Consumer discretionary	Companies with operations related to automobile and parts, consumer durables and apparel, consumer services, retailing.	29
Consumer staples	Companies with operations related to food and staples retailing, food beverage and tobacco, households and personal products.	8
Total number of companies		111

Table 2. Description of the four GICS-industries included in the data population.

	Material	Investment goods	Consumer staple	Consumer discretionary
***N* all firms, *N* firms that responded to the survey**	(18, 10)	(56, 41)	(8, 5)	(29, 16)
		(all firms, firms responded to survey)		
Mapping of risks				
- Does the firm map risks?	83, 90	75, 76	100, 100	69, 75
- Is the method used to map presented?	50, 90	61, 66	100, 100	69, 75
		(all firms, firms responded to survey)		
Type of risk				
- Climate risks in general	72, 90	54. 56	100, 100	51, 75
- Physical risks	72, 90	61, 63	100, 100	48, 56
- Transitional risks	89, 90	21, 22	100, 100	45, 63

Table 3. Percentage of firms that report mapping of risks on their webpages/ in their yearly reports. In percent.
Note: the first statistic all firms, second statistic firms that responded to the survey.

	Material	Industrial goods	Consumer staple	Consumer discretionary
		(all firms, firms responded to survey)		
Method				
- System for mapping risks	56, 90	66, 74	100, 100	69, 75
- TCFD	22, 40	4, 2	0, 0	10, 13
		(all firms, firms responded to survey)		
Time Horizon				
- Short term	11, 20	2, 2	0, 0	14, 19
- Long term	6, 10	2, 2	0, 0	10, 12
		(all firms, firms responded to survey)		
Scenarios presented	17, 30	2, 2	0, 0	3, 0
		(all firms, firms responded to survey)		
Education of UN sustainability goals	50, 60	9, 7	57, 60	3, 6
Manager evaluation; non-monetary sustainability goals	22, 30	14, 17	14, 20	24, 31

Table 4. Percentage of firms that report a specific method to map and report climate-related risks. In percent.
Note: the first statistic all firms, second statistic firms that responded to the survey.

	Material	Industrial goods	Consumer staple	Consumer discretionary
		(yes, working-on-it, no)		
Type of risks:				
- Physical	80, 20, 0	64, 10, 19	100, 0, 0	81, 0, 19
- Transformation	90, 0, 10	84, 7, 2	100, 0, 0	100, 0, 0
		(yes, working-on-it, no)		
Time horizon:				
- 2-4 years	90, 10, 0	40, 40, 14	100, 0, 0	100, 0, 0
- 6-8 years	90, 10, 0	64, 5, 24	100, 0, 0	81, 0, 19
- 10 years +	60, 30, 10	40, 17, 36	80, 20, 0	69, 6, 25
		(yes, working-on-it, no)		
Risks for:				
- Own firm	89, 0, 11	86, 7, 2	100, 0, 0	100, 0, 0
- Supply chain	90, 10, 0	69, 12, 14	100, 0, 0	94, 6, 0

Table 5. Mapping of risks across the four GICS-industries.
Note: a. the numbers for each industry is the percentage of firms that answered "yes", "working-on-it", and "no" respectively to each question. b. only companies that responded yes to mapping risks were asked which type of risk they were mapping.

	Material	Investment goods	Consumer staple	Consumer discretionary
		(yes, working-on-it, no)		
Reporting frameworks				
- NFRD	50, 40, 10	38, 38, 19	40, 40, 20	25, 44, 31
- TCFD	40, 60, 0	7, 38, 50	80, 20, 0	19, 38, 44
		(yes, working-on-it, no)		
Scenarios	60, 30, 0	29, 17, 50	60, 20, 0	50, 19, 0

Table 6. Reporting standard and use of scenarios to map risks
Note: *a. the numbers for each industry is the percentage of firms that answered yes, working-on-it, and no respectively to each question. b. only companies that responded yes to mapping risks are included.*

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