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University of St.Gallen

ENVIRONMENTAL HAZARDS AND RISK MANAGEMENT IN THE FINANCIAL SECTOR: A SYSTEMATIC LITERATURE REVIEW

MIRIAM BREITENSTEIN
DUC KHUONG NGUYEN
THOMAS WALTHER

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Environmental Hazards and Risk Management in the Financial Sector

A Systematic Literature Review

Miriam Breitenstein · Duc K. Nguyen · Thomas Walther

Abstract We conduct a systematic literature review on environmental and climate related risk management in the financial sector. The systematic literature review identified a total of 36 relevant articles. A formal coding leads to the aggregation and classification of papers to three main categories that consider the impact of environmental concerns on financial risk, the current state of environmental risk practices in the finance sector, and lastly measures to assess those risks within financial institutions. Our results put forward the risk reduction for financial institutions which highly commit with environmental responsibility and performance. More importantly, investors' increase in awareness and willingness

M. Breitenstein
Faculty of Business & Economics
Technische Universität Dresden
01062 Dresden, Germany

D.K. Nguyen
IPAG Business School
184 Boulevard Saint-Germain
75006 Paris, France

T. Walther (corresponding author)
School of Finance
University of St. Gallen
Bodanstr. 6
9000 St. Gallen, Switzerland
E-mail: thomas.walther@tu-dresden.de

to assess climate-related financial risk would incentivize corporate managers to adopt more proactive environmental policies and practices. These findings also allow for intriguing discussions about several alleys for future research.

Keywords Environment · Climate · Risk Management · Banking · Financial Institutions

1 Introduction

The relentless global warming becomes increasingly visible within the last years. The years 2014 through 2018 exhibit the highest global average temperatures after nearly 140 years of global temperature tracking (NASA/NOAA, 2019). Moreover, climate change is visualized by the increase of natural catastrophes such as temperature extremes, storms, floods or earthquakes. In this regard, 2018 has been an eventful year with months of drought in Europe, wildfires in the United States, a severe typhoon in South-East Asia, floods in India and Japan, and a series of earthquakes in Indonesia. Those natural catastrophes resulted in economic losses of $160 billion (Munich Re, 2019).

Scientific research regarding global warming therefore becomes increasingly present in media and society, which can be seen in the meta study by Cook et al. (2013) displaying the 97 percent consensus on human-caused global warming among publishing climate scientists. Another climate change report published by Nobel Peace Prize awarded Intergovernmental Panel on Climate Change (IPCC) raised alarms regarding the potential impacts of global warming above 1.5°C since pre-industrial levels. The IPCC endorses the Paris Climate Agreement outcomes to keep global warming well below 2°C and to strive limiting it to 1.5°C (Masson-Delmotte et al., 2018). Climate change urgency is moreover and decisively driven by increasing actionism and societal relevance including the Fridays for Future movements all over the globe. According to the Climate Emergency Declaration campaign, 742 cities and municipalities worldwide have announced climate emergency including e.g. the cities of Sydney, New York, San Francisco, and Milan (Climate Emergency Declaration, 2019).

As science and society become increasingly aware of the risks that climate change can pose, the impact of environmental hazards to the financial sector

subsequently comes into focus. Financial institutions are exposed to those climate or environment-related financial risks through their loan portfolios or other invested capital and investment decisions and environmental risk management needs to consider exposures to environmental hazards (Görgen et al., 2019). In this regard, environmental issues have increasingly find attention in the financial sector. Corporations are starting to address their exposures to climate change and other environmental hazards enabling banks and insurance companies to access relevant data (Ilhan et al., 2019a). Institutional investors form organizations dedicating frameworks, strategies and research to environmental issues and related risks in investments, e.g. Climate Action 100 or Global Investor Coalition on Climate Change, who call for carbon pricing to more adequately allocate capital across lesser environmental risk-impacted investments (De Jong and Nguyen, 2016; Krueger et al., 2019). In 2014, the Portfolio Decarbonization Coalition was formed out of a group of institutional investors in order to decarbonize $100 billion of invested capital (Portfolio Decarbonization Project, 2014).

These are illustrative examples of the increasing relevance of environmental risks in the financial industry, whereby the general knowledge and assessment of environmental risks remains limited among financial institutions. Most recently, the governors of the British and French central banks have warned of climate risks and have highlighted the importance of the financial risk assessment and management in banks as this can mitigate the threats of climate change on the financial industry (Bank of England and Banque de France, 2019). Even though considering climate change hazards as financial risk, the European Central Bank (ECB) fails to account for environmental risks and excludes it in both, supervision and monetary policy (Sustainable Finance Lab, 2018). A survey published by the Carbon Disclosure Project in 2019 reports that the financial sector estimates $693 billion at risk from climate change impacts adding that most of the risks are going to materialize within the next five years (Carbon Disclosure Project, 2019; Financial News London, 2019). These findings, especially the last one, contribute to the necessity of environmental risk management in the financial sector. The Green Finance Study Group (GFSG) finds that while financial institutions recognize environmental risks, they encounter difficulties in pricing and hedging of environmental risks and do not properly use tools to assess within their risk

management. These challenges remain due to constrained knowledge on the institutional investors' side (G20 Green Finance Study Group, 2017; Krueger et al., 2019).

In this paper, we aim to examine more closely fundamental research on the environmental risk and its impact on financial performance, current practices of environmental risk management within the financial sector and to further investigate tools to assess or hedge environmental risk. We particularly focus on two questions. First, how is environmental risk approached to and practiced within the current risk management framework in the financial industry? Second, what are the current challenges to environmental risk management and sustainable businesses? We also discuss research paths that can potentially be investigated in future research. To accomplish our objective, a systematic literature review is conducted that identifies and discusses relevant quality research. This approach is advantageous in that it enables us to addresses two central questions that build on linking the theoretical background of environmental risks in the financial sector with the current state of knowledge on environmental risk management.

Our literature review results mainly show, on the one hand, evidence of dependency of a firm's financial risk on environmental concerns and its engagement in environmental responsibility. The reason is that firms with environmental responsibility and higher environmental performance exhibit lower market risk characteristics. Moreover, environmental risks are found to be negatively associated with financial performance. On the other hand, current practices of environmental risk assessment indicate a clear increase in awareness and willingness to assess climate-related financial risk, moving from no recognition of the financial impacts of environmental risks in 2011 to advanced knowledge about the urgency to address climate risks in financial institutions in 2018. Another important fact is that most investors face difficulties when approaching climate-related financial risk since the basic approaches such as carbon footprint analyses are not efficient enough. The issues and challenges ahead include disclosure of firm data, suitable assessment, and pricing instruments.

One can, therefore, notice that the above-mentioned findings have important implications for corporate environmental behavior, to the extent that investors pay more attention to financial risk and performance effects of environmental quality.

This could, in turn, lead to positive changes in attitudes towards environment and environmental protection intentions of corporate executives and managers, which push firms to more proactive environmental practices. For instance, Liston-Heyes and Vazquez Brust (2016) develop a multi-stage model of corporate environmental behavior where environmental attitudes are allowed to directly affect firms' environmental intentions and performance. Interestingly, their results from a sample of 536 Argentinean firms typically show that pressures from stakeholders can lead to the development of managerial pro-environmental attitudes.

The rest of the paper is structured as follows. Section 2 briefly reviews the concept of environmental risk and hazards as well as the theoretical foundations of risk management processes in financial institutions. Section 3 introduces the systematic literature research approach and presents a preliminary quantitative analysis of the research identified. Section 4 provides insights into the impact of environmental risk on financial performance and current practices of environmental risk management in the financial sector. Section 5 presents possible paths for further research. Concluding remarks are provided in Section 6.

2 Theoretical Background

To approach the research topic of environmental risk management, issues such as financial risk management, the framework of environmental hazards, and its classification within the financial sector need essential explanations.

Taking risk management within the financial sector into consideration, European regulations have been developed to ensure suitable and compliant protection against financial risks. Several regulatory mechanisms are employed to improve risk management within the financial sector. According to the three pillars of the Basel agreement, market and credit risk are components of risk management. The Basel agreement ensures capital requirements for market and credit risks. Solvency II presents a risk-based capital regulation framework that applies to insurance companies (Gatzert and Wesker, 2012). Moreover, Basel III supports risk management in taking a short-term view on financial risk which contradicts the long-term impacts of climate-related risks (D'Orazio and Popoyan, 2019).

Within the financial sector, the management of risks has become its own essential part of the banking business. Risk management is a decision process that includes four consecutive activities: risk analysis, risk control, risk monitoring, and risk communication (Muralikrishna and Manickam, 2017). Risk analysis serves the purpose of supporting the entire decision process of risk management and includes risk identification to assess and communicate uncertainty issues to decision-making bodies. Potential environment-driven risks require identification and assessment through specific risk analysis tools that use different valuation approaches, collectively referred to as environmental risk assessment. The outcomes of the risk assessment are incorporated into the risk evaluation and aggregation to identify options for mitigation or control measures and different levels of minimizing the risk. The choice of adequate risk control, however, greatly depends on the corporate risk strategy and its risk tolerance. Risk control considers different options and measures of avoidance, reduction, transference, or acceptance to control exposure to risk. The choice of an adequate control measure is followed by its implementation and execution. Throughout the execution of control measures, risk monitoring becomes an indispensable process of risk management reflecting on the effectiveness of current risk mitigation/reduction. It also considers future changes of risk, new relevant data to assess more accurate results, and consequently cost reductions of control measures. Lastly, risk communication between various stakeholders is an important part of risk management. It implies a two-way communication that considers relevant information from stakeholders such as risk assessors, management, general public, investors, and shareholders to improve the decision-making process of risk management.

Taking a closer look at the analysis of risk, Muralikrishna and Manickam (2017) highlight the process of identifying and assessing environmental risk. It consists of several steps starting with the formulation of the problem. Problem formulation serves as a basis for the following identification of the adequate risk assessment type and level. Hence, it is necessary to define the problem, boundaries of the problem and constraints of the assessment. Problem formulation also includes modelling the source-pathway-receptor relation that describes the course of risk from the hazard to the eventually affected group of receptors. An example for this modelling could be rainfall (hazard) that causes high water in rivers followed by

over-topping, failure of flood defenses and inundation (pathways) and ultimately harms infrastructure, private/public properties, people, and possibly the ecosystem as well (receptors). Risk assessment contains two key components, namely hazard assessment and environmental exposure assessment. Hazard assessment serves the purpose of identifying the adverse potential impact on receptors through collecting and evaluating relevant data. The exposure assessment identifies the direct/indirect exposure to those hazards (e.g. chemicals) and defines to what extent (e.g. dose, concentration) the human population, environment or industry sector is exposed to. These analyses feed into risk characterization or estimation which qualitatively and quantitatively determine the chance and extent of harmful impact to receptors considering the exposure to the hazard.

In this context, the term of environmental hazards defines threats that are potentially posed by the natural or built environment to humans or nature. This topic of research has found increased attention within the last years since these environmental threats develop or differ through climate change or are in any other way voluntarily encouraged by humans (Smith, 2004). Few different concepts were developed to define and classify these environmental sources of risk (Bank of England, 2015; Caldecott and McDaniels, 2014; Smith, 2004). This paper follows Cambridge Centre for Sustainable Finance (2016) and Mercer Investment Consulting (2015) in classifying environmental hazards.

The Cambridge Centre for Sustainable Finance defines a broad categorization of environmental hazards. Banks are exposed to financial risk caused by acute or chronic physical environmental events but also the appertaining risks of transition (Cambridge Centre for Sustainable Finance, 2016). This framework has originally been developed by Mercer Investment Consulting (2015) who outline the so-called TRIP framework in more detail. The Technology, Resource Availability, Impact of Physical Damages, Policy (TRIP) framework divides the previously mentioned physical events into resource availability and physical damages. Extreme or catastrophic physical damages represent ‘acute’ physical events such as floods or hurricanes. Resource availability comprises all ‘chronic’ and long-term environmental changes that have an impact on investments. It includes impacts that are initially caused by climate change, e.g. water scarcity and changes in weather patterns. These weather patterns may result in positive as well as negative impacts

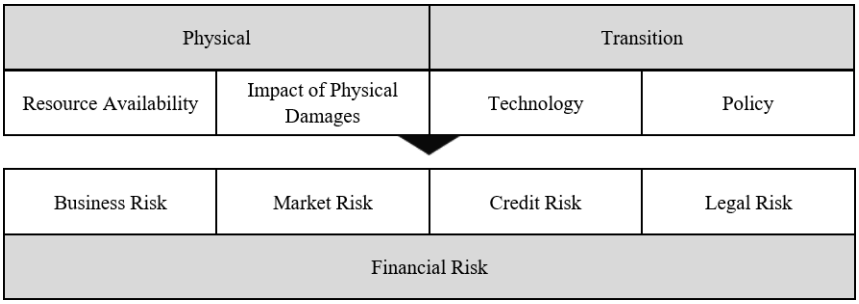

Fig. 1: Categorization of environmental risk sources and conformity of TRIP framework and G20 approach (Cambridge Centre for Sustainable Finance, 2016).

at different times of development. Moreover, the category of transition hazards is split into the policy and technology categories. As climate change increasingly influences political decisions, policies, and economic developments, banks are not only affected by the environment itself but also climate change transition. The policy risk source is based on national as well as international measures to support energy transformation and reduce the steady impact of climate change. It unfolds into different kinds of legislation, regulation, mandates, or targets that comprise direct and indirect pricing mechanisms, and research and development.

Further classification differentiates between demand-side and supply-side policies aiming at either promoting low-carbon alternatives or reducing carbon emissions. On the supply-side, low-carbon technologies and products are encouraged to provide consumers with less carbon-intensive products and services. On the demand-side, implemented policies decrease the consumption of high-carbon products through pricing or non-monetary disincentives (e.g. labeling). Lastly, the technological hazards include technological advancement, disruption and changes in the energy, specifically low carbon, industries. The focus lies on technologies to transform, transmit, and use energy (Mercer Investment Consulting, 2015).

These environmental hazards eventually result in specific financial risks that—in this case—are faced by institutions in the financial sector. There is no consistent distinction between financial and non-financial risk in literature. Financial risk implies an adverse impact on the profitability of a financial institution through e.g. an increase in costs or decrease in revenues. Through climate change, financial risk exhibits specific distinctive characteristics. Within the financial sector's classifi-

cation of risk, environmental hazards affect the key risk areas (business, market, credit, and legal risk) as identified by Cambridge Centre for Sustainable Finance (2016). Figure 1 gives an overview of the different categories of hazards that can impact the outlined categories of financial risk.

3 Systematic Literature Review

3.1 Methodology

The systematic literature review is based on the procedure of Tranfield et al. (2003). It begins with the identification of suitable keywords and search terms resulting from the research question and the literature that has been reviewed up to that point. In addition, only publications with a publication date starting in 2008 are examined in more detail in order to identify current approaches to environmental risk management. This time frame follows the study by Delis et al. (2018) who argue for the novelty of this research. The increased frequency of this topic starting from 2008 is also shown in the conducted research exemplary presented in Figure 6 in the appendix. The keywords used are intended to identify approaches to assess and manage environmental risks in the financial sector, specifically banks. Consequently, the keywords contain synonyms related to environmental risks themselves (such as climate risk, climate-related risk, climate change risk, environmental risk, ESG risk, transition risk) as well as synonyms related to concepts of management (such as approach, assessment, management). Moreover, the search includes keywords aiming at the financial sector including relevant synonyms (such as bank, banking, banking industry, banking sector, financial industry, financial institution, financial sector, institutional investor). The search strings connect these three categories with the Boolean operator `AND` and additionally refer to the use of the truncation "*", if possible. This minimizes the number of searches to be carried out and double counting. These search strings are quite precise in order to focus on environmental risks and exclude further climate change relevant topics that do not with risk management concepts.

An overview with the associated number of search results can be found in Table 3 in the appendix. The search is conducted on the three electronic databases

EBSCOhost, Emerald Insight, and ScienceDirect, whereby for EBSCOhost the sub databases "Business Source Complete" and "EconLit with Full Text" are used. The use of these three different databases, in turn, serves the holistic and comprehensive nature of the research and is intended to prevent subject-relevant literature from not being recorded in the search due to limitations of individual databases.

Using suitable inclusion and exclusion criteria, the results of the search are filtered according to their relevance. For this purpose, the title and abstract of all articles are reviewed and examined with regard to the defined criteria. In this way, literature that is not sufficiently concerned with the subject is excluded. In order to create a shortlist, a detailed full-text analysis is carried out in the next step. The result is a list of articles that are thematically relevant to the study of the research question. Following the research, all literature of the narrower selection is evaluated in terms of its scientific quality and, if necessary, further filtered to ensure an adequate quality of the underlying data. In particular, the use of the journal ranking JOURQUAL 3.0 is appropriate in terms of its scientific relevance and international recognition.[1] The final outcome is a selection of publications that meet the previously defined standards in terms of both content and scientific quality.

After entering the search strings, a total of 378 potentially relevant English-language publications could initially be identified of which 296 were published from 2008 on-wards and thus meet the first two selection criteria (including duplication). By gradually analyzing the titles, abstracts and keywords of all 162 papers identified, a narrower selection of sources could first be determined which were subsequently subjected to a full text analysis to exclude subject-irrelevant papers. In this way, the selection could be limited to 64 articles. Removing duplication eventually led to an interim result of 35 articles relevant to the content. In the final step of literature selection, the corresponding journals were evaluated with regard to the JOURQUAL 3.0 rating. In order to ensure the quality of the scientific statements in this work, only articles with a rating of at least C are further

[1] The VHB JOURQUAL 3.0 ranking was conducted in 2012. The webpage states that the ranking does have a correlation of 0.66 and 0.70 with the British Academic Journal Quality Guide and Scimago Journal Rank, respectively. See https://vhbonline.org/en/service/jourqual/vhb-jourqual-3/ (accessed: July 1, 2019).

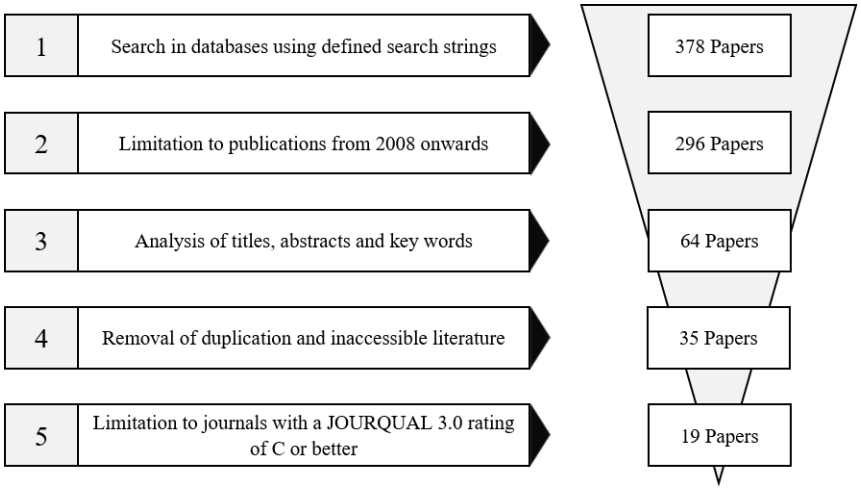

Fig. 2: Process scheme of the systematic literature research.

considered. Finally, we yield a selection of 19 relevant articles meeting all four of the above specified selection criteria. Figure 2 summarizes the procedure scheme of the literature research including the articles left after each step.[2]

In order to collect further subject-relevant literature, a backward reference search, also referred to as snowball principle, is carried out. It specifically analyzes the bibliography of each paper. We start the systematic snowball literature search with Ilhan et al. (2019a). The criteria for choice of literature remain mostly unchanged, focusing on English literature from 2008 onwards and relying on scientific publications in journals with a JOURQUAL 3.0 rating of at least C.[3] It is important to note that three quality working papers have been included in this research selection. Appearing later on in the snowball research, Krueger et al. (2019) cover literature resulting from the Review of Financial Studies (RFS) Climate Finance Initiative to a great extent. The RFS Climate Finance Initiative encourages

[2] The result of the systematic literature research depends heavily on the keywords used, the search strings formulated from them, and the databases employed. This becomes clear when looking at search results per database in Table 3 in the appendix. While a total of 45 relevant articles could be found via EBSCOhost, the identical searches at Emerald Insight and ScienceDirect provided only six and 13 significant publications, respectively. Additionally, literature reviews pose a problem if the literature regards an emerging research topic that is yet to develop and examine further over the next few years. Therefore, searching the databases with the chosen search strings exhibited a small amount of papers to which further criteria could be applied to. Eventually, it results in 19 papers.

[3] The study by Hong et al. (2019) is published in a journal outside of this ranking, but nonetheless comes with an 2018 impact factor of 1.949.

further research in the field of climate finance, including environmental risk management. Since the RFS obtains an A+ rating and the corresponding literature is already conditionally accepted, the snowball literature review also considers publications from the RFS Climate Finance Initiative. Excluding already identified publications through the previous literature research, the snowball principle research adds 15 papers to the existing list of results. A more detailed summary of the process as well as a final overview of papers can be found Table 4 in the appendix.

3.2 Quantitative Results of the Literature Review

Following the explanation of the general methodology and the precise approach of literature research, the results of the study are reviewed hereafter. Before in particular examining what are the current challenges to environmental risk management and considering the state of research, a brief analysis of the general characteristics of the selected literature is carried out. Such an analysis is important in order to classify the statements expressed in the literature in terms of their scientific quality and relevance to the subject, and thus to enable a better interpretation of the results.

Figure 3 illustrates the JOURQUAL 3.0 ratings of the final articles. Most of the literature identified within literature research, namely 64 percent, have been ranked with at least B or above. It is important to highlight the high number of journals with an A-rating or higher (28 percent) which ensures a high quality of the studies examined. Within the range of journals classified as outstanding and world-leading, it is striking that three papers originate from the RFS Climate Finance Initiative eventually being published in The Review of Financial Studies. However, the results of the literature also include four papers that only have a rating of C and are thus titled “recognized scientific journals”. It is to be noted that four of the selected articles have not been published in a scientific journal and are therefore left without a ranking.

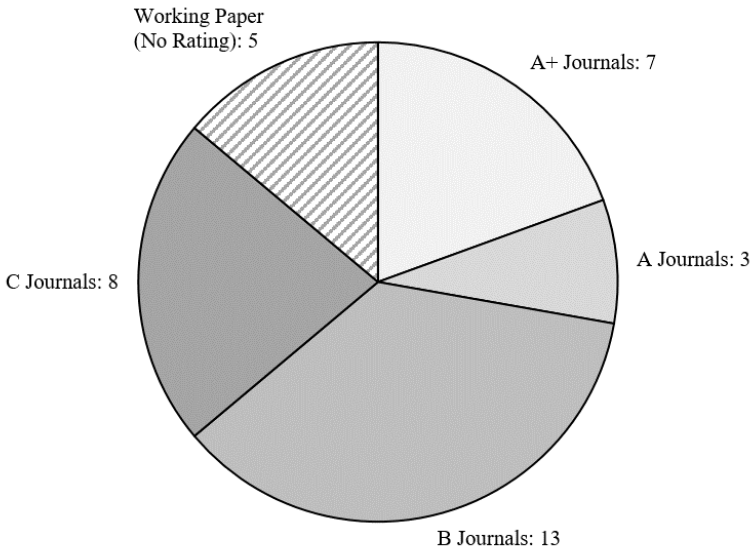

Fig. 3: JOURQUAL 3.0 ratings and number of journals of final selection.

In Figure 4, papers are classified according to the subject area of the journals in which the papers were published.[4] As expected, the figure shows that most papers have been published in journals with a specific relation to the thematic field of financing and banking. This finding matches with the formulated research questions that aim at environmental risk management in the financial sector. As the consideration of financial risk also evolves from an increased sustainability and climate change awareness of the financial sector, around nine papers can be assigned to the category of sustainability management. At the same time, the subject seems to be highly relevant for corporate management due to the comparatively high number of articles in the management area. This can be explained by the general newly gained importance of environmental issues, as risk management is a fundamental for securing the existence of companies.

Figure 5 additionally shows the frequency of identified articles distributed over the considered period of time which also exhibits an increase in relevant literature starting around 2015 which marks the year of the 2015 Paris Climate Conference.

[4] This classification of journals is in accordance with the VHB JOURQUAL 3.0 ranking classification. See https://vhbonline.org/en/service/jourqual/vhb-jourqual-3/complete-list-of-the-journals/ (accessed: July 1, 2019).

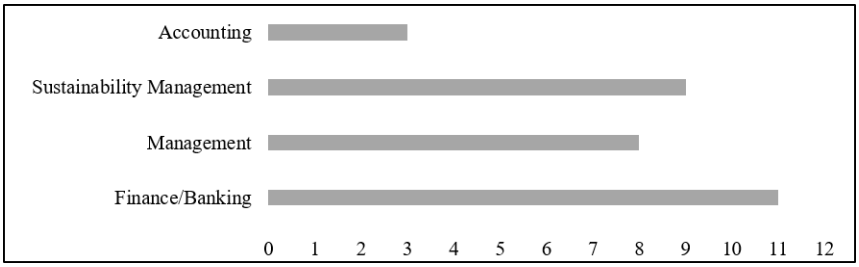

Fig. 4: Thematic classification of the journals with corresponding number of papers.

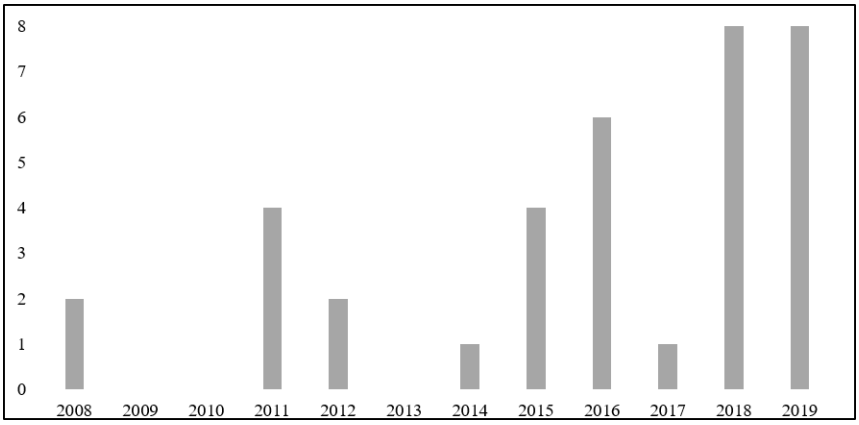

Fig. 5: Chronology of relevant research literature with corresponding number of papers.

The conference of 55 countries was concluded by the Paris Agreement where the countries set eager goals to decrease greenhouse gas emissions in order to not exceed the 2-degree global warming. This agreement also included the financial aspect of global warming broadly referring climate finance flows (UNFCCC, 2015).

4 Research in Environmental Risk and Current Approaches to Environmental Risk Management

This section looks at current approaches of scientific and business practices to assess environmental risks. It also conduces to create a comprehensive understanding of current challenges and potential paths of research that will be addressed in Section 5.

We conduct a qualitative coding through content analysis to draw conclusions from the systematic literature review. In this regard, a categorical framework outlines and classifies the papers extracted. The overview presented in Table 1 shows the key topics and research aspects pointed out in each paper. The papers are classified into three categories. The first category groups studies which address the relationship between environmental risks, environmental engagement, and financial performance. It therefore provides evidence and justification for environmental risk management generally and in the financial services industry. The second category covers papers that either outline current practices in the field of environmental risk management or, more specifically, propose assessment approaches regarding the relevance of environmental risk hazards in the financial sector. The last category of research focuses on environmental risk assessment.

Presented chronologically by date, Table 1 not only highlights the distribution of thematic aspects of research, but also shows which aspects of research in the field of environmental risk management have received or currently receive particular attention. It can be seen that research in environmental risk assessment has been prominent within the last three to four years, whereas the other topics are rather spread over the chosen time period of literature research starting in 2008. In what follows, we successively review these three categories of research.

No.	Author	Impact of Environmental Risk	Current Practices	Assessment
1	Addoum et al. (2019)	X		
2	Alok et al. (2019)		X	
3	D'Orazio and Popoyan (2019)			X
4	Engle et al. (2019)			X
5	Görgen et al. (2019)			X
6	Hong et al. (2019)		X	
7	Ilhan et al. (2019a)		X	

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8	Ilhan et al. (2019b)	X		
9	Krueger et al. (2019)		X	
10	Addoum et al. (2018)	X		
11	Delis et al. (2018)	X		
12	Eccles and Krzus (2018)	X		
13	Huang et al. (2018)	X		
14	Jung et al. (2018)	X		
15	Nguyen (2018)	X		
16	Thistlethwaite and Wood (2018)		X	
17	Fernando et al. (2017)	X		
18	Andersson et al. (2016a)		X	
19	Andersson et al. (2016b)			X
20	De Jong and Nguyen (2016)			X
21	Sassen et al. (2016)	X		
22	Semenova and Hassel (2016)	X		
23	Verheyden et al. (2016)	X		
24	Georgopoulou et al. (2015)			X
25	Kim et al. (2015)	X		
26	Muhammad et al. (2015)	X		
27	Nikolaou et al. (2015)	X		X
28	Chava (2014)	X	X	
29	Flammer (2013)	X		
30	Weber (2012)		X	
31	Campbell and Slack (2011)		X	
32	Litterman (2011)		X	

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33	Salama et al. (2011)	X		
34	Solomon et al. (2011)		X	
35	Sharfman and Fernando (2008)	X		
36	Weber et al. (2008)		X	

Table 1: Overview and classification of papers extracted from the systematic literature research.

4.1 Impact of Environmental Risk on Financial Performance

The relevance of environmental responsibility of corporations in general has become a popular topic of research over the last decades. This development has been motivated by environmental and social concerns and most definitely by its potential impact on risk (Salama et al., 2011). The roots of environmental risk management lie in concepts such as corporate environmental performance (CEP) and environmental, social, and governance (ESG) criteria. These concepts describe business activities in accordance with its stakeholders, namely societies and the environment (Jin, 2018).

The relationship between a firm's environmental performance and its financial performance forms the basis for research on environmental risk since it displays that environmental hazards are reflected in current and past financial performance. It also gives incentives to assessing and managing environmental risks. Five studies published between 2011 and 2016 investigate the impact of CEP on corporate financial performance (CFP) (Muhammad et al., 2015; Salama et al., 2011; Sassen et al., 2016; Semenova and Hassel, 2016; Verheyden et al., 2016). Except for the research conducted by Semenova and Hassel (2016), all studies focus on market risks of firms exhibiting different levels of environmental performance. The studies on market risk have similar methodological settings including the type of analyses and investigated dependent variable. Employing regression analyses, all studies test the systematic risk proxied through the market beta. While Salama et al. (2011) only test the systematic risk, all other studies test the total risk proxied through standard

deviation. In addition, some research considers the idiosyncratic risk (Sassen et al., 2016; Verheyden et al., 2016) or downside risk (Muhammad et al., 2015; Verheyden et al., 2016) using different proxies for the latter, though. The research by Verheyden et al. (2016) stands out due to its complex measurement of risk-return characteristics not only on the stock level, but further on the portfolio-level of six differently screened portfolios. The time periods in total range from 1994 to 2015 and include time overlaps that simplify the comparison of the empirical analyses.

The analysis of empirical results show that the CEP is, in general, negatively associated with the market risk of companies. In particular, the total risk or volatility is lower for firms that have a higher CEP (Muhammad et al., 2015; Verheyden et al., 2016). The evidence presented in Sassen et al. (2016) for environmentally sensitive industries (e.g., the engineering or transportation industries) also corronorates this finding. Regarding systematic risk, there is evidence to suggest that social and environmental engagement of firms lowers the systematic risk (Salama et al., 2011; Sassen et al., 2016). This finding is, however, not in line with Muhammad et al. (2015) whose results were unable to support this statement. Considering the impact of firms' environmental responsibility on downside risks, Muhammad et al. (2015) and Verheyden et al. (2016) show that CEP and ESG screenings decrease downside risk on both the individual stock and portfolio levels. Two studies document opposing evidence for idiosyncratic risk. While Sassen et al. (2016) find that environmental performance decreases the idiosyncratic firm risk, Verheyden et al. (2016) report slightly increased idiosyncratic risks for ESG screened portfolios, despite the fact that they both consider ESG ratings as a choice of CEP proxy. The main difference between their research design is the study period (from 2002 to 2014 for Sassen et al. (2016) and from 2010 to 2015 for Verheyden et al. (2016) as well as the use of either the ESG-rated individual stock level or ESG-rated portfolio level. The increased idiosyncratic portfolio-level risk can be balanced by increased returns that overall positively impact risk-adjusted returns. This finding is especially important for the construction of environmental risk concerned hedge portfolios, as it highlights differences in the ESG-rated stock and portfolio characteristics.

Beyond its impact on market risk, the environmental performance of a firm is found to increase its market value. More specifically, news about environmental responsibility can increase the shareholder value while negative information about a firm's environmental responsibility can negatively affect its shareholder value. There is evidence of the increasing relevance of environmental concerns of shareholders reporting an increase in negative reactions towards harmful environmental behavior over time (Flammer, 2013). Regarding corporate environmental policies, the results reported in Fernando et al. (2017) show that both 'toxic' and green firms have low institutional ownership, suggesting that shareholder value increases with less environmental exposure, but does not further increase with more environmental friendliness of firms.

These findings discussed above are further corroborated by research that directly investigates the impact of environmental hazards on financial risk, which provided evidence for the impact of environmental performance on downside (tail) risk. Ilhan et al. (2019a) use carbon emissions from the S&P 500 companies disclosed by the Carbon Disclosure Project to measure the consequences of emission volatility on downside risk. Downside risk is measured as the average tail loss of out-of-the-money put options because they capture the market expectation of jump risks. They conclude that an increase in the emissions' standard deviation increases the tail risk standard deviation by 13 percent drawing a positive relationship between carbon emissions and tail risk. Moreover, tail risk of carbon-intensive firms increased after the 2015 Paris Climate Agreement which implies that regulation and technology connected with climate change impact financial risk. Nguyen (2018) and Huang et al. (2018) investigate the effect of environmental hazards on financial risk characteristics, more specifically the volatility of earnings and cash-flows measured by standard deviation of probability of loss and pre-tax income, respectively. The authors find evidence that companies exposed to environmental or carbon emission hazards carry higher financial risk. Firms with high climate risk indices exhibit lower and more volatile earnings and cash-flows (Huang et al., 2018) and firms with high carbon emissions are exposed to an increased probability of loss (Nguyen, 2018). In addition, Addoum et al. (2018) provide evidence that earnings are significantly affected by environmental hazards, in this case, extreme temperatures. Regarding U.S. companies and their locations to investigate how the

exposure to temperatures over a 26-year period, extreme temperatures affected 40 percent of U.S. companies in their earnings per share. On the other hand, Addoum et al. (2019) do not find that temperature shocks significantly impact sales and productivity, even for industries that are considered to be heat-sensitive. This finding is contradicted by Nikolaou et al. (2015) who report strong effects of physical hazards on economic performance due to significantly increased costs. Both studies note that the extent of financial damage depends on the specific industry. Severe weather events also impact financing choices, as businesses in such regions hold more cash, less short-term and more long-term debt (Huang et al., 2018). These findings highlight the necessity of firms and financial services industry to account for environmental hazards regarding acute and chronic climate change events such as heat, drought, and other severe weather events.

Chava (2014), Delis et al. (2018), Jung et al. (2018), Kim et al. (2015), and Sharfman and Fernando (2008) examine the impact of environmental risks on the cost of capital, as investors and lenders may mirror their perceived increased financial risk. The financial industry can thereby play a key role in incentivizing environmental responsibility and engagement of companies. Chava (2014) analyzes how environmental hazards impact the cost of equity and debt capital. The exposure to specific environmental hazards is estimated by three concerns, namely exposure to excessive waste, emissions of toxic chemicals, and direct and indirect generation of revenues from fossil fuel products. The cost of equity is estimated by expected returns of stocks and the cost of debt is measured by bank loan spreads. The study documents an increased cost of equity capital for firms with high exposure to environmental hazards. This implies that firms with environmental exposure carry specific risks or are at least regarded to do so from the investors' perspective. To further illustrate these results, Chava (2014) finds no significant association between environmental exposure and default risk and consequently argues that default risk is not the sole factor of higher interest rates. Empirical studies by Jung et al. (2018), Kim et al. (2015), and Sharfman and Fernando (2008) confirm the findings on cost of equity and debt. Measuring the extent to which a firm is exposed to carbon risk by its carbon intensity, carbon risk is found to be positively associated with the cost of equity. This again pronounces the increased total firm risk for which in turn investors require higher compen-

sation. Lastly, Kim et al. (2015) and Sharfman and Fernando (2008) outline the importance of environmental risk management, as it decreases the cost of capital. They conclude that the environmental-economic performance does improve by both better resource utilization and the engagement in environmental risk management. The only partially contradictory result is offered by Delis et al. (2018) who report no significant differences between loan spreads of fossil fuel firms and non-fossil fuel firms until 2015. However, this study's dependent variable differ, as it distinguishes firms with fossil fuel reserves from firms without those reserves which nonetheless may greatly use fossil fuels.

Interesting are outcomes pronouncing the environmental risk of the industry as a contingency for the CEP-CFP relationship at company-level. Semenova and Hassel (2016) test the effect of environmental management and environmental risk policies, primarily reporting efforts, on the market value in industries with low or high environmental risk. The authors find that the effect itself and its strength differ for the various industries. Environmental management and environmental policy exhibit a stronger (positive) effect on market values when the environmental risk of the industry is low. This raises the question of whether risk management is attributed higher importance than the risk itself. Kim et al. (2015) argue that the association between environmental risk and cost of equity at firm-level is stronger for industries with low greenhouse gas emissions since firms from the sector are just as much exposed to regulatory risk as companies from carbon-intensive sectors. The directive effect of industry membership is important to investors in decision-making and assessing not only climate risks at the firm but also industry levels.

This fundamental research corroborates the necessity of environmental risk assessment and management as it provides evidence that firms with environmental responsibility and higher environmental performance exhibit lower market risk characteristics. It therefore pronounces the dependency of a company's financial risk on environmental concerns and its engagement in environmental responsibility. Moreover, studies directly consider environmental risk and its impact on financial performance, especially earnings and cost of capital. The outcomes confirm findings on CEP contributing to the overall conclusion that environmental risks are negatively associated with financial performance. Environmental hazards

pose a significant financial risk to companies and the financial sector, but at the same time provide incentives to improve financial performance metrics.

4.2 Insight into Current Practices and Investors' Views

As mentioned previously, enhanced financial performance characteristics of firms with lower environmental risk or an improved environmental risk management outline the need for the integration of environmental risk assessment in risk management processes. Especially the cost of capital as a financial performance measure is also driven by investors and lenders of the finance sector. Therefore, it already gives an indication of current practices in the banking sector and how investors potentially screen out stocks with environmental concerns implying lower institutional ownership and higher expected returns for equity (Chava, 2014).

In this regard, several studies have conducted interviews, content or literature analyses to find evidence for and information about current assessment of environmental risks in the financial sector. Those surveys are specifically relevant to current research because environmental risk management practices are difficult to examine or derive from other empirical methods (Krueger et al., 2019). Analyses from the financial sector come to ambiguous results highlighting the role of analysts and investors as individual decision makers. Providing negative conclusions on the question of current assessment, Campbell and Slack (2011) state that none of the 19 interviewed analysts considers environmental risks within the risk assessment decision-making process. Additionally, an analysis of the 2012 and 2015 Climate Risk Disclosure Survey of U.S. insurers indicates that most insurance companies do not account for environmental risk resulting from climate change in their main operations. The 2012 survey reports that 11 percent of insurance companies adapt climate risk assessment from versus 39 percent in 2015 (Thistlethwaite and Wood, 2018). Somewhat negative feedback is reported by Weber et al. (2008) who received completed questionnaires from 50 out of 205 European banks and find that more than 80 percent of the banks in the sample integrate environmental risks into the credit risk management process. On the other hand, rather positive outcomes are reported in (Krueger et al., 2019) who conclude from their interviews that only 7 percent of 439 analysts have shown no efforts to account for climate risks within

the last five years. At the firm level, Weber (2012) analyzes the social responsibility reports of nine Canadian banks and finds that all banks systematically integrate environmental risks into their credit management, even business strategies, but do not publish further information about the financial risk induced by environmental hazards.

What is interesting to note is that over time, the collected studies suggest progress in environmental risk assessment driven by increasing relevance of climate change and environmental concerns of firms. For the insurance sector, Thistlethwaite and Wood (2018) confirm an increase in assessment from 11 to 39 percent in only four years (2012 to 2015). Delis et al. (2018) report evidence that investors increasingly considered the climate policy risk of fossil fuel firms in the cost of borrowing from 2015 onward (year of the Paris Agreement), even though the increase is not of significant economic relevance. A similar conclusion is reached by the comparison of Campbell and Slack (2011) and Krueger et al. (2019) works since the conducted interviews resemble each other closely, specifically on the subjects of qualitative outcomes. Both interviews are conducted with analysts and investors and differ in the number of interview partners (19 versus 439) and structure of the interviews (unstructured and qualitatively versus structured and quantitatively). The studies reveal an increase from no assessment approaches at all in 2011 to 93 percent in 2018. However, it is striking that over 21 percent of the interview partners of Krueger et al. (2019) state that they started assessing environmental risks over ten years ago which contradicts the qualitative findings of the study by Campbell and Slack (2011).

Further evidence collected from these studies also portrays investors' perception toward environmental risk and its integration into the risk management process. Campbell and Slack (2011) find that environmental statements of banks generally remained unread and were considered the most immaterial section of annual reports. This is in line with some analysts' perception that environmental risk is not associated with a bank's overall risk at all. Some analysts regard the relevance of environmental reporting to potentially increase due to clients' concerns and valuation, but they screen out the potential materiality of environmental risk to be important to banks in general. Analysts did not find firms' environmental exposures to affect portfolios or forecasts, and environmental risk management to

be important for risk assessment. This finding does not corroborate with research by Solomon et al. (2011) whereby interviewed investors report direct implications of climate change in that it represent a material risk. Krueger et al. (2019) confirm this outcome through interviews, which is in accordance with increasing awareness of investors towards environmental developments and climate change over the last decade. Investors find environmental risks to have financial implications for portfolios and the corresponding portfolio firms. Most investors also report that climate risks have already begun to materialize and around 10 to 25 percent believe that the risk of assets becoming stranded for different electricity industry companies is "very high" (Krueger et al., 2019). Even though, banks perceive risk to already materialize today, they expect the overall risk pricing to be overvalued.

Provided that banks assess environmental risk, it is not genuinely incorporated in all phases of risk management processes. Weber et al. (2008) address the incorporation into the credit risk management of banks and note that environmental risks are mostly considered in the risk identification phase (rating phase), but are less considered in risk evaluation and risk controlling. Environmental risks are less likely to be considered in the process steps of costing and pricing. This shows a lack in systematic and quantitative incorporation throughout the entire risk management process. Krueger et al. (2019) further address tools used to identify and evaluate climate risks. In a broader view, banks take various approaches to cover climate risk management in the investment process, including carbon footprint analyses of portfolio firms and reduction of portfolio footprint as well as analyses and reduction of stranded asset risk. Still, the two mostly used approaches, analyses of carbon footprints and stranded asset risks, have been employed by less than 40 percent of interviewed investors. Other approaches are portfolio diversification, ESG and ESG rating integration, firm valuation models, and climate risk hedging. In order to directly assess the potential impact of climate risk to portfolios, investors rely on carbon footprint measurements, return impact measurements of climate risk, scenario analyses as well as stress tests considering climate scenarios. The data used to assess the carbon footprint of portfolio firms is derived from corporate disclosures (self-collected), private reporting channels, the MSCI ESG database, or the Carbon Disclosure Project database (Krueger et al., 2019; Solomon et al.,

2011). Further relevant data about greenhouse gas emissions is disclosed by Trucost or the South Pole Group (Andersson et al., 2016a).

Regarding public disclosures in 2011, investors state that due to a lack in public corporate disclosures they heavily rely the private reporting channels of companies to receive relevant data about environmental concerns (Solomon et al., 2011). Even though, since 2011, policies regarding the disclosure commitment of firms were introduced and improved access to relevant environmental data, investors still report lacks in environmental public disclosure. Investors criticize the current level of obligatory disclosure and call for standardized and more precise quantitative information on firm climate risk (Ilhan et al., 2019a). In more detail, Eccles and Krzus (2018) consider how companies can meet the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD) in order to make more comprehensive data available to investors. Considering financial and voluntary reports of three oil and gas companies, it is reported that most sophisticated environmental disclosure is found within the voluntary sustainability reports. Only few companies voluntarily published data from scenario analyses, as most companies worry that these analyses are perceived as forecasts by investors and could therefore negatively impact the companies. Eccles and Krzus (2018) highly suggest the compulsory integration of comprehensive environment- and sustainability-related data into financial reports to increase the quality of disclosures. In the knowledge of the disclosure gap, 60 percent of investors disclose or plan to disclose the overall portfolio carbon footprint (Ilhan et al., 2019a). Due to this poor disclosure, food stock prices are found to underreact to climate-related risks. This is indicated by Hong et al. (2019) in that food stocks exposed to droughts are mispriced by the markets. However, assessment and management approaches do not clearly conclude in positive results. Alok et al. (2019) find that investors misestimate climate risks and hold underweight positions in stocks located in disasters zones. This misperception of disaster-driven financial impacts decreases for further off investors. The underweighting of stocks located in climate disaster zones is refuted by the positive risk-adjusted returns of a portfolio that goes long in the most underweight stocks and short in the least underweight stocks.

Overall, current practices of environmental risk assessment give a mixed picture, ranging from no recognition of the financial impacts of environmental risks in

2011 to advanced knowledge about the urgency to address climate risks in financial institutions in 2018. This clearly shows a development and moreover increase in awareness and willingness to assess climate-related financial risk. The assessment shows that even though today most investors approach climate-related financial risk, they face difficulties in employing basic approaches such as carbon footprint analyses. The current challenges to remain are disclosure of firm data, suitable assessment, and pricing instruments. Furthermore, characteristics of climate risks are needed to understand the impact of environmental hazards on the financial risk of firms and portfolios.

4.3 Assessment Approaches

As quite opportunely reported by Krueger et al. (2019), research addressing general risk management approaches mainly focuses on portfolio strategies (hedging, diversification) and risk measurement methods (carbon footprint, stranded asset, ESG rating, firm valuation).

Regarding risk measurement methods and specifically the carbon footprint, Görgen et al. (2019) construct measures of carbon risk. The authors use four ESG databases to construct the "Brown-Green-Score" as an advanced approach to carbon risk. The Brown-Green-Score includes three indicators describing a firm's sensitivity to carbon risk (policy). This score is used to compute the "Brown-Minus-Green" portfolio that reflects the global market carbon risk. The "carbon beta" of a firm describes the firm's sensitivity to the global market carbon risk. Moreover, Görgen et al. (2019) calculated the carbon beta for both countries and industries. While there is a wide range of negative to positive sensitivity of various industries, energy, basic materials, and utilities industries exhibit the highest carbon risk sensitivities. The authors also highlight the impact of carbon risk on the financial sector outlining a high sensitivity depending on the carbon beta of the country. The carbon beta serves as a measure for firms, investors, and analysts generally contributing to further understanding of specific carbon risk sensitivity.

Other studies combine carbon footprint measurement hedging strategies to alleviate the financial impacts of environmental hazards on portfolios (Andersson

et al., 2016b; Engle et al., 2019; De Jong and Nguyen, 2016). The modification of risk indices serves the purpose of subsequently forming index-tracking portfolios where the invested capital is protected against future negative events following climate change. Andersson et al. (2016b) and De Jong and Nguyen (2016) construct carbon risk indices, and more precisely, measures of low carbon intensity to foster portfolio de-carbonization. These low-carbon indices modify the weighting of index components that exhibit high carbon intensity. The carbon intensity for the portfolios is defined by carbon footprints extracted from the MSCI ESG database (originally collected by the Carbon Disclosure Project) (Andersson et al., 2016b). De Jong and Nguyen (2016) screen and select bonds for two portfolios, a low-carbon portfolio and a regular portfolio, using a technique that tracks corporate bond indices. For the low-carbon index-tracking portfolio, the authors add a specific weighting which is the product of the index weight, duration-times-spread measure and carbon-saving score (inverse of the carbon intensity). The higher the value of the carbon-saving score, the more likely is the bond incorporated into the low carbon portfolio. The portfolio constructed by Andersson et al. (2016b) follows a similar two-step approach to construct the low-carbon portfolio, with the first step being the divestment of stocks with high carbon footprints. Secondly, the authors modify the weighting so that the tracking error with benchmark index decreases. Therewith, Andersson et al. (2016b) and De Jong and Nguyen (2016) construct low-carbon index tracking portfolios and compare the performance to the regular index tracking portfolio performance. The portfolios are analyzed regarding their performance in the period of 2011 to 2014. The outcomes of the studies show that the low-carbon index-tracking portfolios achieve a reduction in carbon emissions of 50 to 60 percent. Both studies find no difference in the return-risk performance for the low-carbon portfolios.

For their part, Engle et al. (2019) consider the possibility of carbon emissions pricing and report an outperformance of the low-carbon portfolio compared to its benchmark. However, Engle et al. (2019) do not construct an index tracking portfolio but an equity portfolio that is simply overweight in companies that positively react to climate change news by increased shareholder value. The authors rely on the assumption that low-carbon stock value increase when news about growing climate risk are announced. For this purpose, the portfolio sorting and

weighting of components follows ESG scores from MSCI and Sustainalytics. The two averaged climate change measuring indices for this analysis are each derived and constructed from Wall Street Journal climate change and Crimson Hexagon negative climate change news articles. The portfolio can successfully hedge climate change news out-of-sample, whereby the portfolio using Sustainalytics ESG scores outperforms the ESG score portfolio from MSCI. This study points out how much the performance of a hedge portfolio depends on the adequate measure of environmental performance.

Georgopoulou et al. (2015) propose a methodological framework as well as tool called "CLIMA-RISK" to quatitatively assess climate risks. However, the authors test their tool only for one Greek bank. Interestingly, as it might potentially affect banks, D'Orazio and Popoyan (2019) address prudential approaches and regulation to incentivize banks in de-carbonization including policies that reduce risks resulting from climate change and other environmental hazards. The so-called "green supporting factors" is a measure to foster lending to green sectors. This factor can be combined with adjustments in the minimum capital adequacy requirement of banks. These measures together can enhance investment in green sectors, as they are perceived less-risky (or de-risking) assets and thus receive lower capital requirements. Similar to the green supporting factor, the "brown penalizing factor" works quite oppositely requiring more capital for assets from carbon-intensive industries. This policy can furthermore cover banks, as the capital can account for more losses in case of a carbon bubble or stranded assets.

Other regulations, such as large exposure limits (e.g. credit limits) and the sectoral leverage ratio, can also contribute to decreasing financial risk. Exposure limits for banks will restrict the maximum amount of losses resulting from counterparty failure which is one of the potential financial risks induced by climate change. The sectoral leverage ratio restricts overleveraged asset positions of specific sectors and can consequently also decrease exposure to climate risks (D'Orazio and Popoyan, 2019).

In summary, the development of climate risk measures can be relevant to investors and analysts, as they see challenges in the assessment of environmental risks. Carbon risk measures such as the carbon beta can be considered in analysts' forecasts, investment and portfolio allocation decisions. However, research on

this topic is scarce and needs to be advanced regarding the assessment of other, non-carbon and non-policy related, hazards as well as quantitative and financial analyses.

5 Looking to the Future

Emerging debates about climate change, policy measures on environmental disclosure, and rising awareness of institutional investors regarding environmental risks have enhanced research on the financial aspects of climate change within the last decade. The results of our systematic literature review thus enable the discussions about the current state of research and challenges of actual approaches for environmental risk assessment as well as the potential aspects of research that need to be addressed in the future.

A series of fundamental research addresses not only positive financial implications through corporate environmental performance, but also the downside of financial impacts for companies if they are exposed to environmental risks. Even though most research does assess market risk, the combination of environmental concerns (instead of environmental engagement) and financial risk is rarely investigated. Additional studies to understand more completely the characteristics of climate-related financial risk are obviously required in order to adequately estimate and assess financial consequences of environmental hazards. Future research can be extended to more directly examine the relationship between environmental concerns and financial risk. Bansal et al. (2016) already started to account for that by investigating the impact of temperature risk on risk premium in equity markets and its impact on equity price elasticity. Moreover, the distribution of returns as already approached by research can be further investigated regarding not only fat tails but also the skewness of distribution. Lastly, research can direct the time horizon of when financial risk of environmental hazards will materialize such as Giglio et al. (2015) who study the impact of physical climate change risk on discount rate of real estate for the long run. It is worth noting that current research can hardly address materialization because it also depends on future developments of political and economic reaction to climate change (Bank of England, 2018; 2° Investing Initiative, 2015).

The literature on current practices of environmental risk management exclusively elaborates quantitative and qualitative interviews. It shows the development from a minor, dispensable role a decade ago to the recognition of relevance and engagement in approaches among investors and analysts in the most recent interview conducted in 2018. However, there is a lack in current research that more directly identifies and evaluates concepts of assessment, tools, and the monitoring process of climate-related risks in financial institutions. This, on the one hand, is driven by banks and their willingness to employ company-wide policies and mechanisms and on the other side, by individual investors, as current approaches depend on their perception of climate risk.

It is equally important to acknowledge that research on environmental risk assessment remains scarce and inconsistent including only few relevant qualitative studies. This aspect of research in general needs to be addressed further by estimating not only measures for risk through carbon emissions but also through other environmental hazards. Measures such as the carbon emissions only capture regulatory sources of risk and less physical sources, even though the latter can harmfully impact the operating and financial performance of firms and pose a severe financial risk to banks. Physical risks of climate change have not been measured on firm-level but could be considered through geographic location of firm buildings to the sea or agricultural land in increasingly drought-affected areas. Carbon intensity measures also lack, as they do not account for different policy risk for countries and sectors, technology advancement or EBIT margins. These factors more specifically capture the sensitivity to legislation and policy action. Moreover, and even though they are found to be employed by investors, stranded assets and assessment through stress testing and scenario analyses have not been considered in the extracted papers of the systematic literature review. This is to be investigated in further research.

Key open questions remain especially with respect to the estimation and accessibility of environmental risk-related data which has not been directly addressed within the three topics due to missing discussion in research. One reason is the magnitude of climate change that is inconceivable and therefore difficult to estimate or model. This includes for example natural disaster probability modelling, water resources, or pollution increase (G20 Green Finance Study Group, 2017). Publicly

available environmental data sets the basis for all further research including the assessment of financial risk and poses a limitation towards the financial sector, as it impairs investors in addressing and pricing environment-driven financial risk. Besides, research must investigate how data on environmental concerns of companies can be disclosed more proficiently and standardized to derive quantitative statements from it and, moreover, what quantitative statements about environmental hazards can impact investment decisions. Both aspects, however, require that there is a comprehensive understanding of scientific environmental data and banks as well as firms are able to define the economic meaning thereof. On another note, additional profound and topical research appears in publications by institutions or initiatives, e.g. Bank of England, Mercer Consulting or the G20 Green Finance Study Group. They also offer practical connections to current practices in the financial sector illustrating the current state of risk assessment approaches and tools implemented (G20 Green Finance Study Group, 2017).

6 Conclusion

The aim of this study is to thematically discuss environmental risk management in the financial service industry. In detail, we examine what impact environmental risks have on the financial performance and on the exposure to financial risk, as well as what approaches are taken to assess these risks.

Besides a theoretical background of environmental risks that contributes to solid understanding and delimitation of environmental risks, the main part of the study provides a broad analysis of the state of research on environmental risk and its assessment. A systematic literature review eventually identified a total of 36 relevant articles. A formal coding then leads to the aggregation and classification of papers to three main categories that consider the impact of environmental concerns on financial performance, the current state of environmental risk practices in the financial sector, and lastly, measures to assess those risks within financial institutions. The final consideration of this work is devoted to the discussion of the results on environmental risk management in the financial sector, focuses on current challenges, and puts forward potential alleys of further research.

The procedure of the systematic literature review in this work is to be reflected critically. By restricting the research to three databases and the exclusive use of English search terms and results, a holistic nature of the investigation cannot be guaranteed. By formulating selection criteria and limiting them to ranked journals, further filtering of the results also eliminated potential research. In order to achieve as holistic a scope of the study as possible, a snowball principle research is carried out in addition to the systematic literature review. In both research processes, the articles of this work are selected by the authors which means that a subjective assessment of the journal articles cannot be ruled out.

Given the speed at which environmental risks have become an important topic, our present research has examined and considered environmental risk and especially its assessment fragmentarily. It is recognizable that research on environmental risk assessment is yet to commence, as the necessity of this subject continuously emerges. This, at the same time, poses opportunities for further research which we suggested in Section 5.

Appendix

No.	Authors (Year)	Title	Journal	Rating
1	Addoum et al. (2019)	Temperature Shocks and Establishment Sales	The Review of Financial Studies, conditionally accepted	A+
2	Alok et al. (2019)	Do Fund Managers Misestimate Climatic Disaster Risk	The Review of Financial Studies, In-principle accepted	A+
3	D'Orazio and Popoyan (2019)	Fostering green investments and tackling climate-related financial risks: Which role for macroprudential policies?	Ecological Economics	B
4	Engle et al. (2019)	Hedging Climate Change News	The Review of Financial Studies, conditionally accepted	A+
5	Görgen et al. (2019)	Carbon Risk	Working Paper	
6	Hong et al. (2019)	Climate risks and market efficiency	Journal of Econometrics	IF 1.9
7	Ilhan et al. (2019a)	Institutional Investors' Views and Preferences on Climate Risk Disclosure	Working Paper	
8	Ilhan et al. (2019b)	Carbon Tail Risk	Working Paper	
9	Krueger et al. (2019)	The Importance of Climate Risks for Institutional Investors	The Review of Financial Studies, conditionally accepted	A+
10	Addoum et al. (2018)	Temperature Shocks and Industry Earnings News	Working Paper	

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11	Delis et al. (2018)	Being Stranded on the Carbon Bubble? Climate Policy Risk and the Pricing of Bank Loans	The Review of Financial Studies, conditionally accepted	A+
12	Eccles and Krzus (2018)	Why companies should report financial risks from climate change	MIT Sloan Management Review	C
13	Huang et al. (2018)	The Impact of Climate Risk on Firm Performance and Financing Choices: an International Comparison	Journal of International Business Studies	A
14	Jung et al. (2018)	Carbon Risk, Carbon Risk Awareness and the Cost of Debt Financing	Journal of Business Ethics	B
15	Nguyen (2018)	Carbon risk and firm performance: Evidence from a quasi-natural experiment	Australian Journal of Management	C
16	Thistlethwaite and Wood (2018)	Insurance and Climate Change Risk Management: Rescaling to Look Beyond the Horizon	British Journal of Management	B
17	Fernando et al. (2017)	Corporate Environmental Policy and Shareholder Value: Following the Smart Money	Journal of Financial and Quantitative Analysis	A
18	Andersson et al. (2016a)	Governance and Climate Change: A Success Story in Mobilizing Investor Support for Corporate Responses to Climate Change	Journal of Applied Corporate Finance	C
19	Andersson et al. (2016b)	Hedging Climate Risk	Financial Analysts Journal	B

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20	De Jong and Nguyen (2016)	Weathered for Climate Risk: A Bond Investment Proposition	Financial Analysts Journal	B
21	Sassen et al. (2016)	Impact of ESG Factors on Firm Risk in Europe	Journal of Business Economics	B
22	Semenova and Hassel (2016)	The Moderating Effects of Environmental Risk of the Industry on the Relationship Between Corporate Environmental and Financial Performance	Journal of Applied Accounting Research	C
23	Verheyden et al. (2016)	ESG for All? The Impact of ESG Screening on Return, Risk, and Diversification	Journal of Applied Corporate Finance	C
24	Georgopoulou et al. (2015)	A Methodological Framework and Tool for Assessing the Climate Change Related Risks in the Banking Sector	Journal of Environmental Planning and Management	C
25	Kim et al. (2015)	The effect of carbon risk on the cost of equity capital	Journal of Cleaner Production	B
26	Muhammad et al. (2015)	The Impact of Corporate Environmental Performance on Market Risk: The Australian Industry Case	Journal of Business Ethics	B
27	Nikolaou et al. (2015)	A system dynamic approach for exploring the effects of climate change risks on firms' economic performance	Journal of Cleaner Production	B
28	Chava (2014)	Environmental Externalities and Cost of Capital	Management Science	A+

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29	Flammer (2013)	Corporate Social Responsibility and Shareholder Reaction: The Environmental Awareness of Investors	Academy of Management Journal	A+
30	Weber (2012)	Environmental Credit Risk Management in Banks and Financial Service Institutions	Business Strategy and the Environment	B
31	Campbell and Slack (2011)	Environmental disclosure and environmental risk: Sceptical attitudes of UK sell-side bank analysts	The British Accounting Review	C
32	Litterman (2011)	Pricing Climate Change Risk Appropriately	Financial Analysts Journal	B
33	Salama et al. (2011)	Does community and environmental responsibility affect firm risk? Evidence from UK panel data 1994-2006	Business Ethics: A European Review	C
34	Solomon et al. (2011)	Private climate change reporting: an emerging discourse of risk and opportunity?	Accounting, Auditing & Accountability Journal	B
35	Sharfman and Fernando (2008)	Environmental Risk Management and the Cost of Capital	Strategic Management Journal	A
36	Weber et al. (2008)	Empirical analysis of the integration of environmental risks into the credit risk management process of European banks	Business Strategy and the Environment	B

Table 2: List of results from the systematic literature research.

ID	Search string	Hits (Engl.)	Hits ($\geq$ 2008)	Hits (Relevant)
EBSCOhost		191	126	45
1	TI (environmental risk∗ OR carbon risk∗ OR climate risk∗ OR ESG risk∗ OR transition risk∗) AND AB (financ∗ OR bank∗ OR investor∗) AND AB approach	27	20	8
2	TI (environmental risk∗ OR carbon risk∗ OR climate risk∗ OR ESG risk∗ OR transition risk∗) AND AB (financ∗ OR bank∗ OR investor∗) AND AB assessment	28	13	3
3	TI (environmental risk∗ OR climate risk∗ OR ESG risk∗ OR transition risk∗) AND AB (financ∗ OR bank∗ OR investor∗) AND AB management	94	60	17
4	TI (environmental risk∗ OR carbon risk∗ OR climate risk∗ OR ESG risk∗ OR transition risk∗) AND AB (financ∗ OR bank∗ OR investor∗) AND AB performance	31	23	12
5	TI (environmental risk∗ OR carbon risk∗ OR climate risk∗ OR ESG risk∗ OR transition risk∗) AND AB (financ∗ OR bank∗ OR investor∗) AND AB pricing	11	10	5
Emerald Insight		20	17	6
6	[Content Item Title: environmental risk∗ OR carbon risk∗ OR climate risk∗ OR ESG risk∗ OR transition risk∗] AND [Abstract: financ∗ OR bank∗ OR investor∗] AND [Abstract: approach]	8	8	2
7	[Content Item Title: environmental risk∗ OR carbon risk∗ OR climate risk∗ OR ESG risk∗ OR transition risk∗] AND [Abstract: financ∗ OR bank∗ OR investor∗] AND [Abstract: assessment]	2	1	0

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8	[Content Item Title: environmental risk∗ OR carbon risk∗ OR climate risk∗ OR ESG risk∗ OR transition risk∗] AND [Abstract: financ∗ OR bank∗ OR investor∗] AND [Abstract: management]	6	4	2
9	[Content Item Title: environmental risk∗ OR carbon risk∗ OR climate risk∗ OR ESG risk∗ OR transition risk∗] AND [Abstract: financ∗ OR bank∗ OR investor∗] AND [Abstract: performance]	3	3	2
10	[Content Item Title: environmental risk∗ OR carbon risk∗ OR climate risk∗ OR ESG risk∗ OR transition risk∗] AND [Abstract: financ∗ OR bank∗ OR investor∗] AND [Abstract: pricing]	1	1	0
ScienceDirect		167	151	13
11	TITLE ((environmental risk∗) OR (carbon risk∗) OR (climate risk∗) OR (ESG risk∗) OR (transition risk∗)) and TITLE-ABSTR-KEY (((financial) OR (finance) OR (bank) OR (banking) OR (investor)) AND (approach))	23	22	3
12	TITLE ((environmental risk∗) OR (carbon risk∗) OR (climate risk∗) OR (ESG risk∗) OR (transition risk∗)) and TITLE-ABSTR-KEY (((financial) OR (finance) OR (bank) OR (banking) OR (investor)) AND (assessment))	31	25	2
13	TITLE ((environmental risk∗) OR (carbon risk∗) OR (climate risk∗) OR (ESG risk∗) OR (transition risk∗)) and TITLE-ABSTR-KEY (((financial) OR (finance) OR (bank) OR (banking) OR (investor)) AND (management))	44	41	5
14	TITLE ((environmental risk∗) OR (carbon risk∗) OR (climate risk∗) OR (ESG risk∗) OR (transition risk∗)) and TITLE-ABSTR-KEY (((financial) OR (finance) OR (bank) OR (banking) OR (investor)) AND (performance))	14	12	3

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15	TITLE ((environmental risk∗) OR (carbon risk∗) OR (climate risk∗) OR (ESG risk∗) OR (transition risk∗)) and TITLE-ABSTR-KEY (((financial) OR (finance) OR (bank) OR (banking) OR (investor)) AND (pricing))	25	22	0
Sum in total		378	296	64
Sum in total (without duplication)				35
Sum in total (without duplication, VHB rating C+)				19

Table 3: Overview of search results per database and search string (Accessed: May 30, 2019).

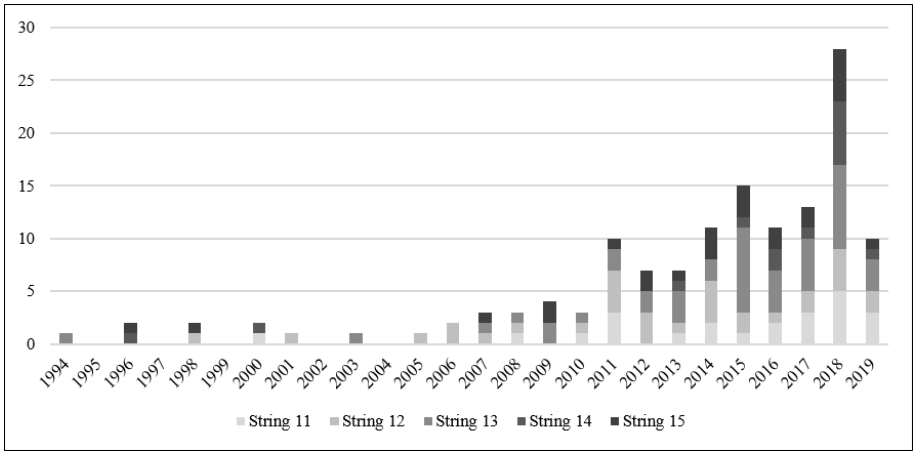

Fig. 6: Historic classification of search results through ScienceDirect database (search strings 11-15).

ID	Authors (Year)	Access	Rating	References
1	Ilhan et al. (2019a)	Yes	–	2, 3
2	Solomon et al. (2011)	Yes	B	–
3	Ilhan et al. (2019b)	Yes	–	4, 7, 12
4	Görgen et al. (2019)	Yes	–	5, 6, 7, 8, 9, 10, 11
5	Barnett et al. (2019)[5]	**No**	A+	–
6	Chava (2014)	Yes	A+	19
7	Delis et al. (2018)	Yes	A+	–
8	Engle et al. (2019)	Yes	A+	–
9	Fernando et al. (2017)	Yes	A	–
10	Flammer (2013)	Yes	A+	–
11	Krueger et al. (2019)	Yes	A+	5, 6, 9, 12, 13, 14[6], 15, 16, 17, 18, 19, 20
12	Andersson et al. (2016b)	Yes	B	–
13	Andersson et al. (2016a)	Yes	C	12
14	Addoum et al. (2019)	Yes	A+	–
15	Addoum et al. (2018)	Yes	–	–
16	Eccles and Krzus (2018)	Yes	C	–
17	Alok et al. (2019)	Yes	A+	18
18	Hong et al. (2019)	Yes	–	–
19	Litterman (2011)	Yes	B	–
20	Sharfman and Fernando (2008)	Yes	A	–

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[5] Barnett, M., Brock, W.A., and Hansen, L.P. (2019). Pricing Uncertainty Induced by Climate Change. Conditionally accepted at the Review of Financial Studies (Special Issue on Climate Finance).

[6] The paper referenced in Krueger et al. (2019) has been split into the two publications, namely Addoum et al. (2019) and Addoum et al. (2018).

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Table 4: Snowball principle literature overview.

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