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Sustainable finance:
A journey toward ESG and climate risk

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April 26, 2022

Abstract

The present paper proposes an overview of the existing literature covering several aspects related to environmental, social, and governance (ESG) factors. Specifically, we consider studies describing and evaluating ESG methodologies and those studying the impact of ESG on credit risk, debt and equity costs, or sovereign bonds. We further expand the topic of ESG research by including the strand of the literature focusing on the impact of climate change on financial stability, thus allowing us to also consider the most recent research on the impact of climate change on portfolio management.

Keywords: Environmental, social, and governance factors (ESG); credit risk; debt cost; equity cost; sovereign bonds; portfolio management

JEL Classification: M14, G24, G11

1   Introduction

The concept of socially responsible investment (SRI), also known under the more recent concept of environmental, social, and governance (ESG) factors, has existed since the 1920s. However, it has recently gained increased relevance due to several cases of poorly managed ESG issues. Indeed, the 2010 *Deepwater Horizon* oil spill, the increased occurrence of extreme weather events in many countries, the poor working conditions observed in production outsourcing in developing countries, the 2008 economic crisis, and the COVID-19 pandemic have revealed key limitations of the production process and the overall functioning of the global economy. These events have led to a widespread questioning of the generally acknowledged paradigm at different levels of society: policy makers, investors, and so on. As a consequence, ESG issues have experienced a considerable surge of interest and become a general concern rather than a niche investment practice. In response, a new segment of rating agencies has started developing, with even the big three credit rating agencies (Moody's, Standard & Poor's (S&P), Fitch) starting, after a certain delay, including ESG evaluations in their ratings. In 2018, the European Commission's Action Plan on Sustainable Finance announced the introduction of a regulation on disclosures. This regulation,the Sustainable Finance Disclosure Regulation (SFDR), entered into force in March 2021 and has a direct impact on companies and their investors through their obligation to integrate ESG factors into their investment decisions and their non-financial reporting. According to the SFDR, companies have to consider integrating 50 sustainability measures, of which 30 are mandatory. More specifically, the environmental pillar encompasses several criteria related to companies' environmental footprint (greenhouse gas emissions (GHGs), water and energy efficiency, waste treatment, renewable energy use, etc.)). The social pillar involves considerations related to both customers and employees (access to employment equality and gender diversity, employee training and development, employee health and safety, human rights, product safety concerns and liability, supply chain transparency). Finally, the governance pillar encompasses criteria reflecting a company's governance structure and efficiency (compensation of employees and board executives, board and company diversity, bribery

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and corruption, transparency and anti-corruption, fraud, shareholder rights).

As part of this growing interest, a wide variety of ESG literature featuring a multitude of studies has arisen. The most common topics are related to the rating methodology used and the impact of ESG matters on companies' profitability and financial performance. Even though a significant part of the literature is focuses on the ESG relevance for financial performance, in the last two years a considerable number of studies have focused on the impact of ESG on credit risk, expressed in terms of credit ratings, credit default swap prices, bond returns and defaults, cost of equity and debt and, and so on.

Nevertheless, all these studies are based on ESG data assessed differently, based on to the chosen data provider and ESG rating agency. Indeed, the evaluation methodology differs considerably among ESG raters. The divergence is expressed not only through the selection of different criteria and the use of different sources but also through the varying weight given to each pillar or the inclusion or exclusion of a given pillar.

For this reason, the present literature review focuses first on the description and comparison of the approaches chosen by the rating agencies (Section 2). The second step considers the literature exploring the relation between ESG issues and credit risk (Section 3). Section 4 is dedicated to the environmental pillar and more specifically to the financial implications of climate change through its impact on financial stability and portfolio performance. Finally, we provide in the complementary material a detailed taxonomy of the literature review.

2 The specifics of the ESG rating market

The ESG market has undergone important changes during the last decade. This section describes the market's features to understand the large variety of rating approaches. Given the inherent link between the methodology applied and the rating obtained, on which investment and organizational decisions will be based, it is essential to understand their functioning before assessing the impact of ESG issues on companies' profitability and credit risk.

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The first subsection summarizes not only the concentration process that has been observed among ESG data providers but also evolution of the criteria applied. The second subsection is dedicated to a brief description of assessment challenges related to non-financial reporting. The third and final section completes the overview through a comparison of the methodologies used by raters.

2.1 The sector of ESG rating agencies and its evolution

The ESG rating agency sector has evolved considerably in the last decade.Considerable concentration has occurred, whether through merger and acquisition (M&A) strategies or partnerships. The major historical ESG data providers are: MSCI ESG, Sustainalytics, Vigeo Eiris, ISS-oekom, Bloomberg, Refinitiv (Thomson Reuters), S&P (dba RobecoSAM), and FTSE Russell. Figure 1 shows the most important M&A activities in the past decade. Concurrently, the "Big Three" rating agencies (Moody's, Fitch, and S&P) have entered the market after a certain delay; as highlighted by Figure 1, they soon consolidated their presence.

<div align="center">INSERT FIGURE 1 HERE</div>

Within the ESG investment framework, it is essential to acknowledge that choosing a specific index as a benchmark also means choosing a specific methodology of and approach to ESG selection. Behind the development of a sustainability index, there is a long research process aiming to identify, measure, and classify hundreds of quantitative and qualitative metrics among a wide range of products. The rating agencies have specialized in working either independently or in partnership with the companies which provide indices. Given the complexity of this analysis, the multitude of approaches, and the different types of information systems among rating agencies, it would not be surprising if the sustainability ratings ultimately obtained varied. In order to meet the market's needs and deliver the most reliable output possible that is coherent with current norms, ESG raters have been forced to change their analytical methodology several times during the past decade. Hence, in a first step, it might be useful to understand the

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evolution and scope of the assessment process and its scope during that period. Analysing the information disclosed by ESG rating agencies in 2008 and 2018, Escrig-Olmedo et al. (2019) found that the integration of ESG criteria changed significantly in that period. Specifically, ESG rating agencies show a greater interest in environmental concerns today than 10 years ago. Indeed, by 2018, environmental assessment has been complemented by the inclusion of new criteria, especially regarding climate change. These more accurate measures allow for a better understanding and evaluation of their potential impacts on companies' performances and risks. For instance, Ganda and Milondzo (2018) demonstrated a negative relationship between carbon emissions and corporate financial performance for 63 South African Carbon Disclosure Product (CDP) companies. Concerning the social dimension, even though some aspects remain almost the same, attention to stakeholder engagement, labour management, and human rights has increased. Another aspect highlighted by Escrig-Olmedo et al. (2019) concerns the recent inclusion of privacy and data security and supply chain management. According to them, these criteria reflect the necessity to consider companies as integrated productive structures instead of independent and isolated organizations. Unlike the first two spheres, the corporate governance criteria have not changed that much. The corporate governance function and committees and board structure remain the main aspects on which raters screen for governance. However, increasing attention to transparency and the prevention of corruption and bribery underline a significant change; they are now are the second and the third most analysed aspects, respectively.

The evolution described above, demonstrates the attempts of ESG rating providers to adapt to the new global challenges through the integration of relevant criteria and anticipates a concept now known as dynamic materiality[1]. The growing attention to anti-competitive practices and antitrust policies suggests that the ESG factors will be included as a risk factor in financial analysis more frequently. The observed changes are related to the evolution of: sustainability data availability, corporate management targets, and normative regulation. More precisely, the constituents of ESG indices tend to adapt

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[1]For more information and definition see Section 2.3

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to the reference universe. Therefore, even if ESG indices are used in the context of passive management, ESG investments are considered semi-active since their composition, in respect to traditional indices, generates tracking errors and changes as the sustainability ratings assigned to companies change.

2.2 ESG assessment challenges: Managing non-financial reporting and major ESG reporting frameworks

Given the rapidly-evolving sectoral specificities, it is not surprising that many investors complain that the ESG data universe is complex and confusing. Whereas international accounting standards define companies' disclosure of financial information, non-financial data, such as ESG information, remained unorganized until recently. For this reason, some organizations have committed themselves to the explicit goal of standardizing non-financial reporting. Indeed, six major ESG reporting frameworks have been created to guide ESG disclosures. They are commonly known by their acronyms: GRI, CDP, CDSB IIRC, SASB, and TCFD.

Historically, the Global Reporting Initiative (GRI) was launched in 1997 as the first global corporate sustainability reporting framework setting standards for environmental factors disclosures. Later, standards on social factors were added, along with specific governance factors. GRI targets ESG issues that might be relevant to a large variety of stakeholders, not only investors and companies. Therefore, the encompassed factors go beyond purely financial relevance. Thus, GRI is the best-known and most widely adopted global standard for sustainability reporting. In 2002, the CDP was launched as a not-for-profit charity. CDP has developed a disclosure system based on the CDP questionnaire, which investors, companies, cities, states, and regions can complete through several platforms: CDP Climate, CDP Water, CDP Supply Chain, and CDP Forests. While CDP provides a framework dedicated mainly to collecting data for reporting, the Climate Disclosure Standards Board (CDSB) aims to integrate climate change-related disclosure into mainstream financial reports such as annual reports and 10-K filings. The International Integrated Reporting Council (IIRC) was created in 2010

to oversee the creation of a globally accepted integrated reporting framework. IIRC promotes better communication between various groups, organizations, and businesses to provide useful insights to investors. In 2011, an industry-specific standards framework was created in the form of the Sustainability Accounting Standards Board (SASB). This non-profit organization aims to provide standards for sustainability information of financial materiality to investors. The SASB Materiality Map identifies sustainability issues "that are likely to affect the financial condition or operating performance of companies within an industry". Hence, on their website, one may evaluate the incidence of a different dimension, divided by sub-category, inside a given industry[2].

The most recently created framework is the Task Force on Climate-related Financial Disclosures (TCFD) launched in 2015 by the Financial Stability Board. Its primary purpose is to help identify appropriate climate risk and opportunity information for investors, lenders, and insurance underwriters. Therefore, it covers only the environmental aspects of ESG and proposes a generic type of voluntary disclosure that could be applied to a large variety of companies across the world.

Despite these signs of progress, there are still no globally accepted standards that enable a univocal judgment of corporate sustainability. Today, most ESG assessments differ widely in terms of measured indicators, methodologies, and the weights applied to different criteria. An ESG rating provider should also consider the industry and location where a given company operates. Industry specifics are key to the weighting process. For instance, the environmental sphere would be less critical for the bank sector than for the mining industry. For the same reason, the social criteria would be more heavily weighted for the pharmaceutical industry, while for the bank and finance sectors, governance criteria would be most relevant. Thus, the financial materiality issue seems nothing less than urgent. Table 1 summarizes the details of the four main reporting frameworks.

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GRI, IIRC, and SASB are the most referenced frameworks in stock exchange ESG

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[2]In June 2021, the IIRC and SASB merged to form the Value Reporting Foundation.

guidance, while TCFD is among those less frequently consulted (Figure 2).

<div align="center">INSERT FIGURE 2 HERE</div>

Given the large variety of existing disclosure standards' frameworks and financial materiality approaches, the European Commission in 2018 launched, the European Commission's Action Plan on Sustainable Finance, which aimed to introduce an EU regulation on disclosures. The SFDR entered into force in March 2021 and establishes the obligation for companies and investors to include ESG factors relevant to their activities into their investment decisions and non-financial reporting. Although more organizations are committing themselves to the explicit goal to standardize non-financial reporting, the ecosystem of organizations that provide ESG data remains vast and in disagreement on some issues. At present, various agencies provide ratings, each with a different scope and focus, based on unique assessment procedures Even though all agencies base their analysis on a two-dimensional materiality framework that evaluates a company's exposure to a given ESG risk and management's reaction to that this risk, the methodologies used to evaluate the performance of a given company differ widely (Billio et al., 2021). The first difference is related to sources of information. The most common channels of information are sustainability reports provided by external consulting companies or from the company itself and data from non-governmental (NGO) datasets. Other information sources are surveys such as interviews of company personnel and other stakeholders. Some agencies use only the first or the second type of source or a combination of both. Finally, all agencies have developed their own assessment methodology based on their own definition of ESG materiality. These several differences thus contribute to the divergence of the final ratings and frequently observed heterogeneity.

2.3   ESG materiality: Definition and current evolutions

In the vast development of ESG and sustainability information public disclosure, investors and companies face not only difficulties related to understanding the underlying rating processes but also difficulties in identifying the information most pertinent to their decisions.

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As a result, the concept of materiality specific to English common law, has emerged as an essential tool for ESG raters, as it refers to all relevant and non-negligible information. Indeed, it was introduced by GRI in 2006 in their G3 Guidelines, which represent the basis of the GRI Sustainability Reporting Framework. In general, materiality in the ESG field corresponds to all factors that might have a relevant impact on the financial situation of a company in a given industrial sector. However, many definitions of materiality have been proposed by regulators, standard-setting institutions, and investors.

Despite their differences, these definitions share two major perspectives: the first focuses on the impacts of the environment and society on stakeholders, while the second focuses on their relevance for the organization or company under consideration. Thus, two major types of materiality can be identified: one relevant to the financial performance of a company (essential for investors) and one relevant to the general image and condition of a company (important not only for investors but also civil society, employees, and consumers).

In order to capture this dual role, the non-financial reporting directive (European Parliament and Council (2014)), Directive 2014/95/EU, focusing only on environmental and climate change factors, proposed a definition of "double materiality". More precisely, the first type of materiality targets the potential and current impacts of climate risks on the "performance, development and position" of the company (financial relevance). The second type concerns the "external impacts of the company's activities" and thus represents "environmental and social materiality".

Furthermore, as stressed by the Directive 2014/95/EU, the notion of materiality can evolve over time and with changing economic and societal conditions. In a nutshell, conditions that currently do not appear financially material, can prove relevant in that regard in the future. This situation corresponds to the concept of dynamic materiality, made popular by the World Economic Forum 2020. Given the diverging views on financial materiality, the OECD advises in "*ESG Investing: Practices, Progress and Challenges*" (2020) that investors and companies should consider materiality from the perspective of systemic issues. As such, the TCFD and the UN Sustainable Development

Goal (SDG) recommendations might be particularly insightful, according to the OECD, as they allow for a certain degree of freedom for companies disclosing standardized ESG information. However, another key aspect of materiality relates to its unique character. Indeed, materiality is specific to each company and its context at a given time. Therefore, the consideration of industry-specific standards enables coverage of all these individual characteristics. As such, the role played by the SASB is of crucial importance, given the definition of standards identifying the most important issues for companies' financial performance in 77 industries. Indeed, the SASB Materiality Map enables the identification of all ESG and sustainability issues that might affect companies' financial conditions and operational performance, which are also the most relevant for investors.

2.4 Comparison of ESG rating methodologies

As discussed in the three previous sections, ESG disclosure standards and rating methodologies vary considerably. Table 2 presents a schematic summary of the major differences among the ESG rating approaches. In this section, we focus on a more detailed description of the specifics of the best-known ESG raters. In an effort to provide a comprehensive overview of the existing approaches, we describe the rating approaches of the "traditional" ESG raters (MSCI, Vigeo EIRIS, Thomson Reuter Refinitiv, Sustainalytics, ISS-oekom, RobecoSAM, ECPI, Bloomberg and FTSE Russell), followed by the approaches used by the Big Three (S&P, Moody's, and Fitch). We choose this more detailed approach (even though the operating market actors have recently consolidated their presence to a significant extent), as it allows for a comprehensive understanding of the underlying details that help explain the disagreement among ESG raters and that can affect investors' decisions and the outcomes of scholarship on the topic. Therefore, we also include a discussion of the academic studies evaluating and comparing the ESG rating methodologies that have been implemented.

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2.4.1 How agencies judge corporates

Table 2 presents selected differences regarding the methodologies applied by nine ESG rating providers. This analysis includes the most relevant agencies in the market before its consolidation in 2020. All the information has been obtained from the organizations' websites. The goal of this comparison is to check whether the agencies converge in methodology and the types of information that the ratings disclose.

a. MSCI

MSCI's ESG experience started in 2010, when they purchased Riskmetriccs[3]. Their rating framework was created to identify the most significant ESG risks and opportunities a company faces in the context of its industry or sector.. The rating also considers the degree to which a company is exposed to those key risks and opportunities. Before any analysis, a data point on ESG policies is collected from different sources. MSCI uses publicly available data from three information channels: (i) macro data from NGO datasets, government, and academia (e.g., World Bank and Transparency International); (ii) company disclosure (e.g., sustainability reports and proxy reports); and (iii) government databases, including more than 1600 media sources monitored daily.

In their rating methodology, the three pillars encompass 10 major topics: climate change, natural resources, pollute & waste, environmental opportunities, human capital, product liability, stakeholder opposition, social opportunities, corporate governance and corporate behavior.Each topic is comprised of industry-specific factors. However, given the universal relevance of corporate governance practices regardless of industry, the major factors providing information on board, payment, ownership, and accounting details are always integrated. To evaluate risks and potential ongoing costs for a company, MSCI assesses of both exposure and management metrics. These measures are computed after a meticulous investigation that also takes into account the exposure towards ESG risk and the extent to which a company has developed strategies for managing its specific risk and opportunity. Thus, even if ESG key issues are standardized for each industry, there are company-specific adjustments, and the risk is measured based on the exposures

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[3]Riskmetriccs had acquired Innovest and KDL, two pioneers of ESG research, in 2009.

a company faces in terms of the location(s) of its operations, its core product or business segment, and its reliance on government contracts. The risk exposures for each pillar are then scored on a scale from zero to 10. Once each pillar has received a score, the ESG rating model uses a weighted average approach to reach a final score, which is finally adjusted for the industry.

Using a similar methodology, opportunities are also integrated into the score. They represent the ESG-related possibilities and capacities of a company to increase its profits. Thus, the exposure and management metrics concern the opportunities' relevance for a company and its management's ability to benefit from those opportunities Companies are also monitored daily for controversies that may indicate structural problems and undergo an in-depth quality review process annually. The final score is expressed in letters from AAA (top score) to CCC (lower score).

The ratings offered cover 7,500 companies and 13,500 total issuers (including affiliated companies). MSCI allows firms to review their ratings and potentially provide further information on their ESG activities.

b. Vigeo EIRIS

Vigeo and EIRIS merged in 2005. Vigeo was founded in France in 2002, while EIRIS was created in 1983 by charities who set up a foundation to fund research to fund sustainable investment opportunities. Since its merger, Vigeo Eiris offers a wide range of services regarding responsible investments. In order to evaluate a company, its research is divided into three domains (E, S, and G) which include 38 generic sustainability criteria based on international standards.

Three factors that vary according to their relevance comprise the weighting criteria. The first looks at the nature of stakeholders' rights, interests, and expectations. The second evaluates the sectorial vulnerability of stakeholders, while the last one is centred on the risk categories for the company (human capital cohesion, reputation, legal risk, operational efficiency).

Vigeo Eiris respects the double materiality definition recommended by the European non-financial reporting directive, as it enables measuring not only the ESG risk

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management capacity of a company but also other potential sustainability impacts.

Concretely, 250 indicators are used to assess the managerial system capacities of evaluated companies. Ratings can also be provided at a sectoral level as 40 industry-specific models have been developed. In general, the rating is organized in four major steps: the generation of the ESG criteria level weighting, the E-S-G scoring, which is adjusted by "controversy monitoring and alerts" to obtain the overall ESG score, and at last the risk mitigation index.

The risk mitigation scores are separate from the first three steps of rating, as they focus on the capacity of a company to properly manage ESG factors influencing the four major types of identified risks: operational efficiency, legal risk, reputation and human capital.

A score of "$--$" is assigned to the worst-performing companies while a score of "$++$" is assigned to those companies which fully integrate social responsibility issues into their managerial system.

In 2019, Vigeo Eiris was acquired by Moody's. It is still headquartered in Paris and, although it is a Moody's affiliate, it continues to operate under the Vigeo Eiris brand.

c. Thomson Reuter Refinitiv

Thomson Reuter Refinitiv provides a variety of ways to access its ESG information. This provider is also the result of a series of M&A activities (from Asset4 in 2009 to Refinitiv in 2019). The indices they offer are known as the Thomson Reuters ESG family. Its ESG dataset cover 7,000 public companies globally. To assess companies, they use 400 different ESG metrics (organized within 10 major topics) combining ESG scores with ESG controversies scores.

The data used are publicly available: annual reports, NGO information, corporate social responsibility (CSR) reports, news and etc. Ratings use a 12 point scale, and companies are ranked from D- to A+. Two ESG scores are offered: one evaluating the ESG performance of a company (ESG score) and a second one adjusted for observed controversies (23 controversial topics are considered and an industry-specific benchmark applied) and called the ESG combined score. Historical data series are available from

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2002 for around 1,000 European and American companies.

d. Sustainalytics

Sustainalytics resulted from the merger between SiRi Company (Switzerland), DSR (the Netherlands) and Scoris (Germany) in 2008. In 2020, it was acquired by Morningstar. The approach used by Sustainalytics comprises three central blocks: corporate governance, material ESG issues, and idiosyncratic issues. ESG ratings are assigned to one of five risk levels based on severity

After having examined the exposure to each material ESG issue (ratings concern not only the risk management capacity of a given company but also its risk exposure), Sustainalytics pays particular attention to the management dimension, which involves a financial materiality approach to ESG factors.

As to the results, 20 major factors are considered, without sharp boundaries between E, S, and G pillars. For those companies which may have unmanageable risk (e.g. a coal-dependent company), that risk is factored out. Sustainalytics discounts the effect of controversies as they show that a company's policies have not been effective. Finally, the unmanaged risk for each material ESG issue is added to the overall company's ESG risk rating. Companies are ranked from 0 to 100, with 100 indicating a high level of ESG risk and 0 the absence of ESG risk.

e. ISS-oekom

Oekom was founded in 1993 in Munich, Germany; before its 2018 merger with the American Institutional Shareholder Services group (ISS), it advised more than 180 financial services companies, ethical banks, and institutional investors collectively holding more than €1.5 trillion in assets. Oekom represented one of the environmental and social rating pioneers in both Germany and Europe, as they evaluated 3,800 companies and specialized in a wide variety of responsible investment solutions and services (selection of securities for mutual funds and segregated accounts).

ISS was founded in 1985 and was previously part of MSCI. It is among the leading actors providing corporate governance and responsible investment (RI) solutions. Before

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acquiring Oekom, it started expanding its expertise in the ESG field through the 2015 acquisition of Ethix SRI Advisors and by forming a strategic partnership with RepRisk. In 2020, Deutsche Börse (the German stock exchange operator) acquired 80

Three types of ESG products and services are offered: ISS-Oekom corporate ratings, ISS QualityScore, and ISS-Ethix's NBR. While the first evaluates the capacity of firms to manage ESG risks and integrate ESG opportunities, the second focuses on the disclosure practices of companies among a variety of industrial sectors (reporting frameworks such as SASB or GRI are used), and the third aims to capture any reputational and potential long-term risks related to company's investments.

For corporate ratings, ISS-oekom uses a twelve-point scale ranging from D- to A+. The evaluation is based on a varying selection of 100 criteria (out of 800 industry-specific criteria) representing environmental factors and combined social and governance factors. In addition, there are 30 cross-sectional ESG topics, such as climate change strategy or business ethics. The weighting procedure is industry specific and depends on international norms and conventions, social debate, regulatory changes, and technological progress. Controversies are also integrated, but on a case-by-case basis and are categorized according to the company's responsibility and the severity of the controversy. Sin stocks are also considered. The rating obtained is communicated to the concerned company, whose feedback contributes to the final rating.

f. RobecoSAM

Created in 1999, RobecoSAM is currently a sustainability investing asset manager with more than US$120 billion in asset under management.Its website reports that "RobecoSAM's research focuses on the link between sustainability and financial materialit". Intangible factors must have an impact on a company's core business value to be defined as financially material. The approach toward ESG issues at RobecoSAM is articulated from a long-term perspective and is based on a questionnaire that is modified annually and reviewed externally.. Every year, more than 3,500 companies are complete the updated questionnaire updated questionnaire and thus to contribute to their corporate sustainability assessment (CSA).

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The criteria used to determine the impact rating are mostly related to the company's reputation. In evaluating the company's response to a situation, RobecoSAM's "goal is to assess whether the communication is timely and useful to understand the company's position and action". In order to reach a final score, each criterion and score is adjusted by a multiplier. The reliability of this provider's results are bolstered by the systematic updating of the ratings that take place periodically.

The analysis is divided into three dimensions: economic, environmental, and social. The first focuses more on aspects which may affect the health of a corporation, such as cybersecurity, corporate governance, innovation management, market opportunity, and anti-crime policy. The environmental dimension measures the management of the risk that may arise once the impact of corporate activity on the environment has been observed. It includes criteria such as climate strategy, biodiversity, and electricity generation. The social dimension is assessed by criteria like health outcome distribution, human rights, social reporting, and talent attraction and retention.

The insights are used for internal investment decisions and to create indices like the Dow Jones Sustainability Indices (DJSI). The number of companies analysed is currently 4,500. Since December 2019, RobecoSAM's ESG ratings and benchmarking are part of S&P.

g. ECPI

ECPI uses a twofold methodological framework: it considers an environmental dimension and an aggregate of social factors and corporate governance. Each section is divided into four categories, which in turn are divided into micro-aspects that produce different indicators. In total, ECPI evaluates more than 100 indicators: "a company must be assessed against all the ESG categories and aspects in order to achieve the final ESG score and rating". The overall rating is thus the sum of the scores form each indicator. The information sources include sustainability reports, annual reports, and company websites.

h. Bloomberg

In 2009, Bloomberg launched Bloomberg ESG Data Service after acquiring New Energy Finance to provide renewable energy and carbon market data. For its ESG rating, Bloomberg gathers publicly available data disclosed by companies through CSR or other sustainability reports, websites, and son on, but it also makes direct contact with the companies it assesses.. If data are missing, a penalty might be applied to the score (Comstock and Huber, 2017). All data abtained are verified and standardized. The analysis is performed through the assessment of 120 environmental, social, and governance indicators, with scores ranging from zero to 100.. As in the case of Refinitiv, both historical data series (up to 10 years) and peer comparisons are available. Bloomberg also provides the ESG scores defined by third-party rating agencies such as: RobecoSAM, Sustainalytics Rank, ISS Quality Score, and CDP Climate Disclosure Score.

i. FTSE RUSSELL

FTSE Group was launched in 1995 and is a subsidiary of the London Stock Exchange Group (LSEG) after having started as a joint venture between the *Financial Times* and the London Stock Exchange. In 2014, LSEG acquired Frank Russell Company to create FTSE Russell. Launched in 2001, the FTSE4Good Index represented a series of ethical investment stock market indices. Today, the ESG ratings are incorporated into the FTSE All-World Index, FTSE All-Share Index and Russell 1000 Index. Evaluations are based on publicly available data that are assigned to more than 300 individual indicators, organized into 14 ESG scoring themes aligned with the SDGs, and assigned to one of three pillars: governance, supply chain environment, and supply chain social factors. ESG ratings are calculated using an exposure-weighted average, so that the most material ESG issues have the greatest weights in a company's score. This methodology enables assessment to be adapted to each company's specific context. The exposure-weighted average is applied at both the pillar and theme levels. The rating scale goes from zero to five, with five being the highest score. The ESG data model incorporates TCFD recommendations and is supervised by an independent external committee composed of investment experts, businesses, NGOs, unions, and academics. Companies are involved through the completion of a questionnaire.

From this initial review, it is clear that the agencies use different approaches to measure a company's sustainability. Even though there are similarities, particularly the use of a three-pillar approach, some pillars differ among rating agencies (economic pillar instead of governance pillar for RobecoSAM, a combined Social and Governance pillar for ECPI, and cross-sectional ESG topics for ISS-oekom and Sustainalytics). In addition, even if most raters rely largely on publicly available data, some base their ratings on industry questionnaires (RobecoSAM) or on information directly obtained from companies (Bloomberg, MSCI). Most integrate industry specifics into their assessments and divide risk evaluation into risk management and risk exposure; however, they apply different weights to each. Finally, most rating providers include controversy evaluations to adjust the scores, but the methodology applied differs significantly, as do the rating scores. In the next subsection, we focus on the academic literature studying the topic and offer a summary of the major findings.

2.4.2 Literature review comparing ESG rating methodologies

The present section focuses on verifying and evaluating the potential disagreements among ESG raters. Having compared the concrete methodological aspects above, we offer a brief overview of the relevant literature and the major conclusions.

One of the first studies on this topic was proposed by Daines et al. (2010). Following the subprime crisis, the authors investigated only the consistency of governance practices. Through descriptive statistical techniques, logistic regression and ordinary least squares (OLS) analyses applied to a sample of 6,827 companies evaluated by three primary corporate governance rating firms (ISS Corporate Governance Quotient (CGQ), Governance Metrics International (GMI), and The Corporate Library's TCL rating) during the 2005–2007 period, they found a large heterogeneity among raters' grades of the same company.They also observed that commercial ratings did not accurately predict governance-related outcomes.

Another study focusing on the crisis period was published by Escrig-Olmedo et al. (2010). The authors included all three pillars in their examination and reminded

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readers of the importance of relevant ESG ratings for encouraging the implementation of responsible corporate policies. With that aim, the authors propose an overview of the European and American ESG markets through the comparison of six sustainable indexes and 10 ESG rating providers for the period from September 2007 to February 2009. They proceed to a comparison of the applied screening criteria, the international standards used, the scoring systems, the services offered by the ESG agencies, and the investment risk. The major findings of their qualitative evaluation stressed the total absence of a standard methodology, the presence of different weightings of the analysed criteria, and the existence of different combinations of positive and negative criteria, different scoring systems, and different risk measurements.

A largely regional study was undertaken by Stubbs and Rogers (2013), based on data provided by Regnan, an Australian ESG ratings provider. The authors noted the lack of transparency of the rating methods and therefore the risks in terms of subjectivity. According to them, ESG factors can account for up to 66% of globally listed companies' market value, and a better knowledge of ESG assessment specifics can contribute to both increased investor' confidence in ESG ratings and the greater involvement of companies.

Chatterji et al. (2016) expanded the sample by considering a longer statistical period (2002–2010) and a greater number of ESG rating providers. They attempted to evaluate the degree of convergence in ESG ratings by comparing six rating providers operating in Canada, the United States, and the European Union at different time periods between 2002 and 2010, based on data availability.. Using overlaps between SRI raters' indexes, pairwise tetrachoric correlations, and pairwise Spearman correlations on overlapping universes, they concluded that there was a clear lack of agreement among the considered raters. Moreover, the observed differences remained even after the adjustment for explicit differences in CSR definitions. As a consequence, they expressed some doubts on the validity of the ratings; given their relevance for appropriate investment decisions, the authors suggested the need for regular evaluations of CSR ratings.

Semenova and Hassel (2015) focused their investigation on the validity of environmental performance measures. They focused on two separate sets of companies:

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one including 466 US MSCI World companies and another one encompassing 113 companies from high-risk industries and 124 companies from low-risk industries. Both samples were used for Pearson and Spearman correlation analyses and univariate tests (t-test; Wilcoxon rank-sum test) performed for the the 2003–2011 period, with data obtained from three ESG data providers (MSCI ESG STATS, Thomson Reuters ASSET4, and Global Engagement Services). The results show that while ratings have common dimensions, on aggregate, they do not appear to converge. Furthermore, according to the authors, using ratings as proxies for environmental performance can mask underlying associations between variables and lead to inaccurate interpretations of the relationships observed.

The major purpose of Hussain et al. (2018) was to analyse the benefits of more sustainable behaviour, but they also provided some evidence on the relevance of ESG indicators. The authors considered 44 companies selected from *Fortune's* Global 100 best-performing US firms and operating in 12 different industries. The time frame of the study runs from 2007 to 2011, using data gathered from 152 sustainability reports obtained from Bloomberg, companies' websites, and corporate register websites. In terms of methodology, the authors applied manual content analysis techniques and panel regressions. Among their findings, they stressed the existence of weak and contradictory linkages between different sustainability performance dimensions. Furthermore, they highlighted that ESG indicators are not appropriate tools for analysing firms' behaviour as they do not capture companies' sustainable efforts in terms of performance criteria.

Escrig-Olmedo et al. (2019) provided an assessment of the American and European markets through a comparison of eight ESG rating providers between 2008 and 2018. Through a thematic content analysis of the common specific criteria, they found a large heterogeneity among CSR components and their relevance. Furthermore, ESG rating agencies apparently did not fully integrate sustainability principles into their corporate sustainability assessment processes. Even though Escrig-Olmedo et al. (2019) focused on several limited cases that do not permit covering all the specifics of ESG rating agencies, and despite the rapidly evolving market sector, their findings confirmed the

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lack of transparency and commensurability of the evaluating criteria.

Berg et al. (2019) focused on the divergence among ESG ratings through an analysis of the methodologies of 6 ESG rating agencies methodologies operating in the United States and European Union.. They began by offering a measurement of the observed divergence through three different approaches: Pearson correlations between ESG ratings and between ESG components (evaluating the level of disagreement), mean absolute distance (MAD, assessing the heterogeneity in the disagreement across companies), and quantile analysis (illustrating the level of disagreement among rankings). To compare the ESG ratings more efficiently, the authors developed a common taxonomy and performed correlation test category scores (to evaluate measurement divergence) and non-negative least square regressions (to assess weights divergence). Based on all these comparisons, they found evidence for clear discrepancies in the consideration of different categories' scopes, measurements, and relative weights; they also noted the presence of a rater effect.

Kotsantonis and Serafeim (2019) analysed the ratings of 50 randomly chosen large publicly listed companies (*Fortune* 500, encompassing a large variety of sectors) and Lufthansa. They undertook distribution analyses and employed different imputation methods (rules based, regression, predictive mean matching) commonly used for filling ESG data gaps. The authors performed a simple exercise using the above techniques for predicting Lufthansa's turnover and compare the results with the real observed value to illustrate the predictive inefficiency of such techniques. Their work confirmed a significant variety and inconsistency in data used, measurements, and reporting methodologies. One of the major observations stressed in the study was the clear lack of transparency on benchmarking procedures and gap-filling approaches involving considerable discrepancies. Furthermore,the authors found that disagreements increased with the quantity of publicly available information.

Utz (2019) proposed an assessment of the reliability of ESG to predict corporate scandals. For this purpose, the author studied more than 5,000 international firms during the 2004–2014 period and the occurrence of 67 scandals. He applied an event study methodology (aiming to test statistical inferences) and evaluated the ESG score evolution

before and after the occurrence of the scandal (i.e., within a year before the occurrence and during the two years after the scandal). Given the small size of the sample, the author used a bootstrap approach generate robust distribution-independent results. In summary, the findings showed that firms that experienced a scandal tried to improve their strategy in the year after the scandal, while in the second post-scandal year,improvements declined in favour of greater monitoring activities. Nevertheless, even though retrospective indicators significantly deteriorated in the year the scandal occurred, the author suggested that firms might not learn enough from earlier scandals and that ESG ratings thus did not provide a good forecast of the probability of a scandal occurrence. Furthermore, scandals in the areas of emission reduction and product responsibility affected firms' market value more than those concerning human rights and community. The significance of all these results, however, has to be considered in light of the restricted number of observations which might affect the reliability of the statistical inference results.

A more recent study on the disagreement among ESG raters, was undertaken by Billio et al. (2021) The authors analysed the ESG rating criteria used by four prominent agencies (Sustainalytics, RobecoSAM, Refinitiv, and MSCI) to show that there was a lack of a commonality in the definition of ESG (i) characteristics, (ii) attributes, and (iii) standards in defining the E, S, and G components. Evidence was also provided on the heterogeneity among the rating criteria which can ultimately lead agencies to have opposite opinions on the same company. This aspect reduces agreement across the investigated providers even further. Moreover, the alternative definitions of ESG also affected sustainable investments, leading to the identification of different investment universes and consequently to the creation of different benchmarks. This implies that in the asset management industry, it is extremely difficult to measure the ability of a fund manager if financial performances are strongly conditioned by a given ESG benchmark. Finally, authors found that disagreement in the scores provided by rating agencies dispersed the effect of preferences of ESG investors on asset prices, to the point that even when there was agreement, it had no impact on financial performances.

In a nutshell, the literature review confirms the existence of important discrepancies

among ESG raters and the methodologies they use to evaluate companies. Therefore, one might suspect that opposing ratings might lead to controversial conclusions and impact investors' decisions and academic conclusions on the impacts of ESG concerns.

These aspects are discussed further below, but we first offer a brief overview of the integration of ESG into the credit assessments performed by the Big Three (S&P, Moody's, Fitch).

2.5 ESG incorporation in credit assessment: The cases of S&P, Moody's, and Fitch

The existing disagreement among ESG raters seems evident. However, before proceeding with an evaluation of the impacts of ESG on credit risk, it is worth looking at how how ESG factors were incorporated into credit assessment before the consolidation of the ESG rating industry and the direct participation of S&P and Moody's.

The present section discusses the approaches implemented by the Big Three and is based on an Allianz report led by Steffan Hörter and his team (2016) along with some more recent agency communications. For this comparison, the authors investigate to what extent and how ESG factors were used in order to complete credit ratings.

2.5.1 S&P

According to their ESG Risks in Corporate Credit Rating 2015 report, the credit rating agency (CRA) incorporated ESG considerations as a means of identifying downside credit risk or social and environmental factors that can influence (positively/negatively) the general credit outlook. As such, ESG information was included as supporting material to enrich the credit risk profile of the considered company. Among the three pillars, governance was the most relevant factor with a potential substantial impact on entities' ratings (especially for lower-rated issuers). Therefore, it was also the most exhaustively examined and precisely defined.

Concerning the environmental pillar, S&P evaluated in its 2017 report, "How Environmental and Climate Risks and Opportunities Factor Into Global Corporate

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Ratings", that out of 717 cases for which environmental and climate risks and opportunities were material, 106 were directly impacted by environmental and climate factors, in most cases negatively (rating downgrading, outlook revised to negative, outlook revised to stable from positive).

2.5.2 Moody's

Moody's had a similar approach as S&P, as it included ESG risks into its evaluation of the overall credit risk. However, ESG was not considered as a main credit determinant; rather, it was one of several elements that can affect the global rating of a company. According to the Moody's, other key credit factors had a more relevant and immediate influence on creditworthiness, while ESG risks were perceived over a longer time horizon. Therefore, factors such as the high financial strength of an issuer might outweigh ESG issues. Nevertheless, several ESG risks (governance factors) were "explicitly integrated into firms' evaluation.

Thus, ESG factors were included in long-term credit risk analyses, especially if they were considered material and having a potential impact on an issuer's default probability and on expected inherent loss.

2.5.3 Fitch

In 2019, Fitch launched the ESG Relevance Scores for Corporates initiative in order to explicitly demonstrate how ESG factors are integrated into their credit risk evaluation. ESG considerations are fully incorporated in the rating procedure and present all the E, S, and G elements that might affect the rating decision without any judgements on companies' activities.

Fitch provides the opportunity to issuers and investors to agree or disagree with the methodology adopted and, if needed, to establish a dialogue with the analytical teams and improve understanding and transparency. Furthermore, Fitch can also propose assistance to investors for their personal evaluation of the impact of ESGs on credit ratings.

According to the 2020 Global Corporates ESG Dashboard Compendium (Fitch

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Ratings (2020)), out of 1,478 considered issuers, 23% had their ratings influenced by ESG factors. Companies in emerging markets are even more impacted at 26%, as well as certain sectors: the food, beverage, tobacco industries (38%); the natural resources industry (31%), retail, consumer and healthcare industries (27%). In general, the governance pillar was most consistently relevant, and the ratings of only 4% of issuers studied changed as a result of ESG risks.

In brief, while Fitch adopts a rather transparent approach on the integration of ESG risks into their rating procedure, S&P and Moody's, which have both become active in the ESG industry through several acquisitions in the last two years, remain quite opaque on this regard. That strategy may shift towards more transparency in the coming years. However, ESG factors are generally considered to provide complementary information (rather than essential information) "that ideally help grasp the specifics of a given company. Indeed, even though some companies are clearly affected by ESG issues, only a limited number of credit ratings are currently changed as a result. Finally, all three CRAs indicate that the governance pillar has the greatest impact on issuers' ratings.

3 Literature review on ESG and credit risk

We now proceed to an overview of the impact of ESG factors on credit risk

Historically, the most investigated relationship in the literature has been between the financial performance of SRIs and conventional investments (CIs). Rudd (1981), a pioneer social responsibility and portfolio performance, pointed out that the imposition of social responsibility criteria (as with all other targeting criteria) can limit portfolio diversification and thus increase the level of residual risk. A large part of the existing literature focuses on investment funds and indices, including firms with and without social responsibility skills. In particular, researchers have analysed the performance differential between SRIs and CIs and found little or no evidence of a significant spread in terms of returns between the two types of investments (Hamilton et al. (1993); Diltz (1995); Goldreyer and Diltz (1999); Statman (2000); Bauer et al. (2005); Bello (2005); Kreander

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et al. (2005); Belghitar et al. (2014);Utz and Wimmer (2014)).

Another stream of the literature examnes the relationship by directly including ESG criteria in the analysis through the rankings of specialized agencies. Given that ESG rankings are assigned at a firm level, the information set here is highly qualitative since it enables building the ESG profile of a company over time and thus obtaining a panel of data. The studies that consider ESG portfolios built on those rankings provide positive evidence about the financial performance of these investments. A group of studies has found that investing in ESG portfolios can provide a positive gain in term of performance (Derwall et al. (2004); Kempf and Osthoff (2007); Statman and Glushkov (2009); Mănescu (2011); Eccles et al. (2014); Nofsinger and Varma (2014); Auer and Schuhmacher (2016); Henke (2016). Friede et al. (2015) performed a meta-analysis of the findings of over 2,200 individual studies and found that about 90% showed a non-negative relationship between ESG and corporate financial performance, with a clear positive relationship in the large majority of cases. Hvidkjær (2017) provided evidence of a strong outperformance of stocks with high ESG ratings with respect to alternative benchmarks, both between 1991 and 2004 and after 2012.

While the previous findings suggest that ESG factors exert a positive impact on a firm's performance and hence on its value over time, there are few investigations about ESG factors and credit ratings. Therefore, the next subsection is dedicated to their description.

3.1 ESG and credit rating

One of the first studies on this topic was presented by Weber et al. (2010). The authors offered an overview of the integration of sustainability criteria into credit risk management practices and their ability to predict traditional ratings. For this purpose, they used a sample of 180 loans provided by 74 loan officers in Germany, with 31 economic sustainability criteria serving as an ESG proxy. The data were obtained from a questionnaire completed by credit officers making loans to small- and medium-sized enterprises (SMEs). The authors performed multiple linear discriminant analyses to

define the predictive capacity of four major factors (traditional rating, economic risk, environmental risk, and social risk) on potential loan default. Their findings confirmed the ability of sustainability criteria to predict traditional ratings. Furthermore, they asserted that firms with better environmental and sustainability performances benefit from credit rating scores, influencing their financial performance and creditworthiness. The authors also stressed the utility of integrating sustainability criteria into financial performance predictions, as they allow for an improved consistency of credit ratings. Nevertheless, a potential limitation of this study lies in its small sample size and a rather qualitative methodological approach. Attig et al. (2013) attempted to evaluate the impact of CSR on credit ratings. For this purpose, they considered a sample of 1,585 firms and their CRA ratings' evolution during the 1991–2010 period (as provided by S&P), while the CSR scores were gathered from MSCI ESG. The CSR scores resulted from the sum of six qualitative issue areas. The authors' assessment is based on ordered probit regressions analysing the effects of CSR scores and a number of controls on firms' credit ratings. The authors found evidence of a positive impact on credit ratings for both included ESG measures (aggregate score and individual components). Moreover, they found that CRAs tended to attribute higher ratings to firms with higher CSR scores. Their results provide evidence that CSR engagement in ESG areas provide useful non-financial information on firms' creditworthiness and thus, affect firms' credit evaluations, leading to lower financing costs. However, one of the limitations of this study lies in the exclusion of corporate governance from CSR scores. Stellner et al. (2015) focused on the impact of CSR on credit risk for a subset of 12 European Monetary Union members, using a dataset extracted from Thomson Reuters ASSET4 (ESG Data) and S&P (credit ratings) and encompassing 872 corporate bonds issued by non-financial companies during the 2006–2012 period.. Given that credit risk is measured through credit rating evolution and z-spreads, the authors offered two types of empirical analyses. The relationship between corporate social performance (CSP) and credit ratings was evaluated through ordered logistic regressions, while the impact of CSP on z-spreads was estimated by using pooled time-series, cross-sectional regressions, and two-stage least squares regressions.

The authors found limited evidence for systematic benefits from greater CSP in terms of lower credit risk. However, their results strongly supported the hypothesis that a country's ESG performance influences the CSP-credit risk relationship. CSP efforts can be beneficial only in countries with above-average ESG performances and z-scores.

Devalle et al. (2017) also studied the relation between firms' credit ratings and their categorical ESG scores (E/S/G) through ordered logistic regressions. The data sample was comprised of 56 public companies and was retrieved from Thomson Reuters/DataStream (ESG Data) and Moody's (CRA). The results indicated that ESG performance was positively associated with higher credit ratings. The social pillar was significantly and positively related to credit ratings. However, no significant result could be reported concerning the environmental metrics. Finally, according to the authors, ESG objectives were not yet fully integrated into credit score evaluations and lending practices. These findings, however, have to be put in perspective given the relatively restricted sample size, and the limited geographical area (Italy and Spain). Kiesel and Lücke (2019) sought to evaluate the integration of ESG in credit ratings and its impact on financial markets. They undertook two different types of analysis. First, they applied a latent Dirichlet allocation (LDA) approach to determine ESG integration into credit ratings (LDA is a topic modelling tool allowing to classify large sets of documents). Second, multivariate regressions were performed in order to examine whether ESG considerations in ratings affected capital market reactions. The data were obtained from Moody's credit rating reports for the period from 2004 to 2015 and concerns 483 companies operating in the United States and the European Union. The results indicated that, in general, ESG criteria were included in rating decisions in a limited but consistent manner during the observed period. Several sectors, such as the manufacturing, transportation, communications, electric, gas and sanitary service and mining industries, were more involved given their greater exposure to regulatory and environmental constraints. Furthermore, the corporate governance was found to have the largest impact on creditworthiness. Finally, ESG rating announcements appeared to significantly affect companies' stock returns and credit default swap (CDS) spreads at

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the time of publication. Even though these findings were solely based on credit rating reports of just one rating provider, they contribute to the existing literature by presenting further evidence on ESG's role in and relevance for financial markets.

Bhattacharya and Sharma (2019) focused on Indian companies. Using a dataset of 122 firms listed on the Bombay Stock Exchange 500 that represented 93% of the exchange's total market capitalization. The ESG data were obtained from Bloomberg and the credit ratings from Indian CRAs. To avoid multicollinearity, the authors performed Pearson correlations. Then, similarly to Attig et al. (2013), Devalle et al. (2017), and Stellner et al. (2015), they used ordered logistic regressions to study the impact of the global ESG score (and each of its components) on firms' credit ratings. The additional control variables are market capitalization, net debt-to-equity ratio, and the number of independent directors. The results revealed a rather positive impact of global ESG ratings on SMEs credit ratings, but no significant effect was reported for big companies already benefitting from higher credit ratings. Concerning the separate components, nurturing environmental and social policies appeared to significantly impact the credit ratings of SMEs, while corporate governance presented a positive but insignificant coefficient.

All six studies found positive impact of companies' ESG performances on their credit ratings and therefore on their financial performances and creditworthiness, although two demonstrated a rather limited effect (Stellner et al. (2015) and Kiesel and Lücke (2019)). Stellner et al. (2015) found that the positive effect of greater ESG involvement was especially reinforced for companies operating in countries with stronger ESG targets. Thus,the authors concluded that the magnitude of the spillover effects was conditioned by the environment. Kiesel and Lücke (2019) found that several sectors were more deeply implicated (manufacturing, transportation, communications, electric, gas and sanitary service and mining industries), given their greater exposure to regulatory and environmental constraints. Bhattacharya and Sharma (2019) stressed the relevance of ESG for SMEs credit ratings, but that did not hold for for big companies already benefitting from higher credit ratings. There was no clear consensus regarding the individual relevance of the three pillars. Two studies highlighted the role of the social

pillar (Bhattacharya and Sharma (2019) and Devalle et al. (2017)). One found no evidence for the effects of the environmental pillar (Devalle et al. (2017)) and two studies stressed the importance of corporate governance (Bhattacharya and Sharma (2019) and Kiesel and Lücke (2019)) .

3.2 ESG and CDS spreads

Another strand of the literature evaluates the impact of ESG factors on credit risk through their effect on CDS evolution.

Drago et al. (2019) studied the effects of CSR ratings on CDS spreads for a sample of 184 firms operating in 18 European countries. The data were obtained from ASSET4 Thomson Reuters (ESG Data) and Datastream (CDS data) and covered the period from 2007 to 2017. The authors offered two types of evaluations. First, an event study and an analysis of the cumulative abnormal returns (CARs) was conducted to verify whether the announcement of a CSR rating had a statistically significant impact on the CDS market; second, a regression analysis evaluated the impact of CSR ratings on CDS spreads. The results showed that CSR rating upgrades significantly decreased CDS spreads (for both global and individual pillar scores), while there was no evidence of a significant impact of CSR rating downgrades on the CDS market. In a nutshell, CSR ratings improvements could reduce credit risk, while it was not proven that decreasing CSR ratings could affect credit risk.

Truong and Kim (2019) evaluated the impact of CSR activities on credit risk by considering the evolution of CDS spreads. They used ESG data obtained from MSCI ESG and CDS data from Markit. A total of 507 firms (excluding utilities and financial sectors) were observed over the period from January 2001 to December 2013. The authors first focused on the slopes of CDS spreads (i.e., the difference between long- and short-term CDS spreads) used as a proxy for the credit-term structure. They then carried out Fama–MacBeth regressions of the individual slopes of CDS spreads on CSR scores to obtain a time series of coefficient values. Their findings supported the hypothesis that firms with higher overall CSR scores tended to reduce the difference between long- and

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short-term credit risks. CSR activities reduced more credit risk in the long run than in the short run.

Höck et al. (2020) focused on the impact of environmental sustainability on CDS spreads as a measure of credit risk. They used data derived from MSCI ESG (ESG data) and Bloomberg (CDS data) for 149 companies (from all industries except the financial sector) over the 2006–2017 period. The authors proceeded in three stages. First, a random-effects estimator was used to the impact of the environmental score on CDS spreads. Second, time-clustered White standard errors corrected for heteroscedasticity and serial-correlation issues. Third, several subsamples were studied to investigate the moderating effect of creditworthiness. Several major conclusions were drawn. In general, more sustainable firms had lower CDS spreads and were thus less exposed to credit risk. Environmental sustainability was particularly beneficial for companies with high credit ratings, while it had almost no effect on companies with low credit ratings. Furthermore, the sustainability effect was strong for companies with low leverage and high market capitalization, while it was not profitable for small or indebted companies (even though no presence of a penalty was observed).

Barth et al. (2019) studies companies operating in the European Union, mainly in Germany and France. Their sample covered 108 companies observed from July 2009 to December 2016. ESG data were drawn from Asset4 Thomson Reuters and CDS data from Thomson Reuters Eikon. To evaluate the impact of ESG ratings on corporate spreads, the authors ran Fama–MacBeth regressions on a monthly basis to obtain time series of coefficient values. With the coefficients they obtained, they proceeded to a linear cross-sectional analysis of ESG and CDS spread level and to a non-linear cross-sectional evaluation of the relationship between ESG and CDS spreads. Finally, they propose a time-series analysis of ESG (Fama and French ESG factor construction) and CDS spread changes. Their findings tended to demonstrate that firms with poor environmental performance had higher credit spreads and thus higher credit risk. In addition, low social performance led to low CDS spreads (except for the lowest-level threshold, below which CDS spreads increased). Finally, according to the authors, the time-varying market

valuation of ESG significantly influenced variations in credit spread changes.

In later work, Barth et al. (2022) expanded their analysis to the United States, covering 470 companies for the period from 2007 to 2019. IThey used data from MSCI and Refinitiv EIKON (ESG data) and Markit (CDS data) and performed linear panel regressions and quantile regressions to assess the relationship between CDS spreads and ESG. As a robustness check, an alternative rating provider was also examined. For the whole sample, the authors found a significant and negative relationship between ESG and credit risk. However, when the EU and the US were considered separately, similarly to Stellner et al. (2015), Amiraslani et al. (2017), ESG let to a risk-mitigating effect in Europe but not in the United States. Furthermore, some sector-specific effects were also observed, with industrials from the healthcare, consumer services and technology sectors benefitting from substantially stronger effects. Moreover, he results showed that the ESG effect was statistically significant during expansions and disappeared during recessions. Finally, the ESG effect on risk mitigation presented a U-shaped pattern, implying that the risk mitigation effect of ESG was strongest in the moderate ESG levels and less pronounced at very high and very low ESG quantiles.

CSR and ESG factors tended to reduce credit risk through decreasing CDS spreads. The sustainability effect was strong for companies with low leverage and high market capitalization, while it was not profitable for small and indebted companies. Furthermore, the risk mitigation effect of ESG was strongest at moderate ESG levels and less pronounced for very high and very low ESG efforts. Finally, the risk-reducing effect of ESG effects were more readily observed in the European Union than in the United States.

3.3   ESG and bond returns and default

Jang et al. (2020) aimed to identify the impact of ESG on bond pricing in Korea. For this purpose, they based their analysis on Korean data providers such as Korea Corporate Governance Service (ESG data), Korea Asset Pricing (corporate bonds data), and Korea Ratings (a CRA), allowing them to gather a sample of 6,832 observations from August

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2010 to July 2015. Based on panel regressions and case studies, the authors concluded that in South Korea, high environmental scores reduced the cost of debt financing for small firms. Furthermore, they suggested that ESG is complementary to credit ratings in assessing credit quality. Li et al. (2020) undertook a country-specific study on China to evaluate the impact of ESG performance on bond default rates. The authors used data from the China Stock Market & Accounting Research Database for the 2011–2019 period. Using logistic regressions, they found that bond default rates were positively correlated with a company's energy consumption and negatively correlated with its attention to social responsibility. Even though environmental variable used was industry- rather than firm-specific, the results supported the view that less energy efficient industries are more exposed to credit risk.

3.4 ESG and cost of equity (consensus among practitioners)

Sharfman and Fernando (2008) studied the relation between environmental risk management and the cost of capital by using a sample of 267 US companies, with data provided by several US sources.. By using hierarchical regression analysis, they found that improved environmental risk management was associated with a lower cost of equity but a higher cost of debt capital. However, the data restricted capacity to capture firms' environmental risk management abilities. El Ghoul et al. (2011) also used KLD STATS data for a sample of 2,809 firms observed between 1992 and 2007. On the basis of regression analysis, they confirmed that companies with higher CSR scores experienced significantly lower cost of equity capital. Lo and Kwan (2017) used Hong Kong as the case and applied both event study methodology and regression analysis. The sample encompassed 17 listed companies for the period from 2010 to 2012, with data retrieved from the FTSE4Good and the Dow Jones Sustainability Asia Pacific Index. The results suggested that the market reacted more positively to ESG initiatives than to sustainability initiatives. This finding highlights the greater capacity of ESG initiatives to better guide investors and provide more precisely defined targets for improvements. Another, more recent study by Miralles-Quirós et al. (2019) was also based on regression

analysis but used Thomson Reuters Eikon data for the 2005–2015 period. The sample contained 51 commercial banks operating in 20 countries. The findings showed that environmental and governance performance significantly and positively affected share prices, while efforts in the social sector negatively influenced them.

3.5 ESG and the cost of debt: Corporate bonds and bond issues

Menz (2010) published one of the first studies investigating the relationship between the valuation of corporate bonds and CSR. Based on data provided by SAM Group and a sample of 498 Euro corporate bonds observed in the period between July 2004 and August 2007, the author used panel regressions to evaluate the correlation between credit spreads and CSR ratings. The results indicated that for the considered period, CSR did not appear to be incorporated into corporate bonds' pricing. Polbennikov et al. (2016) conducted a more recent analysis (for 2006–2015) evaluating the impact of ESG ratings on corporate bonds' performance. They used data from Barclays MSCI ESG on 4,366 US corporate bonds and conducted a simulation of index-tracking portfolios designed to deviate from the benchmark index relative only to the ESG score. They found that companies with higher ESG ratings showed slightly lower bonds spreads, and their bonds performed slightly better compared to less ESG-engaged firms, when controlling for various sources of risk exposures. Baker et al. (2018) compared ordinary bond and green bond pricing for the 2010–2016 period in the United States. They used ESG data from Bloomberg green bond tag; the sample contained 2,083 green bonds and 643,299 ordinary bonds. The comparison, based on an asset pricing framework incorporating an investor preference for green over ordinary bonds, highlighted that green municipal bonds were issued at a premium to otherwise similar ordinary bonds.

3.6 ESG and the cost of debt: Private debt and loans

Chava et al. (2009) were among the first to examine the relation between company governance structure and bank loan costs. Their investigations were based on ESG data extracted from IRRC data (G-Index). The authors focused on a sample of 6,000

loans issued to 1,274 non-financial American public firms between 1990 and 2004 and performed a regression analysis, which allowed them to conclude that lower takeover defences significantly increased the cost of bank loans for a firm. Goss and Roberts (2011)evaluated the impact of CSR on the cost of bank loans, using data provided by KLD on 3,996 loans to 1,265 US firms from 1991 to 2006. The authors used a two-step method to generate optimally scaled principal components on well-defined CSR strength and concern clusters to provide evidence that firms with social responsibility concerns paid between 7 and 18 basis points more than firms that are more responsible. Hanson et al. (2017) compiled and summarized the major messages of a panel discussion of industry analysts on the role of ESG in investment decision-making. The highlighted stylized facts concern the consensus relating high ESG scores and rankings and management "quality", the sustained interest of some of the world's best "business value investors" in factoring ESG considerations into their investment decision-making, the pronounced effects of ESG factors on generating "tail risks", the willingness and mitigated capacity of rating agencies to describe and foresee these risks in their analyses, and the emergence of a new orientation of equity portfolios' investors towards positive sustainability factors (low-carbon, gender-oriented, and so on), alongside the traditional "sin" sector screening. Another investigation focusing on the relation between CSR and bank loan pricing was conducted by Hauptmann (2017). The author ran several regressions with the loan spread as a dependent variable, using data provided by Thomson Reuters Asset4. The sample featured 484 unique borrowing firms and 39 unique lending banks, resulting in 1,226 loan observations for the 2002–2015 period. The findings showed that borrowers with strong sustainability performance benefitted from lower loan spreads than those less involved in corporate sustainability only if the bank providing the loan was also involved in CSR activities. Hauptmann (2017) identified three major mechanisms related to CSR, leading to this observation: improved credit risk, increase in trust due to similarity between banks and borrowers, and reduced reputation risk. The results were confirmed even after several robustness checks. Companies presenting higher CSR and ESG scores benefitted from larger financial facilities, whether in the form of lower cost of equity capital or lower

cost of debt (especially within the last decade).

3.7   ESG factors and sovereign bonds

Finally, a very narrow part of the literature has examined the impact of ESG on sovereign borrowing costs and credit risk. In 2014, several researchers from the United Nations Environment Programme Finance Initiative and Global Footprint Network developed the E-RISC framework. Described in Hill Clarvis et al. (2014), this framework aims at identifying and quantifying the linkages between environmental risks and macroeconomic factors relevant to sovereign credit risk. Encompassing three major strands evaluating a country's risk (natural resource risks, economic significance of resource risks, and country's economic resilience), itconsiders 20 qualitative and quantitative indicators across four dimensions (resource balance, trade-related risk, degradation-related risk, and financial resilience). Thus, it improves the assessment of the environmental risk materiality in the sovereign bond market and compensates for the lack of consideration of environmental impacts on a country's macroeconomic performance. Finally, the framework aims to offer a more complete sovereign credit risk assessment in light of the Basel III financial regulation requirements.

A more empirical approach was taken by Capelle-Blancard et al. (2016). The authors examined the relation between ESG and sovereign bond spreads and thus focused on 20 OECD countries during the 1996–2012 period, by compiling data from data sources like: Vigeo, HSBC AM, Natixis AM, and MSCI ESG Country Ratings. To conduct their evaluation, they developed an ESG index and performed several panel regressions leading to the conclusion that countries with good ESG performance tended to present lower default risks and lower bond spreads. Their work establishes that ESG performance presents a more relevant economic importance in the long run. They also found that governance aspects had the most consistent financial influence, while the environmental dimension did not have any conclusive impact. While Capelle-Blancard et al. (2016) examined OECD countries, their comparative approach found that ESG involvement appeared to have a greater impact in the Eurozone.

Crifo et al. (2017) evaluated the impact of ESG ratings on government bond spreads through a panel regression model, using data derived from Vigeo Eiris for the 2007-2012 period. Based on their results using a sample 23 OECD countries, ESG ratings tended to significantly decrease government bond spreads. Indeed, after introducing several control variables (GDP growth rate, inflation rate, gross debt, fiscal balance, reserves, trade openness, sovereign credit ratings) and using an instrumental variable fixed effects model, the authors found evidence for lower sovereign borrowing costs associated with higher ESG ratings. However, this effect was three times weaker than the impact of financial ratings.

Hübel (2020) studied the impact of countries' ESG performance on sovereign credit curves. He examined 60 countries for the period from 2007 to 2017 using ESG data obtained from RobecoSAM and CDS data from Refinitiv EIKON. Several types of methodological evaluations were carried out: correlation analyses, panel regressions of CDS spread levels on ESG ratings, and panel regressions of CDS curve slopes on ESG ratings. The author concluded that countries with superior ESG performances had lower CDS spreads (irrespective of the ESG pillar or global ESG score), while flatter CDS implied credit curves, thus suggesting lower credit risks.

Countries with good ESG performances were less exposed to credit risk, particularly in the Eurozone

3.8 ESG factors and other approaches to credit risk

Henisz and McGlinch (2019) provided empirical evidence of the mechanisms linking ESG performance to credit risk. Based on 22 company-specific case studies and correlation analyses involving ESG data derived from MSCI, RepRisk, Sustainalytics, and Truvalue Labs, the authors showed that ESG performance led to lower volatility and therefore to a lower exposure to credit risk.

4 Literature review on financial implications of climate change

The transition to sustainable finance is crucial to scale up the massive investments needed to foster a transition to a low-carbon economy that keeps temperature rises below 2 degrees Celsius (High-Level Experts Group on Sustainable Finance 2018)and to prevent permanent environmental damage (International Panel on Climate Change 2014). Many central bank governors have recently started considering increasing regulatory oversight to address climate-related risks to financial stability, including carbon stress tests for banks and other financial institutions to assess the effects of an abrupt transition to a low-carbon economy in response to irreversible climatic catastrophes (Battiston et al. (2017); Gros et al. (2016)).

In fact, climate-related risks can affect companies and thus economic and financial stability from different perspectives. More specifically, firms might be exposed to climate-related damages (in regions affected by extreme weather conditions), stranded assets (in fossil fuel-intensive industries), and reputational harm (for those not involved in climate-friendly activities or not implementing mitigating strategies). With the aim of covering all these aspects, the next subsection reviews the literature focusing on climate change and financial stability and discusses companies' abilities to face climate-related risks through the impact of climate change on portfolio management.

4.1 Climate change and financial stability

4.1.1 Physical risk and transition risk: The two aspects of climate risk

In the climate risk debate, two opposing views coexist: climate-mitigating policies can be seen as a potential generator of systemic risk or as an opportunity to promote low-carbon investments and economic growth. On one hand, the transition of the economy and society would require considerable efforts and adjustments which might affect financial stability. On the other, postponing any actions and climate risk-mitigating policies would certainly expose the global economy and societies around the world to the

consequences of global warming and of course undermine financial stability. Thus, most studies have identified two types of financial stability risks related to climate change: physical risk and transition risk. Physical risk (expressed through more frequent and severe disasters) could directly affect financial stability, while transition risk corresponds to the adjustment processes related to climate transition.

All the reports issued by central banks (Austria, France, England, Mexico) and by international financial institutions like: the Bank of International Settlements, theEuropean Central Bank, the International Monetary Fund, the Network for Greening the Financial System (NGFS), and the European Insurance and Occupational Pension Authority (EIOPA) agree on the potential impacts that climate change could have on financial stability. Both physical and transition risks can affect several financial risk categories. Pointner and Ritzberger-Grünwald (2019) identified the potential influence of climate change on credit risk, market risk, liquidity risk, operational risk, and systemic risk. The National Bank of Austria concluded that potential consequences could be quite consistent: an increase in the probability of loan defaults, and risk premiums, exchange rate volatility, operating costs and correlation risk. It also expects a concurrent decrease in profits, and of sovereign bonds prices, the availability of risk-free assets. Finally, capital depletion is feared. More specifically, European Insurance and Occupational Pensions Authority (2018) and Battiston et al. (2017) evaliated the potential exposure of several sectors; even though direct exposure does not seem extremely important, the "second round effect" related to financial investors' exposures and interconnexions could lead to a considerable amplification of climate risk.

4.1.2 Direct exposure and amplification effect

According to Battiston et al. (2017), the direct exposure of the financial sector to fossil fuel activities can be summarized as such: around 1% of EU banks' total assets, respectively 5% of EU pension funds' assets, and 4.4% of EU insurance companies' assets. Concerning equity holdings, their direct exposure is evaluated at 4%—13%, but their combined exposures to climate policy-relevant sectors is much larger: 36%--48%. The

exposure even reaches 45%–47% for investment funds and pension funds. As such, the authors provide evidence for the potential amplification of climate risk through financial investors' exposures and interconnection. The European Insurance and Occupational Pensions Authority (2018) proposes an enlarged overview of different sectors' exposures. The report presents the housing sector as potentially the most impacted by climate change (7%), followed by the energy-intensive sector (1.5%), the fossil fuel sector (0,8%), utilities (0.8%), and the transportation sector (0.4%). The authors also highlight that 10% to 13% of insurers' held assets may be also implicated. Similarly to Battiston et al. (2017), the expectations for a stronger second round effect due to the high exposure among financial institutions are confirmed. A more recent study by the European Systemic Risk Board (2020) also confirms the limited and decreasing direct exposure of European financial institutions. However, the analysis points out a significant concentration of exposures in several sectors and companies. Finally, the report indicates that transition costs (even corresponding to an abrupt climate policy scenario) are likely to be contained and less significant than physical costs.

4.1.3 Further findings on financial stability risks

Roncoroni et al. (2021) find that under mild shock scenarios, systemic risk and its inherent losses appear to remain contained. However, according to their findings, several combinations of climate policy scenarios and market conditions could induce a threat to financial stability. From another perspective, Battiston and Monasterolo (2020) show that countries with predominantly low-carbon economic activities benefit from lower bond yields and spreads relative to carbon-intensive countries. Thus, countries relying heavily on fossil fuels (directly or indirectly) might be further exposed to climate risk. Indeed, in cases of misalignment with climate policies, carbon-intensive countries might face higher bond spreads, affecting their sovereign risk and investors' portfolio performance, with potential repercussions on financial stability. Focusing on France, Allen et al. (2020) obtain evidence for the negative economic impacts related to a disordered climate transition process. Even though the authors observe restricted macroeconomic and

financial market effects, some sectors (fossil fuels, agriculture, mining) and specific companies seem particularly exposed. The identified sectoral and infra-sectoral effects suggest the appearance of greater potential financial stability risks.

4.1.4 Insufficient data availability

However, all these evaluations have faced and are continuing to face the same type of major constraint: limited or fragmented and incomplete climate data. Thus, a broad consensus is observed on this topic (European Central Bank (2019), including the NGFS (2019), IMF (Grippa et al. (2019)), the Bank of England (2020), European Systemic Risk Board (2020), and Battiston et al. (2019b)). As indicated by the European Central Bank (2019), this situation is related to insufficient reliable climate disclosures and to fragmented carbon emissions reporting. The European Central Bank (2019) and the NGFS (2019) emphasize the role of central banks and financial authorities in the promotion of climate risk' monitoring, taxonomy' development, disclosure procedure' implementation, and the inclusion of climate-related risks in prudential frameworks. Grippa et al. (2019) indicate that the IMF also urges the public and private sectors to adopt further climate disclosures by following the recommendations of the Task Force on Climate-Related Financial Disclosures (2017).

4.1.5 Necessity of adapted assessment frameworks

Beyond the limited access to data, several studies underscore the particularities of climate risk evaluations. Indeed, the BIS report (Bolton et al. (2020)) stresses the inability of traditional backward-looking risk assessments and climate-economic models to predict and analyse properly climate-related risks. Giuzio et al. (2019) also note that the evaluation of the latter is complex (long-term horizon, lack of data, large variety of potential transition paths), but European banks' relative exposure seems generally contained, even though some banks might be more exposed in absolute terms. For all these reasons, several complex frameworks have been developed. Battiston et al. (2017) use a network-based climate stress-test methodology; Roncoroni et al. (2021) apply an

extended bank-fund version that combines climate stress-test features with a financial asset valuation framework (accounting for market volatility and for endogenous recovery rates); Battiston and Monasterolo (2020) implement an adaptation of the CLIMAFIN framework using the LIMITS database[4]; Allen et al. (2020) base their analysis on a complex modelling framework combining several different models, calibrated on the high-level reference scenarios of the Network for Greening the Financial System (NGFS); the European Systemic Risk Board (2020) report applies the De Nederlandsche Bank methodology and the European Central Bank's BEAST model.

4.1.6 The necessity for of a timely and smooth transition and the role of financial institutions

Another issue on which several studies agree concerns the ordered and smooth character of the upcoming transition. Despite the currently observed data issues (and the necessity of further actions and solutions to overcome them), Giuzio et al. (2019) stress the need for a smooth transition to avoid systemic risks. In addition, similarly to the European Systemic Risk Board (2020) demonstrating the limited financial markets' capacity to price climate risk, the authors highlight the necessity to address this aspect since it can affect financial institutions' balance sheets and financial stability. According to Giuzio et al. (2019), all these conclusions motivate a stronger involvement of financial institutions for a better monitoring and management of climate-related risks.

Providing evidence for the potential amplification of climate risk through financial investors' exposures and interconnections, Battiston et al. (2017) highlight the need for timely and credible regulatory policies, along with improved data collection, processing, and analysis. The latter message is reformulated in Battiston and Monasterolo (2020), where the authors suggest that financial regulators can contribute through the creation of a public entity responsible for the collection, validation, and spread of climate-relevant data at the EU level. Finally, Pointner and Ritzberger-Grünwald (2019) conclude that

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[4]LIMITS (Low climate IMpact scenarios and the Implications of required Tight emission control Strategies) aims at advancing the understanding of the implementation of climate policies consistent with 2 degrees Celsius.

there is a limited awareness among Austrian financial intermediaries concerning the risk of climate change's impact on financial stability.. This finding suggests the need for a more intensive involvement of national and international financial institutions.

5 Climate change and portfolio management

While the literature studying the potential impact of climate change on financial stability is rather homogeneous in its recommendations of a greater level of disclosure, the need to overcome data gaps, the necessity for timely and graduated actions, research evaluating the impact of climate change on portfolio management has thus far been more heterogenous. Of course, this observation is clearly related to the characteristics of such topics. While financial stability issues are among the prerogatives of financial institutions and as such require clear research targets and ongoing recommendations, portfolio analysis can be discussed through a much wider variety of approaches. We have identified three major orientations: climate risk pricing and hedging, exposure to climate risk and concerned sectors, mitigation strategies (divestment vs risk management and engagement). A main source of uncertainty for investors is represented by the lack of information on whether financial markets are anticipating the introduction of climate policies and/or pricing the risk of "staying brown" against the opportunities to "go green". In addition, models to assess the conditions under which low-carbon investments and indices could provide systematically higher returns than carbon-intensive investments are missing, and herding behaviour could slow the low-carbon transition (Battiston and Monasterolo, 2020).

5.1 Pricing climate change risk

Recent research aimed to assess whether and to what extent financial markets have started pricing climate risks into carbon-intensive assets or portfolios. The results are rather inconclusive. For instance, Delis et al. (2018) found evidence that banks started to price carbon risks in loan products after the Paris Agreement; moreover, Monasterolo and

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de Angelis (2020) detected a change in market beta for low-carbon and carbon-intensive indices before and after the Paris Agreement; that is, after the Paris Agreement the systematic risk associated with low-carbon assets and indices has decreased, while the level of systematic risk associated with carbon-intensive assets and indices has increased.

However, Morana and Sbrana (2018) found that growing climate risk is not priced into cat bonds. This means that the risk associated with holding assets that could lose much of their value as a consequence of climate change is not yet priced into asset evaluation. Mispricing has potentially important effects, as it could prevent not only investments from flowing into low-carbon sectors but also lead investors to increase their exposure to carbon-intensive sectors; this might then encourage negative consequences on sustainability and financial stability (Battiston and Monasterolo, 2020).

In this respect, Ramelli et al. (2018) show that investors reacted to two main policy "shocks" in 2016: Trump's election victory and the nomination of Scott Pruitt to head the Environmental Protection Agency, which rewarded companies in high-emission industries, at least in the short run. However, similarly to Wagner et al. (2018), companies with "responsible" strategies on climate change also appear to have been also rewarded by long-horizon investors. Finally, Mukanjari and Sterner (2018) did not find unique evidence of portfolios' response to the announcement of the US withdrawal from the Paris Agreement.

Several models have been developed for a more appropriate pricing and hedging of climate risk. Among them, CLIMAFIN (Battiston et al., 2019a), proposes an innovative methodological framework combining climate economic modelling and financial risk pricing in sovereign bonds under deep uncertainty. CLIMAFIN aims specifically at providing a quantitative assessment of climate risks in sovereign bonds and investors' portfolios by integrating several climate risk specifics (the forward-looking dimension, deep uncertainty, non-linearity, endogeneity, etc.) into the performance of financial contracts and investors' portfolios. The framework includes climate scenario-adjusted financial pricing models (for equity holdings, sovereign and corporate bonds, and loans) and climate scenario-conditioned risk metrics (such as the Climate Spread and the

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Climate VaR).

5.1.1 Hedging climate change risk

Another strand of the literature discusses potential solutions for hedging climate change risk. Juarez-Torres and Sanchez-Aragon (2012) were the first to offer a solution for hedging climate change risk, focusing on water management in Latin America. The authors suggest the use of weather derivatives as a complementary financial solution for more efficient water allocations in Mexico and Peru. Andersson et al. (2016) adopt another perspective for climate change risk hedging: assimilating the latter to CO2 emission mitigation policies. The authors propose a decarbonized index that can be considered a "free option on carbon" that should start outperforming the benchmark simultaneously with a stronger signal on CO2 emissions' pricing. Bender et al. (2019) also investigate possibilities for quantifying climate risk and in response, building investable portfolios addressing both climate risk mitigation (at present) and adaptation (in the future). The authors develop a framework for building investment climate strategies within public equities that are aligned with climate model projections. As such, the framework enables building portfolios assuming different GHG concentration levels, tracking errors, and climate risk exposures. Thus, the chosen approach for representing climate risk is the consideration of cumulative CO2 emissions related to different threshold degree scenarios (the most conservative scenario corresponds to a global temperature increase of less than 2°C). Instead of focusing on global temperature change or CO2 price evolution, Engle et al. (2020) propose an approach for hedging against climate change risk by using the growing climate change sentiment among society. For this purpose, two indexes are developed: the *Wall Street Journal* climate change news index (measuring the frequency of climate change and related issues news in the *Wall Street Journal*) and the Crimson Hexagon (CH) Negative Climate Change News Index (measuring the intensity of negative climate news among 1,000 major news sources). Furthermore, the authors use ESG data from MSCI and Sustainalytics to identify the companies most exposed to climate change risk within and across industries. Thus, on the base of a

mimicking portfolio approach aiming to successfully hedge climate change news, they find that betting solely on green energy stocks is not sufficient. Finally, the authors conclude that portfolios built on Sustainalytics E-Scores demonstrate a greater ability to hedge innovations in climate news. Another recent paper investigating climate risk hedging was developed by Rubtsov et al. (2021). The authors examine optimal investment strategies with different investment horizons with the aim of deriving the cost of climate change uncertainty. They find that such uncertainty not only reduces stock investment but also investor' welfare, despite the presence of climate risk-hedging instruments.

5.1.2 Exposure to climate risk and concerned sectors

In accord with other studies focusing on sectoral exposure to climate change,Monasterolo et al. (2018) focus on China's overseas energy investments portfolio and find that the activities most exposed to climate risk and therefore to negative shocks are concentrated in coal and oil projects. Furthermore, the results show that, given the current leverage of Chinese policy banks, the potential losses incurred might induce severe financial distress, with consequences for macroeconomic and financial stability. Battiston and Monasterolo (2020) propose an investigation on the exposure of the European insurance industry through a climate risk assessment of their sovereign bond portfolio. The results show that the potential impact is moderate but regular monitoring is recommended given the non-negligible magnitude.

5.1.3 Mitigation strategies

In addition to evaluating the potential climate change risk, proposing hedging solutions, and identifying the most exposed sectors, searching for potential long-term solutions is also among the options explored in the literature. As highlighted by Fang et al. (2019) in their evaluation of sustainable portfolio management in the North American stock market, most of the current mitigation strategies choose divestment in carbon-intensive industries. This orientation is justified by the relatively lower performance of these sectors. However, the authors stress the necessity of including

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further risk control modules for a more complete representation of complex risk influences. With regard to institutional investors, according to Krueger et al. (2020), most European, American, and Canadian investors are more concerned about the regulatory risk related to climate change. Indeed, they consider the latter to be the major channel that could affect their portfolios. Furthermore, they find that long-term, larger, and ESG-oriented institutional investors favour risk management and engagement rather than divestment. Finally, Alok et al. (2020) propose a study adopting an alternative perspective: managers' capacity to overreact to large climatic disasters, especially if the latter are recent and distant. Indeed, according to the authors, distant managers tend to be more risk averse to disaster zone stocks (compared to local managers), due to a salience bias. However, the overreaction can induce important costs to fund investors, especially in the case of hurricanes and tornados. This finding further highlights the need for appropriate assessment frameworks.

In a nutshell, climate change risk can be represented both through physical and transition risk. The first corresponds to all the damage related to extreme weather conditions, while the second refers to all inappropriate or delayed adjustment processes and actions related to climate transition. Thus, companies might be exposed to climate-related damage, stranded assets, and reputational harm. Furthermore, even though the direct exposure to climate change risk of most economic sectors is limited (with the exception of fossil fuel-dependent activities, mining, and agriculture), the amplification effects might be considerable, given the significant interdependence in a modern economy. Therefore, the potential consequences for the economic and financial stability should not be underestimated. For this purpose, the literature agrees on the necessity of adapted assessment frameworks and on an improved disclosure process that will help solve insufficient data availability issues. Moreover, the role of financial institutions is essential, especially in the implementation of a timely and smooth low-carbon transition. From the perspective of climate risk pricing and hedging, the importance of tangible portfolio selection frameworks incorporating climate risks is further stressed. By combining climate economic modelling and financial risk pricing,

the CLIMAFIN model can be useful for both the assessment of portfolio climate risk exposure and financial stability evaluations.

6   Conclusion

The ESG rating agency sector has experienced a significant concentration process during the last decade. Thus, the major historical ESG actors (MSCI ESG, Sustainalytics, Viego Eiris, ISS-oekom, Bloomberg, Refinitiv (Thomson Reuters), RobecoSAM, FTSE Russell, and ECPI) have been the subject of MA activities, while the Big Three rating agencies (Fitch, Moody's, and S&P) have entered the market. Therefore, by 2020, the major ESG rating providers were: Moody's, MSCI, Morningstar, ISS, S&P, and PwC.

Besides the important M&A processes that have been observed, the ESG rating industry has faced the offspring of six major ESG reporting frameworks aiming to guide ESG disclosures: the Carbon Disclosure Project, the Climate Disclosure Standards Board, the Global Reporting Initiative, the International Integrated Reporting Council, the Sustainability Accounting Standards Board, and the Task Force on Climate-related Financial Disclosures.

There are still no globally accepted standards that offer a univocal judgment of corporate sustainability. Most ESG assessments are still very different in terms of indicators measured (definition of ESG materiality), information sources, and the weights applied to different criteria.

Even though all agencies use a three-pillar approach, some pillars differ among rating agencies. Furthermore, even if most raters largely use publicly available data, some base their ratings on industry questionnaires or on information directly obtained from the evaluated companies. In addition, even if most rating companies integrate industry specifics into their assessments and divide risk evaluation into risk management and risk exposure, the weights assigned to each are different. Finally, controversy evaluations are included by most raters, but the methodology applied differs considerably, as do the rating scores. As a result, the same company might receive contradictory ratings, depending on

the methodology chosen and applied.

These contradictions are confirmed by the literature review and thus, raise the question of their impact on companies' creditworthiness and on investors' decisions. According to Fitch, S&P, and Moody's, ESG factors generally provide complementary information on companies' specifics. Thus, even though some financial ratings might be affected by ESG issues, only a limited number undergo substantial changes.

As to the literature review evaluating the effects of companies' ESG performances on their credit risk, a very large majority of studies concludes that positive ESG ratings are associated with: an improvement in credit ratings, a reduction in CDS spreads, and a decrease in costs of equity capital and debt.

Climate change risk can affect companies directly through physical damages and indirectly via transition processes like stranded assets and reputational harm. Even though the climate risk exposure of most economic sectors is limited (with the exception of fossil fuel-dependent activities, mining, agriculture), amplification effects might be considerable with potential consequences for economic and financial stability.

For this purpose, the literature agrees on the necessity of adapted assessment frameworks and on an improved disclosure process that can help address insufficient data availability issues. Furthermore, timely and smooth low-carbon transition actions are recommended.

From the perspective of climate risk pricing and hedging, the importance of tangible portfolio selection frameworks incorporating climate risks is further stressed. By combining climate economic modelling and financial risk pricing, the CLIMAFIN model can be useful for both the assessment of portfolio climate risk exposure and financial stability evaluations.

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7 List of Tables

Table 1: Differences and specifics of the four major reporting frameworks

	CDP	GRI	SASB	TCFD
Customer Usage	Widely used	Widely used; since 1999; "threshold" expectation for basic corporate sustainability reporting.	Gaining considerable traction, especially after BlackRock CEO Larry Fink support	Gaining considerable traction
ESG Ratings Linkages	Feeds into DJSI questionnaire; CDP Climate Score feeds into EcoVadis Scorecard; posted on Bloomberg terminal	None known	Linkage with ISS	Feeds into the CDP Questionnaire
Industry Focus	Generic set of standards applying to all industry sectors	Generic set of standards applying to all industry sectors	Industry-specific standards for about 77 industry sectors and sub-sectors	Generic set of standards applying to all industry sectors. Supplemental guidance provided for the financial and non-financial sectors.
Level of Detail	Considerable	Considerable	Reasonable detail	Limited
Limitations	Predominantly focused on "E"	Broader definition on materiality compared to other frameworks	Weak on "G"	Disclosure recommendations (for the most part) are quite general
Scope	Limited: narrowly focused on "E"	Initially very strong and detailed content on "E"; later added very strong content on "S"; special emphasis on governance structures and stakeholder engagement.	Strong on key "E" topics relevant to each industry sector; selected "S" topics; limited on "G"	Four broad sections : Governance, Strategy, Risk, and Metrics. A "top-down" structure.
Transparency	Fully transparent methodology and criteria	Fully transparent methodology and criteria	Fully transparent methodology and criteria	Fully transparent methodology and criteria

Table 2: Key differences between ESG rating agencies as reported by Billio et al. (2021).

	MSCI	VIGEO	REFINITIV	SUSTAINALYTICS	ISS OEKOM	ROBECOSAM	ECPI	BLOOMBERG
RATING SCORE	CCC to AAA	-- to ++	D- to A+ and 0 to 100	0 to 100	D- to A+	0 to 100	F to EEE	0 to 100
HISTORY	1990	1983	2002	1992	1985	1995	1997	2008
HEADQUARTERS	New York, United States	Paris, France	Toronto, Canada	Amsterdam, Netherlands	Munich, Germany	Zurich, Switzerland	Milan, Italy	New York, United States
SOURCES	Company disclosure, 1600+ Media sources, 100+ specialized dataset	Company disclosure, Recommendation, Conventions	Company websites, Company reports, NGO Websites, Media and news, Stock Exchange filings	Public disclosure, Media and news, NGO reports	Publicly available information, Interviews with stakeholders, information on company policies and practices, company direct contact	Survey approach	Company reports, Company screening, Media and news, Regulatory data, Bloomberg and Thomson Reuters, University networks	Company reports, Publicly available information, Company direct contact
# OF CRITERIA	37	38	178	155	100	74	80/86	120
MAIN RISK FACTORS	**Environmental** Climate Change, Natural Resources Pollution And Waste Mgmt., Environmental Opportunities **Social** Product Liability, Human Capital, Stakeholder Needs, Social Opportunities **Governance** Corporate Behaviour, Corporate Governance	Human Resources, Human Rights, Environment, Business Behaviour, Community Involvement, Corporate Governance	**Environmental** Resource Use, Emission, Innovation **Social** Workforce, Human Rights, Community, Product Responsibility **Governance** Mgmt., Shareholders, Csr Strategy	Industry-Specific indicators. Factors Change According To The Industrial Group To Which A Company Belongs	**Environment** Climate Change Strategy, Ecoefficiency, Energy Mgmt., Env. Impact of Product Portfolio, Env. Mgmt., Water Risk And Impact **Social** Equal Opportunities, Freedom of Association, Health and Safety, Human Rights, Product Responsibility, Social Impact of Product Portfolio, Supply Chain Mgmt., Taxes **Governance** Business Ethics, Compliance, Independence of The Board, Remuneration, Shareholder Democracy, Shareholder Structure	About 21 Industry-Specific Indicators. Three Main Dimensions: **Economic** (38/100) **Environmental** (27/100) **Social** (35/100)	**Environmental** Environmental Strategy Policy Environmental Mgmt. Products Production Process **Social and Governance** Employees and Human Capital Community Relations Markets Corporate Governance and Shareholder	**Environmental** Carbon Emissions, Climate Change Effect, Pollution, Waste Disposal, Renewable Energy, Resource Depletion **Social** Supply Chain, Political Contributions, Discrimination, Diversity, Community Relations, Human Rights, **Governance** Cumulative Voting, Executive Compensation, Shareholders' Rights, Takeover Defence, Staggered Boards, Independent Directors
MATERIALITY AND WEIGHTING	Proprietary Definition. Analysis on material risks and opportunities for all the GICS sub-sectors	Proprietary Definition. Based on principles developed by International Bodies.	Proprietary Definition. Standard weighting for all the categories Environmental = 34%, Social = 35.5%, Governance = 30.5%	Proprietary Definition of Materiality - subindustry level. Assessment of the potentially material issues in the future	Proprietary Definition. Selection and weighting of 5 key issues per sector and 800 detailed Industry-Specific Criteria	Proprietary Definition. Disclosure of criteria and weighting of the 61 industries analysed	Proprietary Definition. Based on principles developed by International Bodies (eg. UN Global Compact Initiative and UN PRI)	Proprietary Definition. Based on principles developed by International Bodies (eg. GRI, CDP, SASM for three industries. FSB Task Force on Climate-related Financial Disclosures)

8 List of Figures

Figure 1: Milestones in M&A between ESG data vendors. The Big Three rating agencies (Moody's, Fitch, and S&P) have recently consolidated their presence. This process is highlighted in orange.
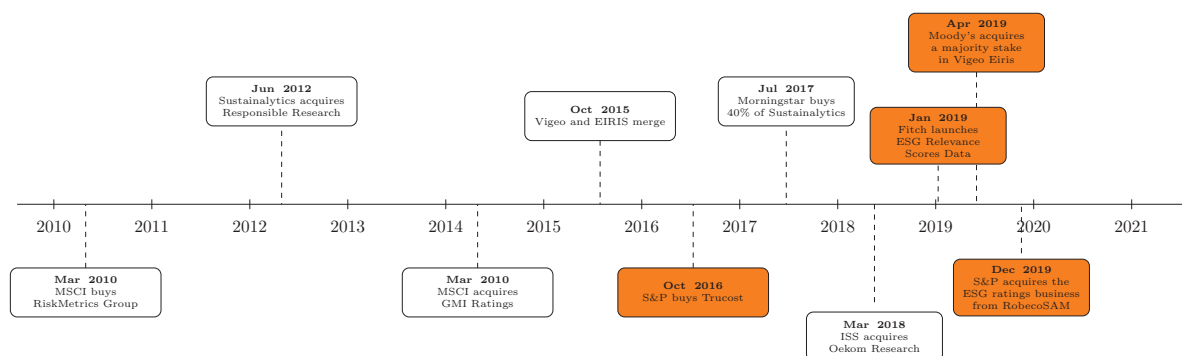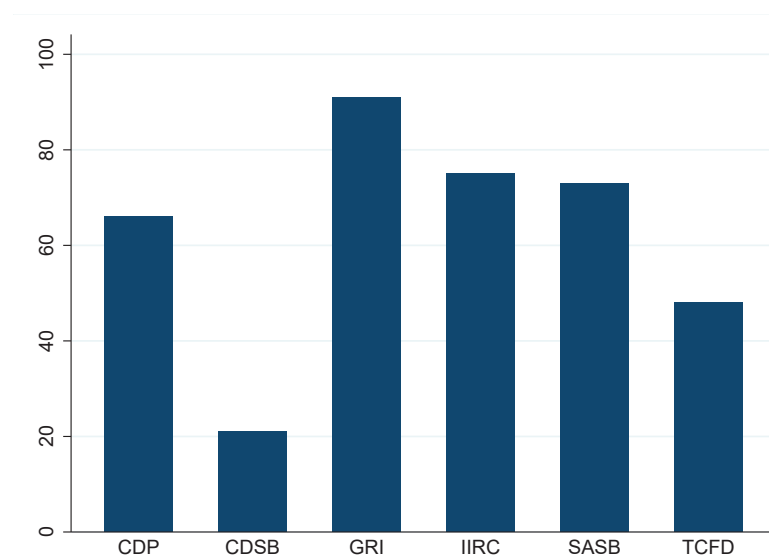

Figure 2: The six global organizations whose frameworks, standards, and platforms guide the majority of sustainability and integrated reporting, broken down by reference in the stock exchange ESG guidelines.

9 Appendix

[Online appendix](#)

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