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ESG and Systemic risk

The mitigation effect of ESG on Systemic risk using a network approach

Supervisor

Ch. Prof. Giulia Iori

Graduand

Massimiliano Traverso

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ABSTRACT

This document aims at contributing to the fervent literature on ESG risk and sustainable finance by exploring the impact of ESG performance on systemic risk within financial systems. The study applies both the Delta CoVaR approach and network analysis. Using equity portfolios from major European banks and creating a system of supply chain relationships in the period from 2019 and early 2024, the study analyses the extent to which ESG factors can mitigate systemic financial risks, emphasizing the connectedness of the economic system rather than focusing solely on firm-specific information. By representing risk propagation through variance spillovers and analysing alternative methods' sensitivity to macroeconomic events, the research identifies key differences in how systemic risk is captured across methods. The comparative analysis of top contributors to systemic risk under different approaches reveals that each method targets distinct risk mechanisms. The main finding of this document is that ESG factors play a significant role in reducing and stabilizing financial systems. Implications for risk management and regulators include the importance of integrating ESG considerations in both corporate and financial decision-making to enhance portfolio and market resilience.

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INTRODUCTION

In recent years, Environmental, Social and Governance commitment has evolved from a social trend to a critical determinant for many modern companies. Corporate sustainability has gained popularity, particularly among larger companies, as they recognized its role in improving financial performance and reducing overall financial risk. As synergies generated by ESG become more and more central in academic and corporate discussion, addressing the need for standardized metrics to assess sustainable performance and to compare it across institutions and debating over the improved financial performance of ESG-driven securities.

The historical relevance of events like the 2008 financial crisis has drawn particular attention on systemic risk, defined as the risk of a system-wide default generated by the failure of a single or a group of institutions. The focus has therefore shifted towards identifying corporate practices could mitigate such destabilizing events with the potential to impact the global economy.

This thesis seeks to understand how ESG performance influences the broader financial system, particularly in inhibiting to some extent systemic risk. The central research question is: How does ESG performance influence systemic risk, particularly within interconnected financial systems like the ones created by major banks' equity portfolios? To address this question, this thesis applies two alternative approaches, network analysis and Delta CoVaR. A panel regression analysis is then conducted to further explore the relationship between ESG scores and systemic risk measures like risk contribution (SRE) and vulnerability (SRR).

By integrating these two concepts, this research provides new insights into how ESG factors may serve as a stabilizing force within financial systems, particularly during periods of systemic stress. The results of this study have significant implications for financial decision-makers, risk managers and regulators, underscoring the importance of incorporating ESG considerations into risk management frameworks and investment strategies.

Chapter 1 presents a comprehensive literature review, examining key aspects of ESG investing, financial externalities generated by ESG commitment, systemic risk and the regulatory framework surrounding corporate sustainability that influence the overall economic landscape.

Chapter 2 outlines the research design, describing sample selection criteria, data collection process and methods used to analyse equity portfolios of major European banks. This chapter also gives useful insights on banks' investment strategy, focusing on their prudent value-oriented approach. The construction and initial analysis of a network of supply chain relationships provides the foundation for the subsequent analysis.

Chapter 3 details the methodologies employed in the study, including the estimation of tail risk with Value at Risk, the quantification of Conditional Value at Risk with GARCH models, the construction of the spillover network with Generalized Variance Decomposition. A panel regression analysis is also introduced to assess the influence of ESG factors on systemic risk measures.

Chapter 4 showcases the results of the analysis, revealing key findings such as differences and similarities between Delta CoVaR and network approaches, the role of central nodes and sectors in risk propagation, underscoring the critical importance of the financial sector in causing and preventing systemic crises through both investment and lending activities. The chapter discusses the panel regression outcomes, confirming the impact of ESG performance reducing systemic risk.

Conclusions draw the sum of the document ex post, showcasing results and their contribution in offering a deeper understanding of the role ESG plays in managing systemic financial risk.

CHAPTER 1. LITERATURE REVIEW

This literature review chapter explores the multifaceted topic of Sustainable Investing, focusing on some of its key aspects, such as the informative power and challenges faced by the ESG scores industry; the investors' attitude towards sustainable investing, highlighting the challenge of overcoming the common belief that ESG securities yield less than traditional ones; and the interplay between ESG performance and credit ratings.

It then examines the influence of ESG on corporate reputation highlighting the reactive nature of ESG commitment to increased reputational risk. The paragraph will further examine the synergies of a bilateral relationship between ESG reputational risk and corporate financial performance.

The chapter proceeds introducing the concept of Systemic Risk and its growing relevance in understanding and preventing systemic financial distresses. It explores the ambiguous effects of portfolio diversification and investment similarities on systemic risk. To conclude, the chapter delves into the mitigating effects of ESG factors on systemic risk.

To provide a full overview of the context of the analysis, this chapter also sheds a light on the most important regulatory frameworks on sustainability, highlighting the governments' concern for sustainability and its importance in the modern era.

1.1 SUSTAINABLE INVESTING

In recent years, concerns for sustainability have evolved beyond a social trend to become a significant economic phenomenon. In fact, by the end of 2022, the market revolving around sustainability has experienced a tremendous growth, to the point that sustainability-focused funds managed more than 2,5 trillion dollars in global assets[1] (Goldman and Sachs, 2023). As global awareness of climate and social challenges increased, expectations for the economic system to integrate ESG considerations into business models and financial decision making have become increasingly relevant. In this environment, sustainable investing represents an innovative approach to foster sustainable development.

The term sustainable investing refers to the practice of considering environmental, social and governance factors in investment decisions, along with financial performance criteria. According to the UN Principles for Responsible Investment (UN PRI) developed by an international group of institutional investors and convened by the United Nations Secretary-General, sustainable investment stands on 6 pillars with corresponding implementing actions. We report the first three:

1) Incorporate ESG issues into investment analysis and decision-making processes,
2) Incorporate ESG issues into ownership policies and practices,
3) Seek appropriate disclosure on ESG issues by the entities they invest.[2]

Sustainable investment is a direct result of the rising pressure from stakeholders on firms to improve the generation of shared value. Consistently with stakeholder theory (Freeman 2010), as opposed to shareholder primacy, firms must maximize returns for all their stakeholders and not just the ones holding shares. Therefore, ESG fundamental strategies that incorporate stakeholders' benefit and empowerment are likely to maximize the firm's overall returns, thereby satisfying the needs of shareholders as well (Freeman, 2010).

For many years, sustainable investing prioritized return maximization and has been associated with the conception of "doing good by not causing harm". This perspective is exemplified by negative screening strategies, which involve avoiding investments in

[1] Goldman and Sachs, asset management, 2022 sustainability roundup and 20223 outlook, re-elaboration of Morningstar data
[2] The six UN Principles for Responsible Investing, overview

sectors associated with harmful activities such as oil and gas extraction, deforestation, tobacco and alcohol while pursuing profit. Sustainable investing strategies have then shifted towards rewarding virtuous behaviours using best-in-class positive screening strategies.

Consequently, as will be seen later in this chapter, ESG performance might become a profitable opportunity for firms in all sectors. As a matter of fact, a better ESG performance might enable corporations to obtain competitive advantages from increased brand strength and stakeholders' recognition, higher revenues, easier access to financing and access to public incentives. Sustainable investment can be profitable for financial institutions as well, and, as will be discussed, the regulator has appointed to financial institutions a crucial role in fostering sustainable development. By regulating financial firms, the regulator indirectly influences the global market and the overall economic environment. In fact, sustainable investment is an opportunity for hedging risk and reducing exposure to markets' volatility, hence making the economic system more resilient to market shocks and more likely to comply with regulation.

However, the sustainable investment industry still faces significant challenges, as it is characterized by subjectivity in defining relevant ESG factors and substantial qualitative information to manage. All these challenges result in the absence of standardized, uniform criteria for assessing sustainable performance, that ultimately complicates the development of coherent investment strategies.

1.1.2 DOES SUSTAINABLE INVESTING PAY OFF?

The debate on Sustainable investing's profitability has been extensively investigated by several studies in recent years, most of which concluding that sustainable (green) investing is a profitable opportunity for generating long-term value, with higher adjusted returns compared to the non-sustainable (brown) counterparts. However, such evidence still turns out not to be uniform, but contextual (Schanzenbach 2022).

For instance, Fulton et al. (2012) in a literature review on sustainable investing found that more than 85% of academic studies support the existence of a positive correlation between ESG performance and adjusted returns on firms. Compelling academic evidence show that strong Corporate Social Responsibility (CSR) and ESG factors are correlated with higher Corporate Financial Performance in the medium-long term, both market and accounting based (Fulton et al., 2012). Most of the remaining studies on Socially Responsible Investing (SRI) securities show neutral or mixed results, but still indicate a tendency in favour of positive rather than negative relationships (Fulton et al, 2012). Such result is consistent with the belief that the presence of financial materiality, better reputation and intangibles should enhance the financial performance of sustainable securities.

Despite these findings, a more recent study on sustainable indices by Jain et al. (2019) showed that “there is no significant difference in yield between sustainable indices and conventional indices, being a good substitute to the latter” (Jain et al., 2019, page 15), contradicting the common belief that sustainable investment securities yield lower financial returns when compared to traditional ones. According to the authors, there is a “bi-directional volatility spillover between sustainable indices and conventional indices” (Jain et al., 2019, page 15), meaning that “information from one index can be used to predict the behaviour of another” (Jain et al., 2019, page 15). Therefore, the authors suggest that the performance of sustainable investment can be more closely linked with traditional markets than previously thought.

The need to correctly diversify risk among sectors and geographical areas can be partly responsible for these mixed results. Using the best-in-class methodology, assigning a score to questionnaire respondents, Sustainable Stock Indexes oftentimes may include companies that are linked to ESG controversies (irresponsible companies). A study by Arribas et al. (2019) argues that traditional screening methodologies “do not correctly discriminate between responsible and irresponsible firms” (Arribas et al., 2019, page 2). In other words, using positive screening means comparing a company’s performance to its peers and choosing the best within the same industry. Consequently, industries whose characterizing activity is potentially harmful are included in the index due to sectorial representation and due to the need to achieve and maintain an appealing return for investors (Arribas et al., 2019).

In response to the wide criticism on screening strategies, indices are adopting increasingly sophisticated approaches aiming at significantly reducing the percentage of irresponsible companies included (Arribas et al., 2019). For instance, more rigorous ESG criteria are being implemented to ensure only genuinely sustainable companies are selected, and exclusion mechanisms are being meticulously designed. Moreover, regulatory framework and policies are constantly developing with the purpose of guiding the economic system through the sustainable transition and enhancing firms' transparency and accountability for their ESG practices.

1.1.3 ESG SCORING SYSTEM

The most used proxy for evaluating a firm's ESG performance are ESG scores. Oftentimes, scores provide valuable insights for investors seeking to make responsible investment decisions. However, the industry still needs to overcome various inconsistencies, which undermine the transparency and reliability of assessments.

Many academic studies question the ability of ESG scores providers to correctly assess a firm's effort to be responsible and analyse correlation between ESG ratings and ESG scandals. Kjaer and Kirchmaier (2023), for instance, address the problem of "ethical window dressing". In their study they suggest that "there is a risk of rating agencies capturing only the superficial commitments to responsible behaviour by companies" (Kjaer and Kirchmaier 2023, page 25). The authors claim that while E scores seem to fulfil their purpose, as a higher E score is linked with lower probability of scandals, S scores serve as a window dressing for companies pretending to be more responsible that they really are (Kjaer and Kirchmaier, 2023). In this way, a higher S score is linked to higher probability of ending up in a scandal. These two effects cancel each other out in part, explaining why there is no significant correlation on ESG aggregated scores (Kjaer and Kirchmaier, 2023).

Another one of ESG scores' inconsistencies is fragmentation is the presence of numerous ESG scores providers, each with its own methodology, format (numeric or descriptive rating), quantity of information considered and informative power. The absence of a common pool of information to consider when evaluating a firm, coupled with the lack of a standardized method for computing the score, causes a significant fragmentation in the scoring industry and fosters distrust in ESG investing.

As pointed out by Billio et al. (2021), "heterogeneity in rating can lead agencies to have opposite opinions on the same evaluated companies" (Billio et al., 2021, page 1), ultimately affecting the choice of the benchmark for the investment. This comparability challenge can cause substantial differences among providers' benchmarks for investments, making it harder to measure the ability of fund managers in security selection and asset allocation (Billio et al, 2021). It is therefore no surprise to find no consistent link between ESG score and financial performance in stocks. If providers agreed on a standardized approach, there would be a more homogeneous stock selection and a unique benchmark, likely resulting in a more noticeable correlation between ESG scores and financial performance (Billio et al., 2021).

In the same fashion, Ingo Walter (2019) states that ESG can be a useful to improve transparency and anticipate market movements. However, ESG scores face significant challenges due to lack of standardized criteria and variety of input sources (Ingo, 2019), including self-reporting and surveys that are likely to be biased. The unique challenge ESG risk rating poses is encompassing a wide range of metrics harder to quantify and standardize. In this environment, ESG scores can result in diluted information and, since there's no standardized rating methodology, there are potential conflicts of interest, especially for providers that also offer consulting services. As a matter of fact, consulting firms are more likely to be biased, improving the scores of their clients.

To conclude, despite ESG scores have been widely criticized by literature, they still represent the pivotal measure of sustainable investing. As a matter of fact, the first alternative measure to evaluate a firm's sustainability performance has been developed by the EU taxonomy in 2020, furtherly discussed in next chapters. ESG scores substantially influence banks' investment decisions and capital allocation, impacting on the perceived value of assets. Nonetheless, they still have a lot to prove, since the ability of ESG models of predicting future risks is very low due to the blend of different inputs encompassed to compute the scores.

1.1.4 ESG SCORES INTERPLAY WITH CREDIT RATING

Even though they still face several challenges, there is also an interplay between ESG performance and Credit ratings.

As a matter of fact, ESG scores can provide useful information for creditworthiness assessments or bond pricing. There is indeed a positive relationship between ESG performance and higher credit ratings, suggesting ESG criteria are increasingly useful for assessing risk sensitivity (Devalle et al., 2017).

Credit rating agencies have recognized the significance of ESG considerations, leading them to revise their methodologies to include ESG measures. This adjustment has led credit rating agencies to develop more accurate models for measuring credit risk, resulting in a more effective risk management (Chodnicka-Jaworska 2021).

Accordingly, Ga-Young Jang et al. (2020) observed that "ESG is complementary to credit rating in assessing credit quality, as credit ratings cannot explain away ESG effects in predicting future bond returns" (Ga-Young Jang et al., 2020, page 10) and that "ESG provides bond investors with extra downward protection by mitigating credit risk of small firms" (Ga-Young Jang et al., 2020, page 11). These considerations lead to the conclusion that "credit rating agencies should either integrate ESG scores into their current rating process with clear guidelines or produce separate ESG scores which bond investors can integrate with existing credit ratings by themselves" (Ga-Young Jang et al., 2020, page 11).

On the other hand, ESG models could benefit from adopting some robust practices typically belonging to credit rating models (for example stress testing and scenario analyses). As Ingo Walter (2019) states, credit rating models can be used as inspiration for designing ESG rating models, as both aim at providing market signals and address and monitor risk profiles. However, ESG ratings are less standardized, less clearly regulated and focused due to the variety of information they need to consider, which ultimately complicates their development and implementation (Ingo, 2019).

1.1.5 BELIEFS ABOUT SUSTAINABLE INVESTING

The aforementioned study by Billio et al. argues that disagreement on scores "disperses preference of ESG investors, to the point that even where there is agreement, it is so weak it has no impact on financial performance" (Billio et al. 2021, page 12). This quote, along with the prevailing belief that sustainable investments yields less than traditional ones, paves the way for a discussion about behavioural biases and challenges to sustainable investing.

For the sake of this analysis, it is important to distinguish between private and institutional investors. A study by Jansson and Biel (2010) investigated the substantial differences in motives for engaging in sustainable investing between institutional investors, professional fund managers and private investors, finding compelling evidence. The study revealed that "professional investors endorse self-transcendent values significantly less than their private beneficiaries" (Jansson and Biel, 2010, page 141). This happens because fund managers are monitored and rewarded based on their ability to generate return in the short term rather than on their capacity to act as socially responsible investors with a long-term perspective (Jansson and Biel, 2010). Additionally, as professionals are constrained by formal procedures, they tend to consider ESG information as “extra-financial information”, thus underestimating the importance of ESG factors in favour of traditional accounting-based and financial measures (Jansson and Biel, 2010).

The same holds true for institutional investors, who tend to be risk-averse with the primary objective of avoiding liabilities, as opposed to private beneficiaries who aim at maximizing their profit (Jansson and Biel, 2010). Nevertheless, while financial institutions still prioritize returns, they are more likely to engage in sustainable practices or invest in responsible firms since they are considered as externally accountable for their investments (Jansson and Biel, 2010). For example, investing in tobacco or alcohol companies is very likely to damage the institution’s image, compromising its attractiveness to investors. We will further discuss the importance of reputation later in this document.

Despite the growing interest on ESG investing of policymakers and institutions, consistently pondering the positive effects of ESG on the cost of debt and overall profitability (i.e. ROA), motives for retail investors to engage in ESG investing are still unclear. A study from Giglio et al. (2023) investigated retail investors behaviour and attitude towards ESG investing. Of all respondents, “45% do not see any specific reason to invest in ESG stocks, 7% of respondents are primarily motivated by return expectations, 22% perceive ESG stocks as a hedge against climate risk, and 25% are most motivated by ethical arguments for ESG investing.” (Giglio et al. 2023, page 2).

On average, then, investors expect returns on ESG products to underperform the equity market (Giglio et al. 2023). Indeed, investors might believe ESG securities are overpriced and likely to experience falling returns, or they might think lower returns are a consequence of an equilibrium mechanism where non-pecuniary benefits of hedging future climate disasters partially offset returns (Giglio et al. 2023). The second important contribution of the study is the inconsistency between individual reported motive and actual investment behaviour. According to Giglio et al. (2023), only 3,5% of respondents owned some share of ESG focused funds at the time of the interview. Half of said holders of ESG assets were primarily motivated by ethical considerations rather than return

(Giglio et al., 2023). Statistically relevant evidence shows that those who report to be motived by higher returns expectations, allocate a higher share of their investments in ESG funds, showing that they are coherent with their belief (Giglio et al. 2023). The most important finding of the study thus is that "within each group of investors with the same motive, ESG holdings vary substantially with expected returns" (Giglio et al. 2023, page 3). The powerful implication of this finding is that "traditional investment motives remain the most important driver in portfolio allocation even among those who engage in ESG investment for non-pecuniary reasons" (Giglio et al.,2023).

To conclude, sustainable investing still faces numerous challenges, primarily driven by lack of standardization in ESG scores, the presence of different motives and widespread beliefs that surround the matter. The overarching challenge remains the dominance of traditional investment motives, which continue to guide portfolio allocation decisions even among those interested in sustainable investing. Addressing these issues is crucial for future growth and effectiveness of sustainable investing.

1.2 ESG REPUTATIONAL RISK

The growing pressure from customers, investors and regulatory bodies to engage in sustainable practices has improved firms' awareness of the critical importance of reputation. As companies strive to meet stakeholders' expectations and adhere to stringent regulatory standards, reputational risk management, especially for ESG criteria, has assumed a pivotal role in strategic planning. As one might assume, a company's reputation can rapidly transform into a valuable intangible asset that can be determinant for the firm's competitive advantage, or into a significant vulnerability that threatens its market position. The debate on this delicate equilibrium between risk and opportunity has evolved into a complex yet fascinating challenge for modern firms.

In light of this perspective, stressing the crucial role of reputation building for modern firms, a study by Power et al (2009) suggests that "it may be more fruitful to regard 'reputational risk' as a reflexive category which has the potential to permeate managerial belief systems, rather than as a discrete risk management practice speciality" (Power et al. 2009, page 303). Their analysis argues that reputational risk has evolved into a managerial object, with organizations now accountable for managing reputational risk as a fundamental part of their risk management practices (Power et al., 2009).

1.2.1 ESG AND REPUTATIONAL RISK RELATIONSHIP

As sustainable finance grows popular, it is reasonable to expect companies to disclose their commitment to environmental, social and governance issues in integrated reports to embellish their reputation. As stated in several academic papers, ESG and reputation (ESG&R) are risk factors to be managed appropriately.

In particular, Karwowski and Raulinajtys-Grzybek (2021), analysed disclosed information on risk and Corporate Social Responsibility (CSR) activities. In line with the former Non-Financial Reporting Directive (NFRD) and the latest Corporate Sustainability Reporting Directive (CSRD), the ESG&R area is essential for both risk identification and future action planning. Although compliance with regulation remains the most common motive for non-financial information disclosure, the authors suggest that "high correlation coefficients between individual risks categories and CSR actions may indicate maturity of companies that has gone beyond the legal compliance and opportunity exploitation stage" (Karwowski and Raulinajtys-Grzybek, 2021, page 1281).

Conversely, it is important to remember that "correlation does not mean causation", meaning that acting responsibly might be a response to a reputation shock (Karwowski and Raulinajtys-Grzybek, 2021, Murè et al. 2020). In other words, a company could be involved in a controversy that compromises its reputation and therefore could decide to undertake responsible activities to repair the damage. In this sense, the increased number of socially responsible activities undertaken is an attempt to repair to a controversy's damage rather than the result of a proactive approach.

All this considered, this finding still highlights that companies are aware of the relationship between their actions and risk management, since they refer to CSR activities as steps to mitigate reputational risk (Karwowski and Raulinajtys-Grzybek, 2021).

A remarkable example of the reactive nature of ESG reputation risk has been documented by Murè et al. (2020). In investigating whether banks adopt ESG practices to reduce reputational damage due to financial penalties, they found compelling evidence in a pool of 13 Italian banks.

Although, as discussed earlier, ESG scores suffer from inconsistencies that ultimately compromise their informative power, a higher ESG score is frequently associated with virtuous behaviours. Accordingly, it seems logical to assume that the more sustainable a firm is, the less likely it will incur a financial penalty. Surprisingly, the research found statistically relevant and robust evidence on a positive relationship between ESG score and probability of sanctions, meaning that "being sanctioned has a positive impact on the bank's level of ESG score" (Murè et al., 2020, page 275).

The authors believe this rather odd phenomenon can be explained on a "reputational basis" (Murè et al., 2020). "In fact, after receiving financial penalties, it is necessary for banks to improve their reputation through the adoption of sustainable activities" (Murè et al., 2020, page 275). In line with Karwowski and Raulinajtys-Grzybek, it seems that the improvements in ESG scores are driven primarily by the firm's effort to rehabilitate their reputation following the sanction rather than a proactive commitment to sustainable practices.

To sum up the discussion, while companies are increasingly aware of the interplay between their actions and reputation, the motivations behind CSR activities are often reactive to a reputational shock. Whereas regulatory compliance still is the main motive driving disclosure, true maturity is shown when companies go beyond compliance to genuinely integrate ESG considerations in their strategic planning.

1.2.2 FINANCIAL IMPLICATIONS OF ESG REPUTATIONAL RISK

Once discussed the rising importance of reputational risk in its managerial and organizational dimensions, let us now delve into the financial considerations surrounding ESG reputational risk. Understanding financial implications of ESG reputational risk is crucial, as it has proven to not only influence corporate financial health, but also shape investor behaviour.

Firstly, it is necessary investigate the link between ESG performance and Corporate Financial Performance. Numerous studies addressing the issue find no significant effect of greater ESG commitment on financial performance (Mandas et al., 2024). This could be due to the use of traditional regressive models, which might suffer from endogeneity issues by not considering that financial performance and ESG could simultaneously influence each other (Mandas et al., 2024). Papers that account for this bidirectional nature of the relationship report that ESG performance is positively associated with future corporate performance, supporting the notion that "good management" and ESG are related (Mandas et al., 2024).

This being said, an inverse bi-directional causality between reputational risk exposure and market valuation appears to exist (Mandas et al., 2024). Accordingly, an increase in ESG reputational risk exposure leads to a decrease in financial measures like price-to-book ratio and vice versa (Mandas et al., 2024). Additionally, institutions with higher reputational exposure exhibit a greater variation in market evaluation in response to an ESG shock (Mandas et al., 2024).

This result aligns with Prospect Theory, according to which, for the same variation of risk, the market punishes more severely those who are deeper in the "negative domain". Furthermore, it seems that while a shock impacts financial performance immediately for up to 5 months, it takes on average 12 months to fully recover, underscoring the concept that "trust is hard to get but easy to ruin" (Mandas et al., 2024).

Reputational risk influences payouts, capital structure and debt structure as well. Evidence shows that "higher reputational risk relates to higher payouts" (Chasiotis et al, 2024, page 871). Intuitively, this quotation seems contradictory with the notion that "higher ESG reputational risk raises financial risk", thus some clarifications are needed.

It is true that "ESG-relevant deeds and misdeeds form expectations with regards to future behaviour" (Chasiotis et al, 2024, page 871), so that higher reputational risk leads to higher agency costs and cause stakeholders' distrust. As a matter of fact, firms with low ESG reputational risk exposure are perceived by investors as "well managed" and tend to be characterized by higher firm value, productivity and profitability and often associated with lower cost of debt (Chasiotis et al, 2024). These advantages attract investors, leading to an easier access to external financing. On the other hand, "increased reputational risk undermines trust between investors and managers, thereby increasing adverse selection costs and consequently impedes access to external financing" due to higher cost of debt (Chasiotis et al, 2024, page 872). Nonetheless, "badly managed" companies, needing to attract investors as their resources shrink, often increase payouts through dividends or share repurchases to reward risk-bearing investors. Generally, as a change in dividend payout policy is likely to trigger a negative market reaction, dividends tend to be rigid and stable. Conversely, an increase in stock repurchases, meaning the firm buys back its own shares in the market, are flexible and do not cause negative market reactions. In fact, sharing buybacks gives spotlight to the firm in the market, signalling undervaluation and stimulating investors to buy. To conclude, low ESG reputational risk is a signal of financial health, very likely acknowledged by investors in financial decision making (Chasiotis et al. 2024).

Moreover, research shows that "governance has a substantial impact on value through its impact on cash" (Dittmar and Mahrt-Smith, 2006 page 599). Dittmar also demonstrates that "$1.00 of cash in a poorly governed firm is valued at only $0.42 to $0.88. Good governance approximately doubles this value" (Dittmar and Mahrt-Smith, 2006, page 599). Applying this concept, investors believe in market potential of "well managed" firms, valuing those likely to make a good use of liquid assets more highly.

In summary, we enforce the vision that ESG reputational risk is indeed relevant for companies' financial health. Excess resources coming from past good corporate financial performance can be used to improve ESG performance, while good ESG performance reduces the firm's future volatility, provides a more flexible and resilient structure, enhances the adaptability to changing market conditions, and reduces the cost of debt and agency concerns.

1.3 SYSTEMIC RISK

When evaluating a firm's risk profile, it is common practice to refer to two types of firm-specific risk: fundamental risk and idiosyncratic risk. The former arises from an asset's basic characteristics that may be specific to its sector or business; the latter pertains to the firm's (or asset's) unique attributes that distinguish it from the others. However, to understand and prevent phenomena of global economic disruption, such as the 2008-2010 financial crisis, academic research, financial institutions and policymakers have increased their focus on the importance of the risk comprised by the economic environment and its relationships. Such risk of a potential collapse of an entire financial system or market due to the failure of a single entity or a group of entities is called systemic risk.

Typically, the systemic risk is analysed with respect to the cascade effect of credit risk. As one might know, credit institutions undertake the collection of deposits or other repayable funds from the public and grant credit for their own account. Granting credit through loans exposes banks to the risk of not getting back the money they lent. This risk is commonly defined as credit risk. Furthermore, banks not only engage with the public, but also interconnect with each other in a network of economic relationships, the financial system. As long as none of the agents default, the system is stable and provides liquidity to the market.

Intuitively, as banks simultaneously hold claims on each other's liabilities and with clients, the risk of a systemic default becomes noticeable. If a bank agreed on giving out a loan to a particularly risky counterpart who is very likely to not pay the money back, the resulting loss would directly affect the bank's financial health. Consequently, the bank might struggle to fulfil its obligations to other banks from which it has borrowed money, defaulting on its own contracts. This "contagion" effect can spread rapidly throughout the financial system, leading to widespread defaults of interconnected institutions. To manage such risk, banks' approach aims at creating sophisticated credit scoring methods that account for both assessing clients' creditworthiness and their systemic relevance.

This cascade of defaults also impacts the stock market. When a defaulting bank sells stocks from its portfolio to gather liquidity, it hints the market that the securities are overpriced, causing many other investors to sell. If then several banks have invested in the same assets and the stock's value decreases due to the high trading volume, the value of the portfolio of all the banks in the network also declines. The benefits or undesired effects of diversification will be discussed later.

Systemic risk, being a very complex phenomenon influenced by several aspects, presents a formidable challenge for regulatory action to mitigate the worst possible scenarios. For instance, a study by Roukny et al. (2018,) highlights that "even in the case of complete knowledge of the web of contracts and shocks, multiple equilibria can exist depending on the network structure" (Roukny et al., 2018, page 94) and the presence of cycles and mutual dependencies. This implies that as market structure becomes more complex, uncertainty, the probability of loops and the number of different outcomes increase.

An additional layer of complexity is introduced by agent behaviour. According to the study by Roukny et al. (2018), the realization of each equilibrium is the result of a set of actions of market participants. Therefore, "there exists a range of external shocks such that the equilibrium where all banks default and where none defaults co-exist" (Roukny et al,2018, page 94).

1.3.1 DIVERSIFICATION AND SYSTEMIC RISK

Both the financial system and systemic risk revolve around correlation. The more similar two portfolios are, the more likely it is to experience poor performance in both because of the same shock, thus they are riskier. To overcome such issue, Markowitz (1967) pioneered the theory of efficient diversification, which comprises increasing the number of holdings in a portfolio to hedge financial risk. However, recent literature suggests that diversification sometimes increases risk rather than reducing it.

For instance, Wagner (2010) argues that diversification raises the probability of joint failure and, consequently, of systemic crises. The intuition here is that while diversifying into the assets of another bank reduces the probability of failure, "diversification makes the two banks more similar to each other by exposing them to the same risks" (Wagner, 2010, page 373). Therefore, a bank's payoff is influenced not only by its own financial conditions but also by the conditions of the institutions to which it is connected.

Enforcing this perspective, Tasca et al. 2017 conclude that the probability of a systemic crisis also depends on the ability of banks to internalize the negative externalities within the network. As a matter of fact, if a bank becomes insolvent and sells its asset to a solvent bank to avoid incurring in liquidation costs, the two banks increase overlapping in their portfolios, thus increasing the probability of failing together (Tasca et al, 2017).

Generally, it is true that diversification reduces returns' variance (risk indicator) and increases the likelihood of portfolio returns moving along with the market. Since the future trend of the market is unpredictable ex ante, the optimal level of diversification should be in between the two maxima of a bimodal function of forecasted market trends (Tasca et al, 2017). However, Tasca et al. (2017) found that this intuition of balancing risks by not fully diversifying suffers from a "logical fallacy, as maximizing convex combination of functions is not equivalent to take the convex combination of maxima" (Tasca et al, 2017, page 112). They conclude that banks' optimal choice is to fully diversify across external assets, even if it leads banks to have highly correlated portfolios and suffer from simultaneous defaults (Tasca et al. 2017). Therefore, full diversification is often the rational choice to hedge against individual asset failure, even if it entails the potential for increased systemic risk.

A great example to investigate the efficacy of diversification strategy under financial distress is provided by mutual funds and investor behaviour during the period between 2008 and 2010. Assuming that "a more densely connected financial network serves as a mechanism for the propagation of shocks" (Delpini et al., 2019, page 2), similarity across investments is a fundamental driver of systemic risk. Delpini et al. (2019) observed that portfolios tend to become more diversified during financial crises. Nevertheless, "depending on the structure, the way diversification is pursued and the level of interdependence between strategies … increase cross-correlation among assets, thus amplifying financial risk" (Delpini et al., 2019, page 2). They argue that, despite increased diversification, investment decisions among market players are still highly correlated, so that investment similarities become more likely (Delpini et al. 2019). For example, investors tend to shift from equity funds to fixed income funds due to increased risk aversion, and professional investors with similar targets are likely to adopt the similar investment strategy (Delpini et al, 2019). This herding behaviour ultimately limits diversification benefits.

In summary, while diversification is seen as a strategy to mitigate financial risk, recent literature suggests that under specific conditions it can foster systemic crises. Diversification can increase similarities and correlation between portfolios, ultimately amplifying the risk of joint failures. Therefore, the optimal diversification strategy, balancing risk mitigation and systemic stability, is context-dependent.

1.3.2 ESG AND FINANCIAL SYSTEMIC RISK

The fervent discussion on sustainable investing tends to shape corporations' practices and regulatory frameworks. There is broad consensus that material concerns should determine a firm's commitment and strategic planning. Materiality entails that companies shall consider the impacts they can directly cause on ESG factors (impact materiality) and the impacts ESG factors can have on their performance (financial materiality). Regulators' efforts to foster sustainable transition comprise rewarding green companies while negatively affecting brown ones. However, as previously discussed, progressively imposed regulatory uniformities can potentially increase similarities and correlation in business models, negatively affecting diversification opportunities and creating a more fragile financial and economic system. It is therefore worth to discuss the relationship between ESG and financial systemic risk.

Compelling evidence shows that positive ESG performance significantly increases "sensitivity" of systemic risk. As a result, the more a company improves its commitment to ESG, the greater its contribution in mitigating systemic risk will be (Curcio et al, 2024). As previously stated, the integration of sustainable practices signals financial health, enhanced profitability and productivity, stronger stakeholder relations due to better reputation and trust; all these variables collectively contribute to an overall more stable financial environment.

However, the flip side of the coin manifests when market conditions deteriorate. Indeed, in response to experiencing negative results, the risk exposure towards ESG-compliant firms (their value at risk) can increase steeply, ultimately increasing their contribution to systemic distress (Curcio et al., 2024).

In essence, while positive ESG performance generally acts as a stabilizing force under favourable conditions, it also introduces a higher degree of sensitivity to market fluctuations.

1.4 CONTEXT and REGULATORY FRAMEWORK

The common term "Sustainability" is a multifaceted concept that is worth exploring. In the report on Environment and Development "Our Common Future", the World Commission outlines the overall strategy towards sustainability, providing detailed guidance through the regulators' common concerns, challenges and endeavours. In this report, sustainability is defined as intragenerational fairness for the environment and society, emphasizing the importance of acting today to safeguard the wellbeing of future generations. In this definition, sustainability represents an ideal state of things, a scenario in which future generations enjoy the environment in the same way as current generations do. To achieve such scenario, the United Nations introduced the concept of Sustainable Development, a process of change in which actions to preserve or improve environmental conditions are made consistent with the needs of both future and present generations.

Sustainable development is a response to unprecedented challenges of our time, seeking to balance beneficial actions for the environment, society and the economy. Moving along with this view, the United Nations have developed the Sustainable Development Goals (SDG), seventeen ambitious objectives to be included in the global 2030 agenda.

Every human organization shall contribute to the achievement of SDGs, as they simultaneously impact the environment and rely on it. Within this framework, sustainability accounting is a range of techniques designed to measure, plan and control the organization's impact. Sustainability accounting plays a pivotal role in identifying and stopping unsustainable actions, in supporting decision making and in curing the relationship with stakeholders. Sustainability accounting techniques generally follow three different approaches: estimating of the sustainable cost, the cost of restoring Earth to the state preceding the organization's impact; tracking the stock of natural capital over time looking for detrimental factors, natural capital inventory; and recording of flows of input consumed and waste generated.

While sustainability accounting has internal focus, providing managers with critical insights, sustainability reporting serves an external purpose, providing stakeholders the information they need to make thoughtful investment decisions. Oftentimes, organizations report their sustainability initiatives not only to fulfil responsibilities for their actions and enhance their reputation but also to demonstrate accountability for their actions.

Although sustainability reporting has recently become mandatory, it had already grown popular among large companies in recent years, driven not only by stakeholders' pressure but also by the potential to leverage competitive opportunities and capitalize advantages. Nevertheless, critical issues like greenwashing and lack of authenticity still undermine the credibility of this practice.

1.4.1 SUSTAINABILITY REPORTS BUILDING BLOCKS

Effectiveness of the sustainability report is enhanced when it accounts for three characteristics: the report shall comprise the information stakeholders need, shall address material aspects of the corporation's activity and shall maintain clarity, especially when including relevant details on the corporation's supply chain. More specifically, a high-quality sustainability report shall be accurate, clear and tailored to its audience, presenting both positive and negative information with a detached perspective. It shall be corroborated by empirical evidence or data, and shall maintain comparability with past reports as well as with other companies' reports.

The process for disclosing sustainability performance comprises five building blocks that represent fundamental information. The first is to showcase the motive behind the report's publication, whether it is carried out for economic strategic motives or resulting genuine commitment to the environment. Usually, economic motivations are rooted in the desire of improving revenues, retaining powerful stakeholders and exploiting the reputational benefits for strategic advantage. Conversely, a genuine commitment pertains to the belief of the report being a powerful tool to inform a wide range of stakeholders about the use of their resources for the greater good, thereby increasing transparency and discharging accountability for their actions.

Stakeholders' identification is a second crucial building block of sustainability reporting, intrinsically linked to the motive for reporting. Institutions reporting for economic reasons are likely to prioritize stakeholders with economic interests, since they can potentially provide greater financial income and have economic and decisional influence on the institution itself. In contrast, some companies just want their report to be accessible to every stakeholder that might have some kind of interest in it. In general, it is usual practice to follow the salience model for stakeholder identification. Such model identifies relevant stakeholders according to their ability to impose their will on the company, their power, the appropriateness of their claim, legitimacy, and urgency of their demands, the nearer the threat, the more important they become. Companies are then expected to disclose their policies for engaging with stakeholders and to manage the relationship with them, mainly disclosing the means of communication and the plans of action to incorporate stakeholders' claims into their objectives.

The third step is to identify what information is to be reported through the materiality analysis. Information is included when it can have potential financial effects on the value of the company, namely financial materiality, or, on the other hand, when it concerns the organization's impact on the environment. An interesting discussion surrounds the matter and the process to assess materiality of information at regulatory level, thus it will be further dealt with in next paragraphs.

At the core of the disclosure process is portraying corporate action and plans to deal with sustainability issues.

The final common practice is external assurance, an independent review of the report by an external institution to prove its credibility. Assurance can be conducted at two levels:

limited assurance only checks for alignment to legal and standard requirements and reasonable assurance, which offers a more accurate examination of the company's disclosed performance.

Arguably, creating such a comprehensive document can be a significant challenge for companies, not to mention costly. To aid this process and foster comparability, many standards and frameworks to provide guidance have been developed. The most notable examples are the Global Reporting Initiative (GRI) standards with focus on societal value and how the company contributes to sustainable development and the Sustainability Accounting Standard Board (SASB) standards, that are more focused on the environment's impact on the company's cashflows.

1.4.2 NON-FINANCIAL REPORTING DIRECTIVE NFRD

As forementioned in previous paragraphs, one of the most critical issues in non-financial reporting is greenwashing. When companies have freedom to selectively disclose information or omit negative aspects of their actions or even avoid disclosing anything at all, stakeholders might be damaged. In fact, not being able to discern truthful information might mislead investment decision-making, granting competitive benefits to unworthy players. Consequently, regulatory intervention is justified and necessary to enforce correct disclosure and warrant sustainable investors' interests.

The European Commission strongly believes that disclosure of non-financial information is essential to the transition to sustainable economy, as it helps identifying sustainability risks and increases investors trust. Thus, with regulatory pieces such as the 2014 Non-Financial Reporting Directive (NFRD), the Commission established minimum disclosure requirements and mandatory reporting for certain types of corporations.

The personal scope of the directive is limited to large undertakings and public interest entities and activities. This includes all listed companies, financial institutions and companies that meet at least two of the following criteria: over 20 million euros in revenue, 40 million in total assets and more than 500 employees.

Though firms are free to choose to write their report in accordance or with reference to the standard they want, the directive requires them to include information about every dimension of Environment, Society and Governance. In this framework, firms are expected to disclose their approach to the most material issues about environmental impact, workforce conditions, human rights, their stance on corruption and bribery. Although the structure of the report follows a flexible scheme, it is common practice to follow this format: the report starts with a brief description of the firm's business model, it then encompasses stakeholder identification and engagement policy, followed by the materiality analysis focusing on risks and opportunities with particular declination or physical risk factors and transition risk factors, a description of pursued policies relating tot the most material issues and concludes with non-financial key performance indicators.

Materiality assessment is maybe the most crucial prescription on the directive. There are three substantial approaches to materiality: impact materiality focuses on the impact on the environment generated by the company (inside-out approach), financial materiality prioritizes the consequences of environmental factors on the company's financial performance (outside-in approach) and double materiality combines the two approaches, stating that information shall be disclosed if it is material for either perspective. The heated debate stems from the fact that NFRD prescribes a double materiality approach while not properly defining it. This ambiguity resulted in reduced comparability, as different standards adopt different approaches; for example, using the GRI standard and using the SASB standard might result in completely different materiality assessments.

When it comes to assurance, the NFRD package does include a requirement for statutory assurance yet leaves the Member States free to transpose the requirement in their national law.

The main criticisms of the NFRD pertain to comparability issues and reliability. Many stakeholders express the need for a common standard, more assurance requirements and more detailed guidance on materiality assessment process.

1.4.3 CORPORATE SUSTAINABILITY REPORTING DIRECTIVE CSRD

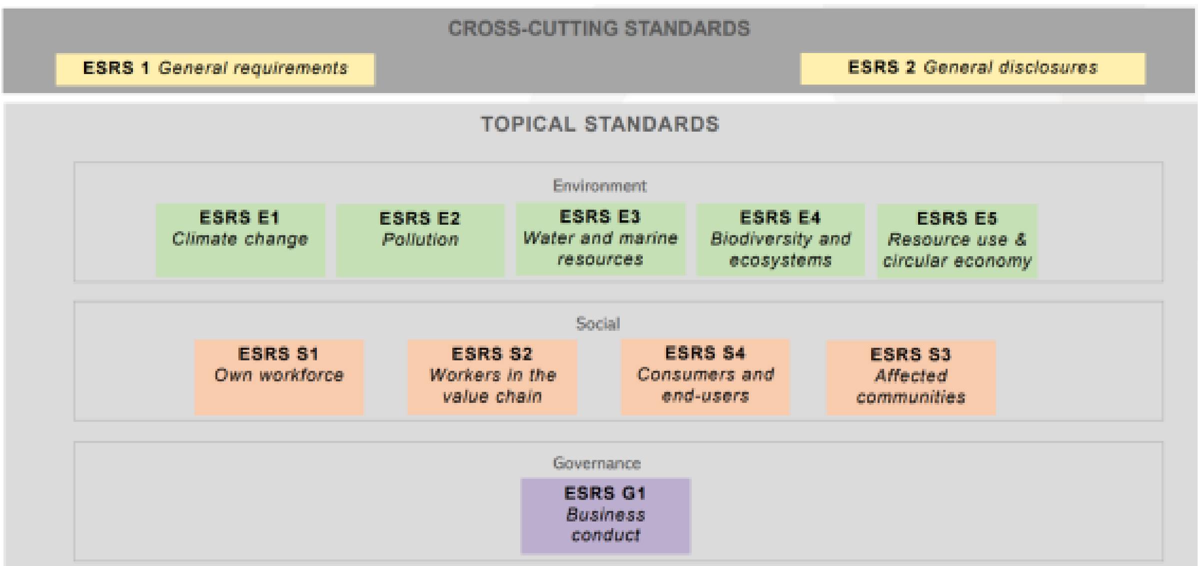
The claims of stakeholders have been addressed with the introduction of the corporate sustainability reporting directive. In response to surveys, the personal scope of the directive has been expanded to large non-listed companies 250 or more employees, all companies with registered office in Europe that have their securities listed in European markets, companies that are subsidiaries of groups based in Europe, non-EU companies generating net turnover of over 150 million euros having one of their subsidiary listed in EU markets or falling under the large company threshold.

Contents under CSRD are similar to those of the NFRD with some new elements. These include target description, details on administrative supervisory bodies, and the due diligence process along the value chain (which involves collecting information prior to an operation in order to achieve an appropriate degree of knowledge on relevant issues). Additionally, the CSRD mandates risk descriptions, indicators that inform on key intangible resources and dependency on such resources. A significant new requirement is mandatory limited assurance, even though member states can apply national assurance standards.

The strongest prescription of the CSRD is the introduction of a unified standard for reporting: the European Sustainability Reporting Standards (ESRS). The goal of the regulator is to enhance consistency across various regulations outlined in the 2018 EU action plan, the first group of regulatory bodies for sustainable development. The action plan aims to encourage investors to incorporate ESG criteria into all investment decisions, alongside financial considerations. Ultimately, the plan seeks to reorient capital flows towards sustainable investment, reducing risk of environmental degradation and improve transparency.

ESRS structure: two cross-cutting standards that apply to all companies, topical standards divided into three categories environmental, social, governance, and sector-specific standards.

Picture 1. General structure for ESRS



(source: Shape the new European sustainability reporting standards for SMEs)

The two cross-cutting standards define general requirements and general disclosure, outlining the standards' architecture while setting up general requirements. As stated in ESRS 1 general requirements, every standard comprises four reporting areas: governance, strategy, impact risk and opportunities and metrics and targets. Information must be relevant and provide a faithful representation of the company's reality.

To take an example, ESRS 2 general disclosure encompasses every aspect comprising general information about the institution: governance pertain to administrative bodies composition, due diligence process, incentive schemes and internal control processes, strategy includes the overview of the firm's strategy and value chain, stakeholders identification and the most material risks and opportunities related to the strategy, risk and opportunities showcases the process to identify material topics and a summary of disclosure of requirements covered by the report, metrics and targets showcase the metrics used to evaluate risk and performance and establishes outcome oriented targets.

In response to criticisms to the NFRD, ESRS 1 provides a clearer definition of materiality: as in NFRD, double materiality is the combination of both impact and financial materiality. Impact materiality is defined as the effects of a company's actions that could harm future generations' interests, either directly or indirectly. For instance, a financial firm who invests in harmful activities must consider the impact of such activities as material, even if it is not directly involved. Financial materiality, on the other hand, is determined by what is considered significant by economic stakeholders. Thus, a topic is material when it potentially triggers financial effects on the undertaking.

Assessing materiality involves analysing magnitude and probability of something to happen; in this sense, companies shall consider the existence of dependencies on natural and social resources, as well as the risk and opportunities stemming from these dependencies. The process thus begins with considering the context, identifying and evaluating actual and potential impacts, assessing the significance of impacts, prioritize the most significant ones and ultimately producing a list of the most relevant topics.

1.4.4 EU TAXONOMY

The first major regulatory initiative of the 2018 EU action plan is the EU Taxonomy. The purpose of this regulation is to establish a unified classification system and a clear definition of sustainable activity. The rationale behind this regulatory intervention is the need for a standardized measure to compare different companies' ESG performance, address the fragmentation in methodologies used by the ESG rating industry, and achieve a higher level of detail in sustainability assessments. Hence, the purpose of the EU taxonomy is neither to mandate a list of activities in which investors must invest nor to define a rating of sustainability performance. instead, it provides criteria for defining whether an activity can be classified as sustainable.

Since a company is the collection of the various activities it performs, with countless different combinations, the regulation seeks to be as comprehensive as possible by achieving the highest degree of granularity: the single economic activity. The "taxonomy compass" is essentially a list of all verified sustainable activities. Given the complexity of analysing every single economic activity, not every activity has available screening criteria for the time being. Therefore, an activity is called eligible when it is included in the list of activities that are sustainable but lack of specific technical criteria, and it becomes aligned when it is included in the list, has technical screening criteria and the company complies with them.

According to article 3 of the EU Taxonomy, an activity is defined as sustainable when it is in line with four requirements:

1. It substantially contributes to the environmental objectives set out by article 9. Such objectives include climate change mitigation, climate change adaptation, protection of water bodies and marine resources, circular economy, pollution prevention (air, water and soil) and protection of biodiversity.
2. It does not significantly harm any of the other objectives. Such provision is fundamental and tackles a critical issue, the need for a neat contribution. If, for example, an activity reduced a company's carbon footprint by storing CO_2 in water, such activity would substantially contribute to climate change mitigation, but negatively affects water bodies protection, thus failing the DNSH criteria.
3. Is carried out in compliance with minimum safeguards.
4. Complies with the screening criteria established by the Commission. Technical screening criteria are based on previous regulation and refer to conclusive scientific evidence

Financial entities, whose activity does not directly cause environmental impacts, play a critical role in this framework by redirecting capital flows towards sustainable securities.

Whereas the taxonomy cannot constrain the financial market to invest on green projects by promising greater returns, it leverages reputation an alternative solution. Articles 5,6,7 of the taxonomy therefore divide financial instruments into three categories: article 5 instruments are financial products linked to activities that explicitly pursue one of the six objectives of the taxonomy, article 6 instruments are financial products that integrate sustainability risks, article 7 includes all other financial instruments. The sustainability performance of a financial institution is measured through the Green Asset Ratio and the Green Investment Ratio, which reflect the proportion of green assets and investments over total assets and investments. In other words, such ratios measure the proportion of article 5 products issued over the total instruments issued. In such way, the more article 5 financial products, the better the reputation, thus the more investors are attracted.

Moreover, every article 5 instrument is related to a Capex plan, a plan for a company to improve the proportion of capital expenditure in sustainable project over the total capital expenditure with both backward- and forward-looking perspective. Such instruments are beneficial for all parties involved: the company obtains access to financing, the financial institution GAR increases, and the environment enjoys innovation from science based sustainable transition plans.

1.4.5 OTHER RELEVANT SUSTAINABILITY REGULATION

This paragraph will very rapidly address other pieces of regulation that directly or indirectly influenced sustainable finance by affecting other sectors' activities.

2019 Single-Use Plastics Directive: as part of the EU plastics strategy, this EU directive aims at reducing the environmental impact of plastic products, by focusing on the reduction and eventual elimination of single-use plastics. It bans the use of certain products and requires producers to cover waste management costs. This regulation has significantly impacted the packaging and consumer goods sectors by pushing companies to innovate sustainable packaging solutions and reduce plastic waste.

Single use plastic products SUPs are used once or for a short period of time before being discharged. Since plastic waste, along with fishing gear, accounts for 70% of all marine litter in the EU, the directive assumes a critical role in the fight against marine litter and plastic pollution. To this end, items such as beverage and food containers, plastic bags and packets and wrappers can no longer be placed on EU Member states' markets, since sustainable alternatives are easily available and affordable.

In the same fashion, many other countries such as Canada (2022), India (2022), Australia (2021) and South Korea (2022-2023) have implemented similar restrictions to the use of SUPs, demonstrating once again EU's leading and inspiring role for a global sustainable transition.

2015 UK Modern Slavery Act: this legislation requires companies to report on measures they are taking to prevent slavery and human trafficking within their operations and supply chains. Although focused on social sustainability, this piece of regulation has broader implications for sustainable sourcing and ethical supply chain management, especially in the manufacturing sector. As a result, the UK modern slavery act has led to increased supply chain scrutiny, encouraging businesses to adopt more careful and transparent practices.

The EU Emission Trading system: developed in 2005, becoming part of the EU's 2030 climate and energy framework established in 2014, and boosted by the launch of the more ambitious climate initiatives of the European Green Deal, the Emission Trading System (ETS) represents an innovative approach to manage GHG emissions on the atmosphere. As a matter of fact, the EU ETS was the first market-based approach to help reducing EU emissions while generating revenues to finance the green transition. The system is based on the "cap and trade" principle, setting a limit on the total amount of GHG that can be emitted by all operators. This quantity of total emissions is expressed in emission allowances where each allowance represents the right to emit one tonne of CO_2. Allowances are then negotiated in auctions first and can then be traded as needed among companies. The price of allowances is set out by the EU carbon market, and represents the revenue generated from the sales, over 175 billion euro since 2013. The ETS revenue primarily flows to national budgets used to support investments in renewable energy, energy efficiency improvement and low carbon technologies. The remaining share of the revenues supports low carbon innovation via the Innovation fund and Modernization fund. Of course, the introduction and the progressive shrinking of the cap has substantially impacted the energy and utility sectors, spurring innovation and increasing acute and chronic risks of incurring in heavy sanctions and in limited access to financing.

2020 Japan's Green Growth Strategy for Carbon Neutrality: this regulation outlines a roadmap to achieve carbon neutrality by 2050. It focuses on promoting investment and innovation in the most relevant sectors, including electric vehicles, hydrogen, offshore wind. The strategy encourages companies to invest in renewable energy and zero emission technologies through financial incentives.

Finally, in 2023 the United States Environmental Protection Agency (EPA) updated regulations on the **Toxic Substances Control Act** to impose stricter controls and bans on the use of a group of persistent environmental polluters ("forever chemicals"). This act most important objective is to reduce environmental contamination and mitigate the risks for human health linked to the exposure to harmful chemicals.

The regulation requires manufacturers to notify new chemical substances prior to the manufacture, require testing, certification and reporting requirements of chemicals by manufacturers, importers or processors, the EPA maintains an inventory of dangerous substances.

This regulation impacts on the manufacturing and chemical industry as well as on the consumer product industry, requiring companies to phase out forever chemicals in their products (cookware, packaging materials, textiles).

CHAPTER 2 RESEARCH DESIGN: SAMPLED DATA AND PRELIMINARY ANALYSIS

This chapter explores the research design methodology, presenting a comprehensive overview of the data collection process and preliminary analysis.

It begins by outlining the methodology used to gather and process the data to create a network of economic relationships that resembles the economic ecosystem. The paragraph emphasizes the importance of a robust dataset for analytical integrity, though highlights some possible limitations linked with the manual data collection process.

The discussion then progresses to a detailed examination of the sample's descriptive measures, offering insights into sectorial and geographical attributes of the collected data. The paragraphs consider data on averages and standard deviations observing sectors and geographical area specific characteristics based on the sample’s structure and the time interval considered.

Following this, the chapter explores banks’ portfolio analysis techniques, including individual portfolio performance measures and sectorial performance attribution. A cross-cutting analysis is then presented, investigating potential overlaps and correlations among different portfolios.

Finally, the chapter concludes with an examination of banks' disclosed orientations towards Environmental, Social, and Governance (ESG) factors, as emerges from their non-financial reports.

Throughout, the chapter maintains a focus on the interplay between financial performance, risk management, and sustainability considerations in the banking sector.

2.1 DATA COLLECTION AND DESCRIPTION

To ensure the robustness of the empirical analyses conducted, it is essential to outline the data collection process and identify the primary sources from which the data was obtained. As one might imagine, a strong data base is essential for analysis robustness.

The data collection process begins with the careful selection of banks. Given the complexity of systemic risk analyses, caused by the multifaceted nature of the phenomenon under study, it is essential to choose sampling variables carefully. Two key variables in this process are size and geographical representation.

In general, larger institutions tend to hold a dominant position in the economic landscape, exerting significant influence on other market participants. As a result, these banks typically have higher systemic importance, impacting financial markets, national economies, and other banks more profoundly with respect to smaller counterparts. Another common challenge when considering smaller institutions is the availability and transparency of data.

Larger banks, due to their systemic significance, are subject to stricter disclosure requirements, resulting in a substantial amount of information that is often not available for smaller entities. Additionally, larger institutions generally have more resources dedicated to reporting, leading to more comprehensive non-financial disclosures.

The geographical diversification of the sample is intentional to ensure a broader scope of analysis and to compare potential differences across countries. However, to maintain consistency in the regulatory framework, only institutions subject to the same European regulations are considered, excluding those from Asia or America.

For these reasons, five of the largest European banks have been selected for this analysis, ensuring both the relevance and availability of the data required for a robust study.

The second step of the data collection process consists of analysing banks' investor profiles, specifically by examining the most weighted equity holdings for each bank. Considering the top holdings in the equity portfolios of banks can indeed be valuable for an analysis of systemic risk. These top holdings can provide insights into the banks' exposure to certain sectors, companies, or markets, revealing potential vulnerabilities or concentration risks that could have broader implications for the financial system. Since equity holdings are typically more transparent and publicly available compared to credit portfolios, analysing them allows for a more detailed understanding of the interconnectedness between banks and the broader economy and reduces the probability of data gaps or inaccuracies. Moreover, equities tend to be more liquid than loans and other financial assets as they are designed to be easily transferred. This feature makes them more sensitive to market changes, making them more suitable for systemic risk considerations. Since banks are highly diversified, there is a substantial amount of equity holdings in their portfolios, sometimes with minimal weight. To avoid diluted results and analyses, holdings were chosen with the following selection criteria and were normalized, if needed: the sum of all weights considered shall exceed 20% of the original portfolio weight, the single security shall cover at least 0,3% of the portfolio, the number of considered holdings shall exceed the top 10 holdings.

To replicate a real economic system, supply chain relationships have been considered as the third step of the data collection process. Specifically, for each holding in the equity portfolios, the most relevant suppliers, determined by the relationship size, have been considered. The cost category of the supplier to the supplied company has been ignored, since the focus of the systemic analysis is on the significance of the resource flow within the relationship. This process has then been extended to find the suppliers of the mentioned suppliers, thereby creating a network of relationships resembling the economic system.

For each institution in the system, available weekly stock prices were collected for the period between January 2019 and May 2024. In selecting the companies to be included in the sample, the following selection criteria have been applied: the company must have been listed throughout the whole analysis period or for a substantial portion of it, the proportion of missing data points for the entire sample must not exceed 10% of the total data points, the institution's ESG rating must be available for at least three out of five years. Missing data points can pose challenges to future analyses, so an interpolation process is used, replacing the missing values with the median.

Market data for the analysis was sourced from Bloomberg, ensuring comprehensive and up-to-date information on stock performance. Other control variables were extracted from the banks' financial reports, providing a solid foundation for evaluating financial metrics and performance indicators. ESG strategy information was obtained from the most recent banks' non-financial disclosures, which offer insights into their sustainability practices and commitments. The ESG scores used in the analysis are the Bloomberg aggregated scores, which consolidate various environmental, social, and governance factors into a comprehensive measure of each bank's sustainability performance.

2.1.1 BLOOMBERG'S ESG SCORING METHODOLOGY

Bloomberg is maybe the vastest library of economic data, providing a wide range of tools and functions for financial and economic analysis.

As previously stated, ESG scores' industry is fragmented since every score provider is allowed to choose the preferred methodology to compute their score. In this analysis, Bloomberg's aggregated ESG score is considered due to its wide coverage of around fifteen thousand companies worldwide, representing approximately 90% of global market cap.

According to Bloomberg's methodology, in its November 2023 update, ESG scores are designed to evaluate and measure a company's management of financially material ESG issues, whose identification is based on quantitative proprietary research based on assessment of probability, magnitude and timing of the impact.

Bloomberg's esg scores measure best-in-class performance within peer groups, defined as companies sharing similar business models and facing similar ESG risks and opportunities.

Scores range between 0 to 10, with 10 being the best management of material issues.

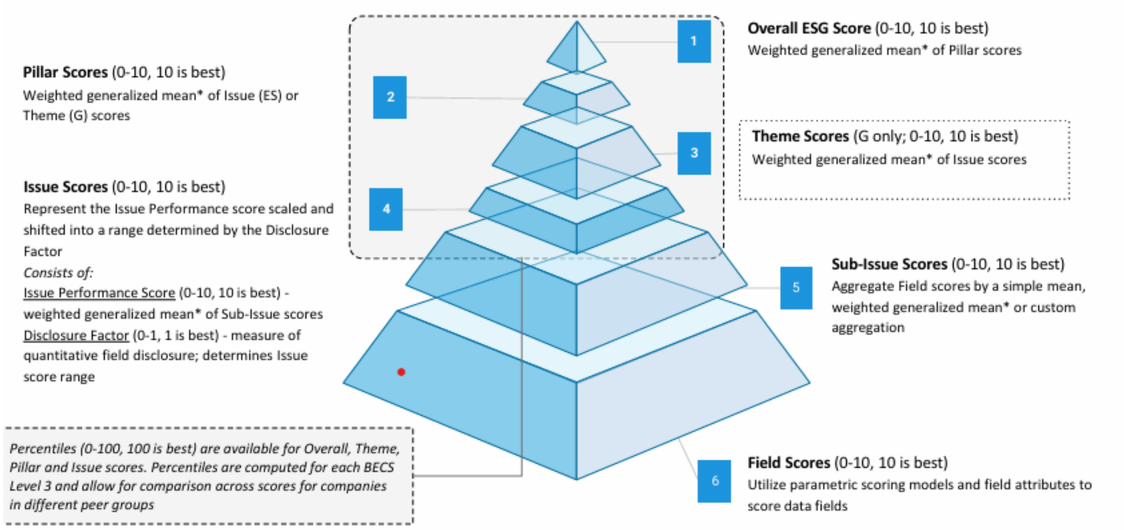
The scoring process comprises five phases:

1. Research: Bloomberg scrutinizes company-reported information that is publicly available, for example from non-financial reports, integrated annual reports, 10-Ks, corporate responsibility reports and other ESG releases. Bloomberg scores are not influenced by analysts' opinions or estimates.
2. Data collection and quality assurance: all information is assured over multiple levels of quality checks and data on reported information is collected.
3. Scoring of each field and pillar follows a quantitative model, based on quality of disclosure, the relevance of the issue and its financial materiality.

4. Validation process with statistical and heuristics checks before and after data publication.
5. Publication and documentation on the Bloomberg terminals.

The overall ESG score for the company is the result of aggregation and weighting of different fields and pillars. As shown in Picture 2, fields represent the most granular input, each field is scored using parametric scoring models on field attributes. Fields are then aggregated on sub-issues scores by computing the mean or with custom aggregation processes. Sub-issues are furtherly aggregated into Issues, a combination of the weighted means of sub-issues scores and a range from 0 to 1 that represents the measure of field disclosure named Disclosure factor. Issues scores are then averaged to become theme scores and pillar scores E, S and G. On top of the pyramid, the overall ESG score is the weighted generalized mean of pillar scores.

Picture 2 Bloomberg's ESG score structure



(source: Bloomberg ESG scores overview & FAQ)

As previously stated, the scores measure a company's effectiveness in managing financially material ESG issues relative to its peers. This includes how well a company handles risks and opportunities associated with ESG factors and its transparency in disclosing data. For each peer group, pillar weights are determined by Bloomberg Intelligence fundamental research. The weighting process starts by assigning to each pillar a rank of importance on a 1 to 5 scale (1 is the most important). Every rank is then translated into percentages that reflect the weights.

Overall, Bloomberg ESG scores provide a robust, reliable and transparent way of assessing ESG performance. Methodology and data sources are fully transparent, allowing users to trace scores back to the original documents, the scores are solely based on quantitative data and regularly updated as new information becomes available and its quality is regularly checked through validation processes.

2.1.2 DATA TRANSFORMATION AND STATIONARITY TEST

Prices alone are inadequate for comparing different investments, because they are influenced by a variety of factors, making direct comparison misleading. While it is common belief to associate higher prices with profitability, the true measure of stock performance lies in price variations over time. However, intuitively, a 1-euro price change in a stock priced at 10 euros is far more impactful than a 1-euro price change in a stock trading at 100 euros. A normalization factor must therefore be introduced to effectively compare performance of different assets on a common scale regardless of the initial price levels.

Returns are standardized measures that allow for a consistent comparison across different stocks and periods. They represent stocks' relative performance by measuring the percentual variation in price. When compounded over time, returns more effectively reflect cumulative growth or decline of an investment, giving a more accurate representation of its performance over the time horizon. Furthermore, returns are essential for evaluating risk-adjusted performance and risk measures, which are crucial for insights into an investment's profitability, variability, and for forecasting potential future behaviour.

Returns can be calculated following two alternative methods: one computes the difference between price at time t and price at time t-1 and divides it for price at time t-1 to obtain relative the percentage change in price.

$$R = \frac{P_t - P_{t-1}}{P_{t-1}}$$

Alternatively, returns can be computed as the difference between logarithmic transformation of returns.

$$R = \ln(P_t) - \ln(P_{t-1}) = \ln\left(\frac{P_t}{P_{t-1}}\right)$$

Transforming prices into returns also favours time series stationarity. The term stationarity refers to the statistical property of time series where their fundamental characteristics (mean and variance) remain constant over time, ensuring the behaviour of the series remains stable and predictable across different periods. A commonly used tool to check for time series stationarity is the Augmented Dickey-Fuller (ADF) test. Under this statistical test the null hypothesis is that the series is non-stationary. If the p-value of the test is lower than a chosen significance level (0,05) the null hypothesis is rejected with high confidence, concluding that the series is stationary.

2.2 SAMPLE'S DESCRIPTIVE MEASURES

2.2.1 SECTORIAL OVERVIEW

The following paragraphs will refer to sector performance, focusing on how sector idiosyncrasies lead to portfolio overexposure or underexposure to risks. To highlight which sectors are the most volatile, therefore the riskiest, as well as which of them are more profitable or are characterized by the best ESG performance over the considered time interval, let's analyse Table 1.

Table 1 Sample's sectorial summary attributes

SECTOR	AVERAGE ESG SCORE	ESG SCORE VARIANCE	AVERAGE STD DEV	AVERAGE RETURN
Communication Services	3,18	2,175	0,0398	0,138%
Consumer Discretionary	4,06	1,417	0,0545	0,049%
Consumer Staples	4,82	1,715	0,0451	0,216%
Energy	4,48	2,448	0,0711	0,102%
Financials	3,71	3,355	0,0471	0,230%
Health Care	3,55	2,302	0,0552	0,090%
Industrials	4,12	1,484	0,0520	0,236%
Information Technology	3,74	2,016	0,0513	0,256%
Materials	4,21	2,136	0,0590	0,180%
Real Estate	4,49	0,840	0,0476	-0,029%
Utilities	4,57	2,181	0,0389	-0,017%
SYSTEM	*3,99*	*2,026*	*0,0533*	*0,174%*

(source: Bloomberg's data elaboration)

The sector characterized by the highest standard deviation is Energy (0,0711). This sector's increased volatility stems from the strong dependency from raw material prices, especially gas and oil, which can experience high fluctuations. Following Energy, Materials (0,059) and Consumer Discretionary (0,0545) also exhibit significant riskiness. These sectors are strongly influenced by the growth of the global economy, and during periods of economic uncertainty, such as the sample period, discretionary expenses tend to decrease and raw material prices to increase, making these sectors particularly risky.

In terms of profitability, Information Technology is the sector that yields the highest average return (0,256%). This sector is often associated with higher returns because of the rapid technological advancement and constant innovation sought by companies in recent times. Financials follows with an average return of 0,230%. Despite its cyclical nature, Financials tends to react more strongly after periods of economic crises, since it is more responsive to economic trends. However, the flip side of this responsiveness is that the financial services' sector is more sensitive to market shocks and to systemic shocks, due to its high number of economic relationships (financing and investing).

Consumer staples lead with the highest ESG score, reflecting the sector's strong commitment to sustainability and equality in operations and supply chains. Interestingly, Utilities and Energy sectors have relatively high ESG scores, which might seem unexpected since they are often associated with higher environmental impact. However, one should remember that Bloomberg's ESG scores focus on how well companies manage financially material ESG issues, rather than directly measuring environmental impact. Moreover, the increased adoption of more sustainable practices and sectorial innovation towards renewable energy boosts ESG scores in these sectors.

Variance in ESG scores can provide valuable insights into the reliability of average ESG performance within a sector. By measuring the dispersion of individual scores around the mean, variance can help distinguish between sectors where companies consistently demonstrate strong sustainability practices and those where performance is more variable. A high average ESG score combined with low variance, as in the case of Consumer Staples and Industrials, indicates a sector where most companies are aligned in their commitment to sustainability. Conversely, a high average score accompanied by high variance, as in Financials and Energy, suggests that the overall average is influenced by some high-performing companies, while others may be poorly performing.

Taken together, all these considerations display a sectorial overview of the risk, return, ESG score relationship for the period considered: Consumer Staples appears as an attractive sector with high average return, standard deviation below mean values and high sustainability scores. Information Technology and Financials sectors also offer a good combination of volatility and return but with lower average ESG scores. Conversely, even though they have high ESG scores and in this case also low standard deviation, Real Estate and Utilities suffer from weak financial performance.

2.2.2 GEOGRAPHICAL OVERVIEW

By examining the data presented in Table 2, several conclusions can be drawn on geographical areas' specific attributes.

Table 2 Sample's geographical area summary attributes.

AREA	AVERAGE ESG SCORE	ESG SCORE VARIANCE	AVERAGE STD DEV	AVERAGE RETURN
Asia Pacific	3,31	1,34	0,0519	0,190%
Eastern Europe	3,18	1,12	0,0348	0,192%
Latin America	5,30	2,55	0,0662	-0,029%
Middle East Africa	1,43	6,15	0,0511	-0,019%
North America	4,13	2,08	0,0554	0,219%
Western Europe	4,53	1,53	0,0511	0,082%
SYSTEM	*3,99*	*2,03*	*0,0533*	*0,174%*

(source: Bloomberg's data elaboration)

As expected, North American companies appear as the most represented, due to their strong presence in almost every top holding from the portfolios considered. Despite having slightly higher standard deviation (0,0554) than the others, they offer the highest return, positioning North American companies as key for substantial gains. Their global relevance has led many North American companies to prioritize sustainability issues and their impact on financial performance, resulting in a high average sustainability score. Yet, the relatively high variance for ESG scores suggests that this overall performance is slightly skewed, with companies that substantially overperform or underperform with respect to the mean.

The second most represented geographical area is Asia Pacific, mostly because of the strong presence of suppliers for Information Technology and Industrials companies (semiconductors). Asian companies show significantly lower ESG scores with low ESG score variance, indicating that such companies are less concerned about sustainability issues or manage them poorly (workforce exploitation, poor working conditions some of the most notable scandals).

Western Europe has the highest ESG score average with below-average variance, in line with the strong sustainability commitment of EU institutions. However, the average return is lower than other regions, suggesting that high ESG performance comes at the cost of profitability, at least in the short term.

Middle East and Africa have very few representatives, exhibit negative average returns, making them highly unattractive.

Latin America also has limited representation, showing negative but highly volatile returns. The region has the highest average ESG score but also the highest ESG score variance, highlighting that the performance is highly skewed by the contribution of one of the best performing companies in the sample.

2.2.3 NETWORK PRELIMINARY ANALYSIS

This section provides an overview of network analysis, focusing on the "handmade" network of supply chain relationships as described in Chapter 2.1.

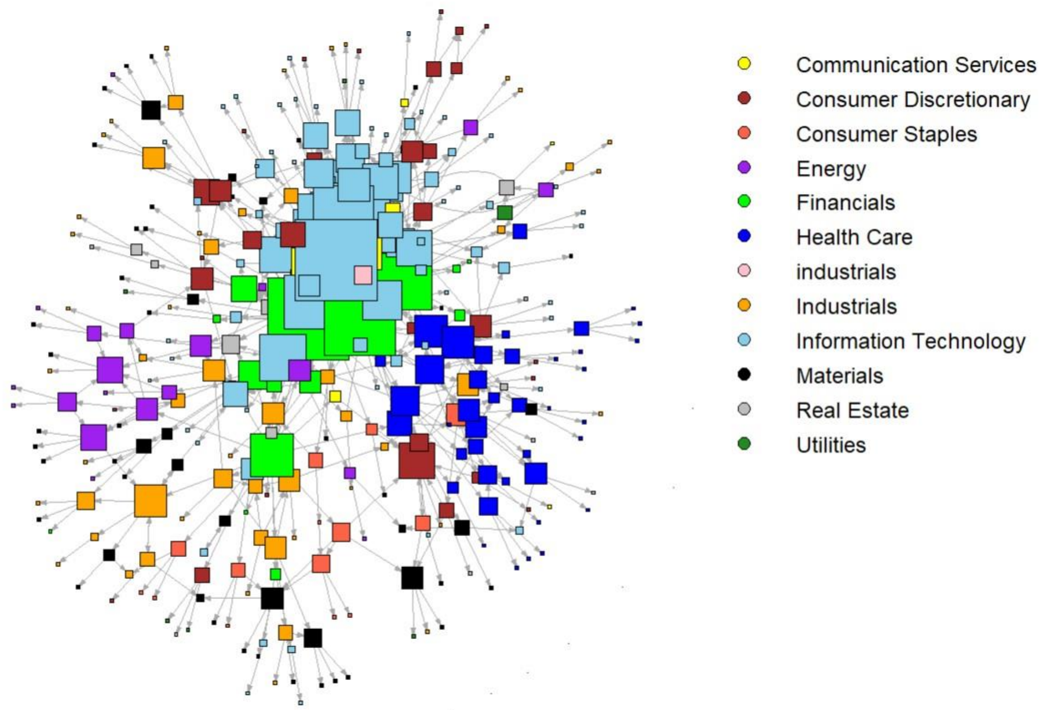
Networks are collections of interconnected entities. These entities, often referred to as nodes or vertices, can represent individuals, organizations, or countries. The connections between these entities, known as edges or links, represent relationships, interactions, or dependencies. Network analysis is a powerful tool to study the structure, dynamics and properties of interconnected systems, including techniques such as community detection, which implies the identification of densely connected groups of nodes, centrality analysis, which highlights the most influential nodes in the network, and path analysis, investigating which is the best path between nodes.

Visualizing and plotting networks requires two fundamental inputs: a list of all nodes and a list of all relationships (graph from tables), or, alternatively, an adjacency matrix where connections are represented as 1 in case of connection and 0 otherwise (graph from matrix).

Networks can be classified based on edges' characteristics. In undirected graphs, edges are bidirectional, meaning that there is no distinction between start and end points. In directed graphs edges have directions, implying careful attention to the flow across nodes. Finally, to represent the strength of a relationship, edges can be assigned weights.

Graph visualization can be challenging, especially for large and complex networks. Layout algorithms can increase the informative power of the visualization by organizing nodes and edges positions, but in some cases, they fail to give accurate representations. Also, customizing node and edges attributes, like thickness or colour can be used to represent different properties, can enhance visual clarity.

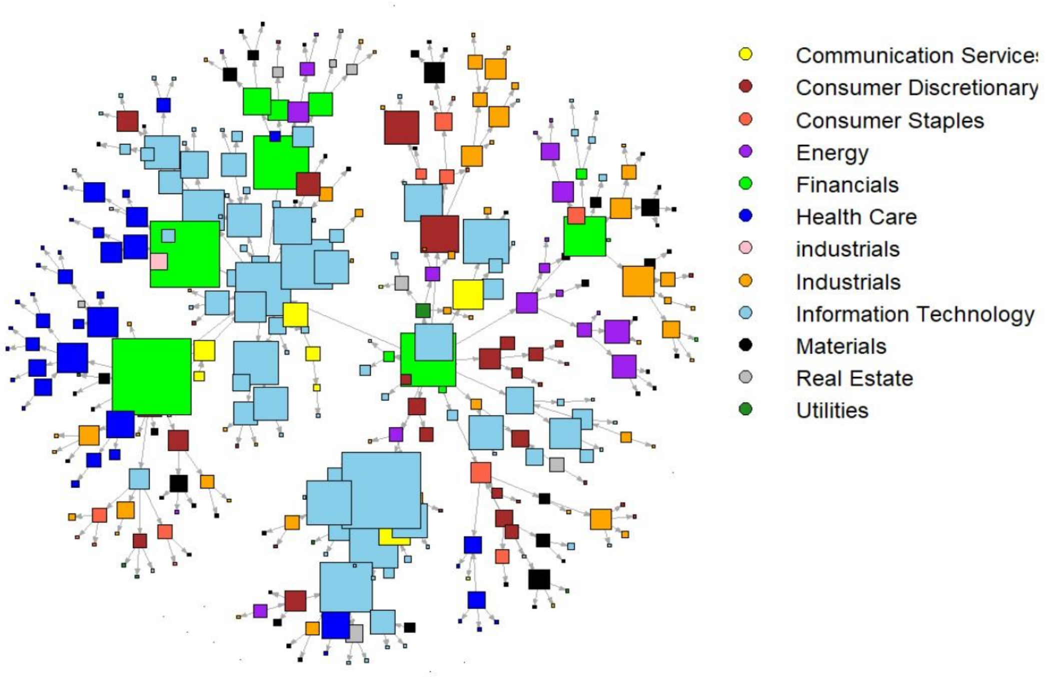
Picture 3. Network's graphical representation



(source: Bloomberg's data elaboration)

Despite these techniques, large networks can still be difficult to interpret visually. For instance, the network in Picture 3 does not provide sufficiently clear information on the most important nodes for the network. In such cases, network filtering techniques are essential. One common method of filtering networks is the Minimum Spanning Tree. This approach entails reducing the network to a subset of edges that connect all nodes without forming cycles, using the minimum number of edges.

Picture 4 Minimum spanning tree representation



(source: Bloomberg's data elaboration)

Since the sample was constructed manually to intentionally stress supply chain overlaps, the number of relationships highlighted in these visual representations might be misleading. As will discussed in next paragraphs, the strong presence of Information Technology companies in banks' portfolios and the high concentration of suppliers of said sector, has led to overemphasize certain companies. In the same way, some of the Financials sector's relationships are the banks' investment relationships. The inclusion of such relationships in the network is intentional, as they are an important part of the ecosystem. Since banks often play a crucial role in supply chains, even indirectly, by providing liquidity, financing or in this case owning a share of these companies, including them in the system could offer insights on their role in influencing the system.

Centrality measures are key for identifying the most crucial nodes. Several centrality measures are commonly used in network analysis; however, for this analysis, only a selection of the most important ones is considered.

- Degree centrality measures the number of connections (edges) a node has. In directed graphs, degree centrality can be further divided into in-degree, which represents the number of incoming edges and out-degree, which displays the number of outgoing edges. Despite the common belief that associates the number of connections with centrality, this relationship is not systematic.

- Betweenness centrality measures the number of geodesics or shortest paths going through the vertex. In other words, it measures how often a node, or a link is included in the shortest paths between every other possible pair of nodes. Nodes with high betweenness are critical for controlling the flow of information or resources in the network, thus are often referred to as bridges or a bottleneck.
- Closeness centrality measures how quickly a node can reach all other nodes with the shortest path. Higher closeness indicates more efficient access to the rest of the network.
- Eigenvector centrality assesses a node's importance based on the importance of its neighbours. In other words, a node is considered central if it is connected to other important nodes.

Since the objective of this analysis is to identify which nodes exert the most control over resource flow in the system, betweenness centrality is chosen as the principal metric. Thus, the network needs to be filtered to consider only the most important relationships in the system. To this end, the graph is filtered by retaining only those nodes and relationships whose betweenness exceeds a certain threshold. The resulting network reveals the most central and influential nodes in the "handmade" supply chain system. This approach effectively highlights the nodes with the greatest influence over the system, enabling more targeted analysis of their roles and behaviour within the supply chain network.

Table 3 centrality measures summary, top 10 ordered by betweenness

NODE	*DEGREE*	*BETWEENNESS*	*CLOSENESS*	*EIGENVECTOR*
NVDA US	23	1817,36	0,01	1,00
IBM US	15	1670,29	0,01	0,25
ASML NA	10	1182,35	0,04	0,34
2330 TT	13	758,72	0,01	0,54
INTC US	17	739,76	0,01	0,66
CLS US	10	575,20	0,01	0,28
005930 KS	12	568,11	0,01	0,50
LONN SW	8	562,83	0,00	0,06
AVGO US	15	556,55	0,01	0,55
7731 JP	6	517,83	0,09	0,04

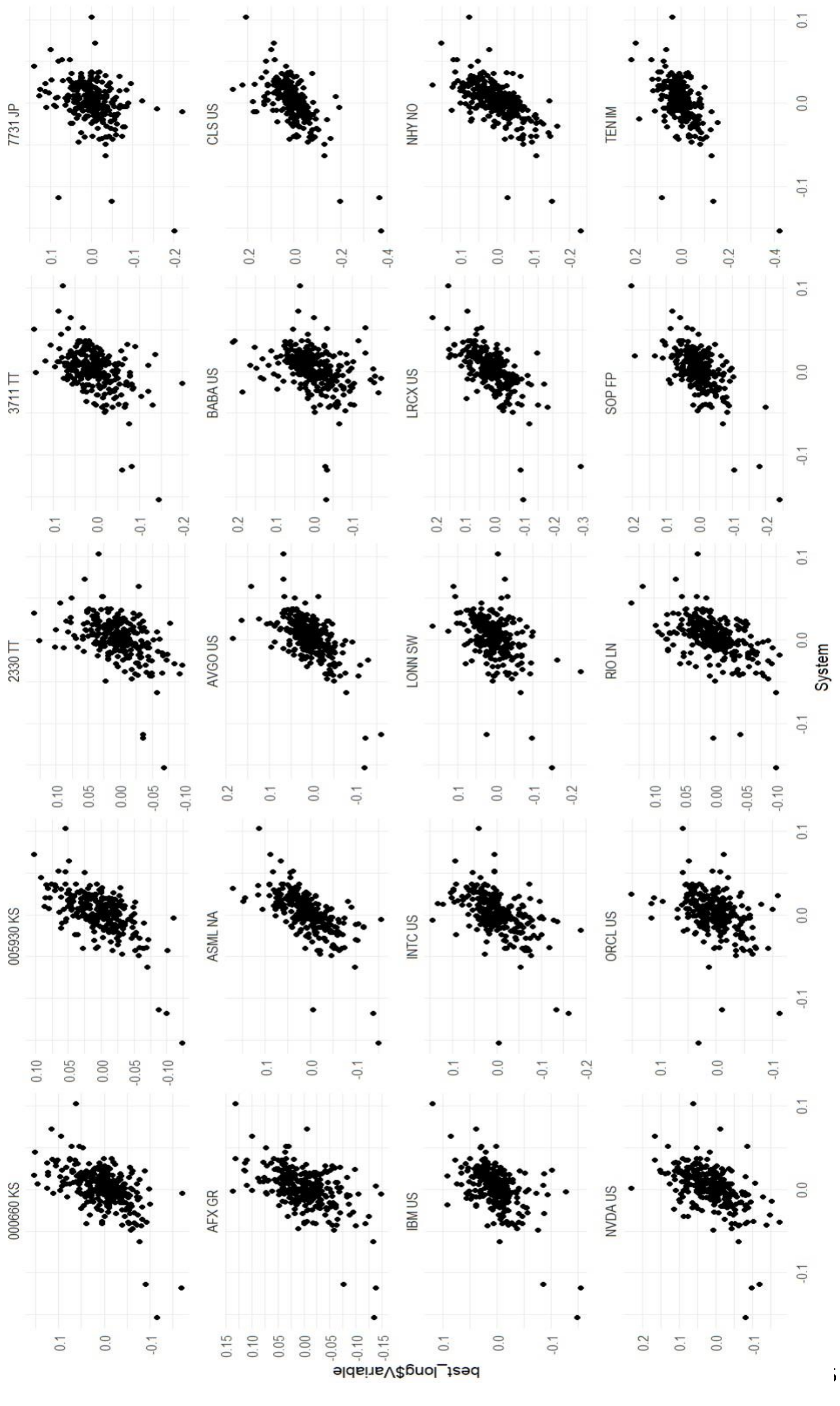
(source: Bloomberg's data elaboration)

Plotting the most relevant institutions' returns against the system's provides valuable initial insights on systemic risk, helping to identify its key contributors. As a matter of fact, highly central institutions, either through size, leverage or relationships, can significantly impact the stability of the entire system. By comparing their return with the system's performance, one can assess their role in mitigating or amplifying shocks. Furthermore, analysing the most central companies' risk profiles helps determining whether the system is vulnerable or resilient.

The scatter plots displayed in Picture 5 reveal several key insights regarding the relationship between the most central nodes and the system (on the X-axis). Most scatter plots exhibit a positive relationship, suggesting that the companies' return, and the system's performance move together. The concentration of data points near the center suggests low variance, implying limited variability. Many plots also indicate the presence of a linear, upward trend.

These observations suggest that when the system experiences a shock, the most central companies are likely to move in the same direction, contributing to its rapid propagation. Since the system's health is closely tied to these companies' performance, if they face the same macroeconomic shock, their simultaneous movement will amplify systemic risk. Furthermore, given the integrated nature of the ecosystem, a shock in a central company in sectors as Financials of Information Technology, is likely to have a sizeable impact on the system. For example, the failure of a key technology firm could cause investor panic, leading to widespread selloffs across the sector, affecting many other companies' value and potentially resulting in a coordinated collapse.

Picture 5. Scatter plots of the most central nodes against the system



2.3 PORTFOLIO ANALYSIS

Banks’ equity portfolios generally reflect a conservative yet strategic approach to sector and geographical allocation. The most common sectors in which banks invest heavily are Financials, Technology, Consumer Discretionary, and Industrials. Financials and Technology dominate the portfolios, often being the top two sectors. While Financials is a core component of every portfolio, Technology also plays a prominent role, reflecting its high growth potential. Healthcare emerges as a significant, though less dominant, investment, occupying a steady third place in many portfolios.

On the other hand, sectors such as Energy, Consumer Staples, Utilities, and Real Estate are underrepresented. Real Estate and Utilities investments are minimal or nearly absent, reflecting banks' avoidance of sectors with low returns or uncertain growth. Consumer Staples also features lower allocations, despite its typically stable performance.

In terms of geographical representation, North America leads as the most prominent region, followed closely by Western Europe. North America takes a dominant position in most portfolios, reflecting the global economic importance of U.S. markets. Western Europe consistently ranks second, underscoring its role as another key region for equity investments. An anomaly in one portfolio is the substantial allocation to Eastern Europe, specifically Poland, which appears as an unusually large and high-risk investment in a local subsidiary.

These sector and geographical choices highlight the banks’ preference for stable, well-established markets and industries with growth potential, consistent with their cautious, value-driven investment strategies. The underexposure to volatile or low-return sectors, combined with a strong focus on North American and Western European markets, reflects their desire to balance steady returns with controlled risk exposure.

2.3.1 INDIVIDUAL PORTFOLIO PERFORMANCE MEASURES

Understanding opportunities and vulnerabilities within portfolios is crucial for achieving investment objectives, as the combination of securities and their interaction can make the difference between a well-managed portfolio and a poor-performing one.

Portfolio designing involves two fundamental decisions: selecting the securities in which to invest (security selection) and determining how much of the available capital to allocate to each security (asset allocation).

The trade-off between risk and return is one of the core concepts in finance; greater risk typically offers greater rewards. Consequently, investing in more volatile stocks could yield a substantial return in favourable market conditions. However, this also means that the portfolio's value will fluctuate more significantly, which can lead to substantial losses in adverse times. On the other hand, investing in less risky assets could grant a more stable stream of returns, due to the overall lower sensitivity to market changes, yet returns might fall short of the investor's expectations. Portfolio theory seeks to best balance risk and return to find the optimal asset allocation. In the case of banks, whose primary income source is credit granting, a prudent investment strategy often dominates. This results in a preference for lower-risk or riskless securities such as bonds, rather than highly volatile equities.

To properly evaluate a portfolio's performance, it is essential to compare it both to the risk-free assets and the broader market. For the portfolios analysed in this study, given the significant presence of US firms and the US's role as a common reference for geographically diversified investments, the 10-year US Generic Government Bond has been selected as risk-free rate, while the Standard and Poor's 500 Index (SPX) serves as market benchmark.

Table 4 displays the key risk-adjusted performance metrics for each portfolio under scrutiny, as well as the market index.

Table 4. risk-adjusted performance measures

	BNP PARIBAS	DEUTSCHE BANK	CREDIT AGRICOLE	HSBC HOLDINGS	INTESA SANPAOLO	SPX
Portfolio return	0,23%	0,50%	0,16%	0,57%	0,47%	0,25 %
Portfolio variance	0,0024	0,0007	0,0012	0,0008	0,0006	0,00 07
Std Dev	0,0492	0,0257	0,0339	0,0291	0,0235	0,02 71
Sharpe Ratio	0,0051	0,1149	-0,0136	0,1275	0,1122	0,01 63
Beta	0,0492	-0,0252	-0,0523	-0,0184	-0,0263	1
Treynor's measure	0,0051	-0,1172	0,0088	-0,2021	-0,1003	0,00 04
M^2	0,22%	0,513%	0,165%	0,547%	0,506%	
Jensen's alpha	0,0002	0,0030	-0,0004	0,0037	0,0026	

(source: Bloomberg's data elaboration).

Interpreting these results wisely is key for understanding not only the selected banks' attitude towards risk, but also gives useful insights on the contextual frame of the analysis. Each of these metrics contribute to provide a comprehensive overview of the portfolio's performance over the time interval considered:

- Portfolio return reflects the portfolio's overall economic result over a specified period. In this environment is computed as the sum of weights times the average of the individual asset return within the portfolio.

$$Port\ return = \sum_{i=1}^{N} R_i * w_i$$

  Where R is the security's average return and w is the weight of the security in the portfolio.

- Variance measures the dispersion of returns around the mean, higher variance indicates greater volatility, as observations are distributed over a wide range from the mean. Standard deviation, derived from variance, is often used as a proxy for portfolio risk; portfolios with higher standard deviations are considered riskier due to their increased volatility. Portfolio variance is computed as a combination of the variance covariance matrix the weights vector:

$$\sigma^2 = [w * \Sigma] * w^T$$

Where w is the vector weights, Σ is the variance-covariance matrix of the returns of the individual stocks in the portfolio and w^T is the transposition of the weights' vector. Note that the multiplication between matrices works with the multiplication of lines and columns. For example, defined Σ a matrix of N x N dimensions and w a vector 1 x N, the result of the first term of the equation is a vector 1 x N. Then, the multiplication of the result for w^T, a vector N x 1, results in a single value (scalar), because each element in the line vector is multiplied by every element in the column vector.

- Beta measures a portfolio's sensitivity to market movements. It is derived from the Capital Asset Pricing Model (CAPM), where the portfolio's returns are regressed against those of the market index. A beta of 1 indicates that the portfolio moves along with the market, while a beta greater than 1 suggests higher volatility. Negative beta values imply that the portfolio moves in the opposite direction of the market. In this analysis, the low or negative betas observed across portfolios highlight banks' conservative, risk-averse strategies, which aim to hedge against market risk while sacrificing some potential profit during market rising movements. Since betas for the portfolios are computed as the weighted sum of individual stock's beta, a combination of positive and negative betas that results in a very low or negative beta allows to hedge against market risk while not completely renouncing to market growth opportunities.

$$Beta\ port = \sum_{i=1}^{N} \beta_i * w_i$$

- Sharpe Ratio measures the ratio between the portfolio excess-return and its volatility, where excess-return is the difference between portfolio return and the risk-free rate and volatility is the portfolio's standard deviation. A higher Sharpe Ratio indicates a more favourable risk-adjusted performance. A negative Sharpe ratio would entail the portfolio did not outperform the risk-free asset; thus, it should have been better to invest in a riskless security and not bear any risk.

Though not very high, most Sharpe Ratios of the analysed portfolios are higher than that of the market, suggesting a slight over-performance.

$$Sharpe\ Ratio = \frac{R_p - rf}{\sigma}$$

Where Rp is the portfolio's return, rf is the risk-free rate and σ the portfolio's standard deviation.

- Treynor's Measure, similarly to the Sharpe ratio, evaluates risk-adjusted performance but considers beta instead of standard deviation. As for the Sharpe Ratio, a higher Treynor's measure suggests the portfolio is generating more return for the level of systematic risk assumed. In the case of negative Treynor measures, the portfolio is not generating sufficient excess returns for the risk taken, a scenario often seen in periods of market stress.

$$Sharpe\ Ratio = \frac{R_p - rf}{\beta}$$

- Jensen's Alpha compares actual portfolio returns to expected returns based on beta and the CAPM model. A positive alpha indicates outperformance relative to expectations, suggesting the portfolio manager has added value through effective security selection, allocation and timing. Conversely, a negative alpha implies underperformance, and that poor portfolio management has destroyed value. When alpha is approximately zero, as in the case of the observed institutions, the portfolio neither generated nor destroyed value, because it is perfectly aligned with CAPM expectations.

$$\alpha = R_p - (rf + \beta_p(R_m - rf)$$

- M-squared measure or Modigliani-Modigliani measure adjusts a portfolio's return to the market's risk level, allowing a direct comparison. A positive M2 value indicates that the portfolio would outperform the market if it had the same risk profile. In the sample, most of the portfolios demonstrate positive M2 values, which implies that even with lower risk profiles, they would still outperform the market in risk adjusted terms.

$$M^2 = \left(R_p - rf\right) * \frac{\sigma_m}{\sigma_p} + rf$$

Taken together, these performance metrics confirm the observation that banks' portfolios tend to prioritize risk reduction, often at the expense of higher returns. This prudential approach is particularly evident in the sample given the inclusion of the Covid-19 pandemic outbreak, a period of critical economic uncertainty. During such times, banks appear to favour stability and risk mitigation over high growth, which helps explain the relatively conservative performance measures observed.

2.3.2 SECTORIAL PERFORMANCE ATTRIBUTION

In portfolio analysis, a widespread tool for evaluating the effectiveness of investment strategies is the Performance Attribution analysis. By investigating and breaking down the sources of a portfolio's return, this powerful tool distinguishes between managers active decisions and market-driven factors.

Performance attribution compares the portfolio's return with the return of a boogey portfolio, that in this case resembles the market index, and multiplies the excess return for the average return of an asset class. In this way, the performance is linked to the risk taken, analysing whether higher returns came from higher risk or result from careful management.

Also, performance attribution gives useful insights on risk exposures and on their impact on portfolio's performance. In this analysis, a sectorial performance attribution is expected to highlight which sectors contributed positively and negatively to the overall performance, allowing to make consideration on overexposure to certain sectors relative to the market index.

Table 5 provides an example of the performance attribution for a clearer understanding of the results interpretation:

Table 5. example of performance attribution

Sector	Port	SPX	Excess weight	Average sector return	Contribution
Communication Services	13,97 %	8,20%	5,77%	0,14%	0,008%
Consumer Discretionary	12,82 %	9,90%	2,92%	0,05%	0,001%
Consumer Staples	0,00%	7,40%	-7,40%	0,22%	-0,016%
Energy	4,37%	4,50%	-0,13%	0,10%	0,000%
Financials	11,95 %	12,90 %	-0,95%	0,23%	-0,002%
Health Care	11,04 %	14,50 %	-3,46%	0,09%	-0,003%
Industrials	3,17%	8,60%	-5,43%	0,24%	-0,013%
Information Technology	42,68 %	26,10 %	16,58%	0,26%	0,042%
Materials	0,00%	2,60%	-2,60%	0,17%	-0,005%
Real Estate	0,00%	2,50%	-2,50%	-0,03%	0,001%
Utilities	0,00%	2,90%	-2,90%	-0,02%	0,000%
				Total contribution	0,014%

(source: Bloomberg's data elaboration)

As noticeable from Table 5, the normalized weight distribution of the portfolio is compared to that of the market index (SPX). The excess weight is then multiplied by the average sectorial return to obtain the sector's contribution to the performance. A positive sectorial contribution suggests the sector's performance was favourable, meaning overweighting a successful sector or underweighting a poorly performing one was indeed a successful decision. Conversely, negative contributions highlight a missed opportunity underweighting a profitable sector or overweighting a falling sector.

The total contribution is the total active return of the portfolio relative to the benchmark. When positive, it indicates the portfolio has outperformed the market benchmark on sector allocation.

In most of the observed portfolios, the total contribution is positive, mostly highlighting a successful allocation across sectors. The general tendency is to prefer overexposure to the Information Technology sector, that yields the highest returns of all sectors. Most portfolios report overexposure to Financials sector, reflecting its profitability in periods immediately after market stress. Unexpectedly, most portfolios substantially underweight Consumer Staples, thus negatively contributing to the performance over the market index.

Most banks tend to avoid overweighting sectors with low returns, such as Utilities and Real Estate, as well as highly volatile sectors such as Energy and Materials. This pattern reflects banks' cautious approach to investing, avoiding high-risk and low-return sectors is a sign of prioritizing stability in returns and minimizing exposure to excessive market volatility.

2.3.3 CROSS-CUTTING ANALYSIS

As discussed in Chapter 1.3.1, diversified portfolios may increase the likelihood of joint failure. This is because the greater the overlap in portfolio components, the more similar the portfolios become, thereby exposing their holders to the same risks. To investigate this phenomenon, a brief analysis of the correlation matrix across institutions' portfolios and the variance covariance matrix was conducted.

Computing returns for the portfolios over time requires a fundamental assumption: portfolio weights are stable throughout the whole period considered.

At first glance, assumption is flawed, as equities are typically subject to frequent trading and to follow market dynamics. In fact, whenever there is a mismatch between a stock's intrinsic value and its price, or when noise traders spread rumours about this potential mismatch, the stock is sold or bought, causing consistent price fluctuations. As a result, it is common practice to frequently adjust portfolio weights in response to a change in market sentiment or of a security revaluation.

However, as seen in previous paragraphs, banks generally adopt a more precautious investment approach, favouring long-term value investing over short-term growth investing, especially in uncertain market conditions. The low or negative beta and the low variance profile indicate a more predictable and steady performance, reducing the need for frequent adjustments. Moreover, banks are often subjects to regulatory constraints, requiring them to maintain stable and conservative investment strategies. Consequently, assuming portfolio composition to be stable over the period appears to be reasonable in this approach.

The analysis of the variance covariance matrix is essential to make thoughtful considerations on aggregated risk. This matrix captures both the variability of individual portfolios and the relationships with all other portfolios. Variability of an asset with itself, which represents the asset's dispersion from its own mean, is reflected in the main diagonal as the asset's variance. The off-diagonal elements represent covariances between different assets, showing the dispersion of returns from one portfolio to the mean of another one. Positive covariance values indicate that the portfolios share common exposures to systematic risk, meaning they are likely to react similarly under macroeconomic stress. Yet near-zero values observed suggest that risk stemming from portfolio similarities can be mitigated through diversification, thus needing some clearer and more impactful representation.

Table 6. Variance-covariance matrix across portfolios

	BNP	*DEUTSCHE*	*CREDIT AGRICOLE*	*HSBC*	*INTESA*
BNP	0,0026				
DEUTSCHE	0,0004	0,0007			
CREDIT AGRICOLE	0,0007	0,0005	0,0012		
HSBC	0,0004	0,0007	0,0004	0,0008	
INTESA	0,0004	0,0006	0,0005	0,0006	0,0006

(source: Bloomberg's data elaboration)

Additionally, the correlation matrix offers insights on standardized relationships between portfolios, with values ranging from -1, indicating perfectly opposite movements, to 1 showing perfectly aligned behaviour. Table 7 showcases the correlation matrix. As expected, portfolios that follow the same investment strategy and invest in the same securities, show high correlations. Such high values for correlation indicate that diversification between institutions is weak, which can increase the risk of contagion in the case of a systemic distress.

Table 7. correlation matrix across portfolios

	BNP	*DEUTSCHE*	*CREDIT AGRICOLE*	*HSBC*	*INTESA*
BNP	1				
DEUTSCHE	30,83%	1			
CREDIT AGRICOLE	38,74%	51,61%	1		
HSBC	26,28%	97,94%	42,79%	1	
INTESA	35,67%	96,34%	61,15%	93,98%	1

(source: Bloomberg's data elaboration)

In conclusion, this analysis indicates that while some institutions' portfolios are exposed to similar risk profiles, the potential for diversification remains key for mitigating such phenomenon. However, the high correlation values suggest limited diversification between institutions, which could potentially amplify systemic risk.

2.4 DISCLOSED ORIENTATION TOWARDS ESG

This section provides general insights into banks' non-financial disclosures, highlighting their general orientation in response to the growing sustainability trend.

Banks are increasingly committed to integrating ESG principles across their operations, aiming to create long-term sustainable value for stakeholders while addressing environmental, social, and governance challenges. Although the level of detail varies between institutions, the general orientation emerging from non-financial disclosures includes disclosing governance structures for responsible management, social initiatives for achieving a safe and inclusive workspace, environmental policies for addressing the most material impacts and fostering the diffusion of an ESG-driven culture within their organizations.

Many banks recognize the risks tied to not contributing to the sustainable transition, such as exposure to controversial sectors, which might lead to increased reputational risk, competitive disadvantages and loss of sustainability driven clients. To deal with those risks, banks are implementing comprehensive risk mitigation strategies, like incorporating ESG factors into risk appetite frameworks, investment products and credit rating models. Banks also support global sustainability efforts by aligning their actions with frameworks such as the UN Sustainable Development Goals (SDGs), developing products like green bonds and sustainability-linked loans, and setting ambitious decarbonization and net-zero targets. For instance, many banks publish their Net Zero Emissions Plan or Emission Reduction plan where they disclose their commitment and planned action to increase energy efficiency of their operations and their partners along the value chain. These plans are often corroborated by empirical scientific data, and aligned to international agencies standards, like 2050 Net Zero Emission Plan by the International Energy Agency.

Disclosing practices are also becoming increasingly transparent, with banks providing detailed information on financed emissions (particularly in high-risk sectors like oil, gas and coal) and on their ongoing efforts to phase-out or compensate the emissions coming from harmful activities. Recognizing their critical role in channelling resources towards sustainable alternative, banks offer several products to incentive renewable energy investment and adopt risk-based approaches to every client transaction, focusing on sectors' environmental impact. Moreover, banks show a deeper level of engagement and responsibility, where are not just passive investors but "active owners" of the companies they invest in. Banks also strive to achieve close tied relationship with their stakeholders through an increasing engagement on key issues.

Despite this, banks' non-financial disclosures often emphasize internal initiatives, products, and client-facing sustainability efforts, while providing limited insight into how ESG factors are integrated into their equity portfolios. This likely stems from the complexity of internal equity portfolio management, which relies on dynamic market data and is often less suitable for non-financial reporting. As non-financial disclosures are specifically designed to inform and attract investors and clients with strong sustainability values, it is more likely for the document to focus on products and initiatives that demonstrate commitment rather than internal portfolio management strategies. Additionally, regulatory requirements typically focus on operational sustainability rather than internal investment strategies, leading banks to prioritize areas where disclosure is mandatory or where they can demonstrate direct impacts.

Arguably, the pursuit of net zero targets, as seen in the case of several banks, is also pushing them to integrate ESG factors in portfolio construction, ensuring that their investments are aligned with a low-carbon future. By including companies with strong ESG performance in their equity portfolios, banks mitigate the financial risks associated with environmental degradation, regulatory changes, social scandals, and governance failures. This aligns with a broader market trend of minimizing exposure to companies in controversial activities. However, even recognizing the long-term opportunity of ESG investments, banks typically aim to balance ESG considerations with financial returns, therefore it is very likely they still prioritize financial performance in the short term.

Although the focus is often on regulatory compliance and stakeholder pressure, equity investments also offer banks potential benefits such as reducing credit risk by gaining better insight into companies' operations and aligning their interests with corporate success. However, this double exposure to both market and credit risk might be a double-sided sword when the invested companies underperform. The potential rising of conflicts of interest and excessive risk concentration has led regulators to impose prudential limitations to the extent to which banks can hold equities in non-financial companies.

Overall, while banks are making significant strides in sustainability through product offerings and operational practices, they could improve transparency regarding how ESG factors influence their equity investment strategies. Greater disclosure in this area would enhance understanding of how banks manage both risks and opportunities within their portfolios, contributing to their broader ESG goals.

CHAPTER 3 RESEARCH DESIGN: METHODOLOGY

This section provides an explanation of the procedure performed to carry out the study. The main goal is to analyse whether a company's sustainability performance, represented by its ESG score, impacts the company's contribution to systemic risk. Following this idea, a stronger corporate commitment to ESG can reduce the risk for the economic system in case of extreme distress, while ESG increased reputational risk (lower ESG score) can increase the company's vulnerability to systemic shocks. Companies with higher ESG score would be more resilient to shocks with respect to the lower score counterparts, ultimately losing less money in the case of a widespread crisis. Observing a significant inverse relationship between the risk measure and the ESG score would highlight ESG factors' impact on a company's overall risk profile and on economic stability. ESG criteria would therefore be worthy of being considered when making systemic risk evaluations, as they can have a strong contribution in developing a more resilient financial system.

Operatively, to test this hypothesis, a panel regression with fixed effect is conducted on systemic risk measures. Two alternative methods to assess systemic risk are proposed:

- A network approach that develops a spillover index network for tail risk and then analyses the company's contribution and vulnerability to systemic risk.
- A Delta CoVaR approach that computes how the company's tail risk deviates from the normal conditions in case of crisis by computing the difference between conditional tail risks.

Although alternative, the two approaches have some common points. For example, both use Value at Risk as the measure for tail risk (further analysis on paragraph 3.1), and for both a panel regression is performed to investigate the relationship between systemic risk and ESG scores (paragraph 3.4).

Consequently, consistent and coherent results between the two approaches will strengthen the robustness of the analysis.

3.1 VALUE AT RISK (VaR)

The base layer for both the network approach and the Delta CoVaR approach is Value at Risk (VaR). Value at Risk indicates the maximum potential loss for an asset for a given confidence level. In other terms, its result shows how much the value of the asset will drop in the worst-case scenario, with a certain probability. For example, if an asset had a VaR of 1000 euros with 0,95 confidence level, there would be a 95% chance that the asset's value will not decrease over 1000 euros in a specified period. Hence, there is 5% probability the loss will exceed 1000 euros.

Using notation, let X be a random variable for the returns of the asset with a cumulative probability function $F_X(z) = P\{X \leq z\}$. This function indicates, for a given value of z (loss), the probability of the variable X to be lower than z. As a result, VaR is the minimum z for which $F_X(z)$ is still higher than the confidence level α.

$$VaR_\alpha(X) = \min\{z \mid F_X(z) \geq \alpha\}$$

To provide a numerical example, if α is 0,95, VaR represents the value of z (loss) that will not be exceeded in 95% of cases.

Adjusting with clearer notation allows to say that the probability of the return of the asset X to be lower than the Value at Risk is the given tail level p used to compute VaR:

$$P\left(X \leq VaR_p\right) = p$$

In this way, if the confidence level is 0,95 so that p is 0,05, there is a 95% probability the returns are not lower than VaR.

It is possible to use an alternative method for VaR estimation when returns are assumed to be normally distributed variables. This approach will be referred to as parametric approach, as opposed to the previously discussed historical approach. Letting μ be the mean return and σ the standard deviation of returns, it is possible to derive VaR as follows:

$$VaR = \mu - z * \sigma$$

Note that z is the critical value of the normal distribution corresponding to the confidence level, $\Phi^{-1}(\alpha) = z$.

For the sake of detecting the impact of shocks on financial stability, a dynamic representation of Value at Risk through the whole time series is fundamental. To fulfil such task, GARCH (generalized autoregressive conditional heteroskedasticity) models are widely used instruments in time series analysis, as they allow to model the variable volatility of time series. Indeed, they compute the conditional variance of observations assuming that it depends on both past variance (h_{t-1}) and past quadratic residual error (ε_{t-1}^2). Since financial returns are in fact more sensitive to bad news than to good news, this time series analysis requires a model that weights the disruptive nature of negative shocks more than beneficial externalities of positive ones. Glosten-Jogannathan-Runkle model is considered by many as one of the most suitable models to fulfil this task, as it either computes today's volatility as a consequence of past shocks and accounts for the asymmetry between positive and negative shocks.

Notation for the GJR-GARCH (1,1) model requires to define the equation for the return and for the conditional variance:

1. Returns can be defined as the mean return plus an error term, the residual:

$$R = \mu_i + \varepsilon_t$$

2. Conditional variance on the other hand is defined as the combination of several terms. The GARCH model runs an optimization process (maximum similarity) to find the best fitting coefficients, which further define the results. As a general rule, the conditional variance at time t in a GARCH (1,1) model is a function of a constant (ω), the past variance (h_{t-1}), the square of past residuals (ε_{t-1}^2) and a dummy variable which is equal to 1 if residuals are negative and 0 otherwise (I_{t-1}).

$$h_{i,t} = \omega + \alpha * h_{t-1} + \beta \varepsilon^2{}_{t-1} + \delta * I_{t-1}\varepsilon_{t-1}^2$$

Then, the model computes the conditional variance iteratively for every point in the time series, that shall be used to compute Value at Risk with the parametric formula:

$$VaR = \mu_{i,t} + z\sqrt{h_{i,t}}$$

3.2 NETWORK APPROACH

3.2.1 PHI MATRICES ESTIMATION WITH VAR-L MODEL

Observing interdependence between time series assumes a pivotal role in understanding how institutions influence each other. A model to catch such interdependence is a VAR (vector autoregressive) model. While autoregressive models in general allow to derive a time series whose values are a function of past values, for example, the GDP of a country at time t depends on past GDP values until that moment, vector autoregressive models compute the value of a time series assuming it depends not only on its past values but also on other variables' values. To continue with the GDP example, in an autoregressive model, the value of a country's GDP at time t is influenced not only by past GDP values for that country, but by GDP values of other countries as well.

In general, in a sample of N variables, VAR models consist of the sum of coefficient matrices (N x N) (Φ_i) times lagged time series vectors (Y_{t-i}), which are the values of time series in a moment in the past with respect to t. Hence, the general notation stands as follows:

$$Y_t = \sum_{i=1}^{p} \Phi_i * Y_{t-i} + \varepsilon_t$$

For a clearer understanding of the formulation, a VAR model with lag order 3 would require the series at time t as dependent variable (Y) and the series lagged at time t-1, t-2 and t-3 as independent variables (X). The model would then produce the coefficient matrices Φ for every lag (so Φ_1, Φ_2 and Φ_3) so that Y_t becomes:

$$Y_t = \Phi_1 * Y_{t-1} + \Phi_2 * Y_{t-2} + \Phi_3 * Y_{t-3} + \varepsilon_t$$

It is assumed the error terms to be distributed as i.i.d. with mean zero and constant variance covariance matrix.

However, due to limited computational capacity, it becomes necessary to select the most important variables for the model. In presence of numerous variables with scarcity of data, introducing a regularization criterion might be very useful. Therefore, a VAR-L with Lasso penalization (Least Absolute Shrinking and Selection Operator) is formulated as follow:

$$\min_{\Phi_1,\Phi_2,..\Phi_p} \left\{ \sum_{t=1}^{T} \left\| Y_t - \sum_{i=1}^{p} \phi_i * Y_{t-i} \right\|^2 + \lambda \sum_{i=1}^{p} \|\Phi_i\|_1 \right\}$$

The model aims at computing the best fitting coefficient matrices for every lag by minimizing the difference between the values forecasted by the model ($\sum_{i=1}^{p} \phi_i * Y_{t-i}$) and the actually observed values (Y_t). The problem this approach would resolve is overfitting. In such case, the model would be too complex and would adapt perfectly to existing data, but it would resist the introduction of new data. Thus, the introduction of the L1 penalization term reduces the unnecessary coefficients to zero. For a better understanding of this concept let us make an example: imagine being a football coach willing to create the best team possible. While one could choose the players that are the best at their role despite them not being able to team up well, the correct strategy would be to sacrifice the single player's ability in order to create synergies within the team. In the same way, the model sacrifices the single variable's explanatory power to enhance harmony within the model.

3.2.2 SPILLOVER NETWORK ESTIMATION

Once obtained the coefficient matrices for the lagged values in the VAR-L model, it is possible to obtain a network for the spillover of risk between two institutions. The mentioned spillover index network consists of a network in which every node is an institution, and every edge represents how much of the institution's variability is caused by another institution, the risk spillover.

The spillover index is ultimately a matrix in which every coordinate represents the risk spilling from one institution to each other one in the system. As one might know, talking about risk is equivalent to talking about variances. Consequently, the spillover index is the result of a variance decomposition, determining how much of the variance (or risk) of the company depends on shocks on other companies. In this document Generalized Variance Decomposition is used to compute the spillover iteratively for every company combination in the sample.

The spillover index notation stands as:

$$\theta(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H} \left(e_i^T * A_h * \Sigma * e_j \right)^2}{\sum_{h=0}^{H} e_i^T * A_h * \Sigma * A_h^T * e_j}$$

Where H are the steps of forward prediction (in this document H is set to be 8), σ_{jj}^{-1} is the j element on the principal diagonal of the VAR-L residuals' variance covariance matrix Σ, e_i and e_j are selection vectors, or vectors whose only element is a 1 that changes positions according to the position of i or j.

In this environment, the coefficients' horizon needs to be extended beyond the lag order to all steps of forward prediction. The transformation into Vector Moving Average elements fulfils this task. The transformation is iterative and expressed as follow:

$$A_h = \sum_{i=0}^{H} \Phi_i * A_{h-i}$$

Note that for h=0 the corresponding matrix A_h is an Identity matrix I, thus for the first steps the transformation follows this notation:

$$for\ h = 0 \rightarrow\ A_0 = I$$

$$for\ h = 1 \rightarrow\ A_1 = \Phi_1 * A_{1-1} \rightarrow A_1 = \Phi_1$$

$$for\ h = 2 \rightarrow A_2 = \Phi_1 * A_{2-1} + \Phi_2 * A_{2-2} \rightarrow A_2 = \Phi_1 * A_1 + \Phi_2$$

$$for\ h = 3 \rightarrow A_3 = \Phi_1 * A_{3-1} + \Phi_2 * A_{3-2} + \Phi_3 * A_{3-3} \rightarrow A_3 = \Phi_1 * A_2 + \Phi_2 * A_1 + \Phi_3$$

$$for\ h = 4 \rightarrow A_4 = \Phi_1 * A_{4-1} + \Phi_2 * A_{4-2} + \Phi_3 * A_{4-3} \rightarrow A_4 = \Phi_1 * A_3 + \Phi_2 * A_2 + \Phi_3 * A_1$$

Due to the model's high sensitiveness to shocks and occasional high correlation between firms, results might seem unconventional. However, it is difficult to assess whether high peaks of spillover are caused by data anomalies or by relevant economic trends. Despite the descriptive measures analysis underscoring some outliers, the fact that the same number of observations for each vector needs to be removed fosters the hypothesis of a relevant economic trend, highlighting the presence of a disruptive systemic phenomenon in the considered time interval. In any case, spillover data needs to be normalized so that different matrices can be compared, even though the presence of outliers might have distortive effects on results. Normalization is carried out to keep proportions among different observations unchanged while returning a uniform data range. Normalization satisfies two important conditions: contributions for each row add up to one and the sum of all contributions in all rows is equal to N:

$$\theta_N(H) = \frac{\theta_{ij}(H)}{\sum_{j=1}^{N} \theta_{ij}(H)}$$

As a result: $\sum_{j=1}^{N} \theta_N(H) = 1$ and $\sum_{i=1}^{N} \sum_{j=1}^{N} \theta_N(H) = N$

In order to observe the evolution of the spillover effect over time, the spillover index is computed with a rolling window of 100 observations with step size 5. Each window is represented by a N x N matrix.

3.2.3 SYSTEMIC RISK MEASURES

As the network is designed to portrait the interdependence between institutions, a single institution can simultaneously influence the system and be influenced by it. In this sense, systemic risk can be declined into two components for each firm, one capturing the risk spillover from the company to the outside and one capturing the risk spillover towards the company from exogenous variables, other firms. Consequently, to split systemic risk into its components with a network approach, two measures are defined: one to portrait institutions vulnerability to systemic risk and the other to compute contribution to systemic risk.

The measure for vulnerability, measuring risk that stems from other companies towards the observed one, is Systemic Risk Receiver (SRR). This measure is computed as the sum of the market value of the starting company at the end of the window and the market value of companies to which the starting company is connected and receives risk. In other words, this measure evaluates the effect that every hedge that arrives to the starting company has on the starting company itself.

$$SRR = MV_j + \sum D_{i \to j} * MV_i$$

The measure to quantify the share of systemic risk that is caused by one firm is Systemic Risk Emitter (SRE). This measure is computed as the sum of the market value of one company j and the market value of all the other companies who j is connected times the power of the relationship. In other words, every edge in the network that starts from j and arrives to i should be considered for computing the risk spread by the company.

$$SRE = MV_j + \sum D_{j \to i} * MV_i$$

To appreciate the evolution of both systemic risk contribution and vulnerability, the whole spillover index is computed in different time windows with a rolling window analysis. Each window is composed by 100 observations with a time skip of 5 observations for a total of 36 windows. Then, in order to obtain monthly observations to be compared with the chosen control variables, a weighted average according to the coverage of the window is performed. While this procedure might compromise the informative power of the rolling window analysis, it is essential to obtain sufficient observations for the panel regression.

3.3 DELTA COVAR APPROACH

The Financial stability board defines Systemically important financial institutions (SIFI) as "financial institutions whose distress or disorderly failure, because of their size, complexity and systemic interconnectedness, would cause significant disruption to the wider financial system and economic activity" (FSB, 2021, page 1). Institutions' systemic relevance can be assessed through two different approaches: the supervisory approach, which uses firm-specific information like accounting measures and other confidential data and market-based approach that relies on publicly available market data (i.e. stock prices).

The Delta CoVaR approach is one, if not the most, sophisticated market-based risk assessment methodology designed to measure the systemic risk contribution of individual financial firms. Developed by Adrian and Brunnermeier in 2011, the Delta CoVaR approach extends the traditional Value at Risk (VaR) framework by considering the interconnectedness of financial institution in their potential to amplify systemic risk. Delta CoVaR quantifies the difference between the Conditional Value at Risk in a distressed state and in a normal state, capturing the single contribution of an institution to overall systemic risk.

2.4.1 COVAR ESTIMATION

Conditional Value at Risk quantifies an institution's downside tail risk based on the condition that other institutions are under distress. In other words, it measures how the company responds to situations in which the whole economic system is under distress. As the name suggests, CoVaR derives from Value at risk, measuring the value at risk conditional to the distress. Consequently, as for VaR, CoVaR represents the maximum loss for the whole economic system with a certain level of confidence, assumed that an institution's return is equal to its VaR_p.

Defined X as a random variable for return with cumulative probability function $F_X(z) = P\{X \leq z\}$, Conditional Value at Risk is defined as the average of the losses higher than VaR for the confidence level alpha. In other words, if $F(VaR_\alpha) = \alpha$, CoVaR averages the losses that are higher or equal to the VaR.

$$CoVaR_\alpha = E[X \mid X \geq VaR_\alpha] = \frac{1}{1-\alpha} \int_{VaR_a}^{\infty} z * dF(z)$$

Since CoVaR only accounts for losses beyond VaR, the cumulative distribution function is defined as follows:

$$for\ z < VaR_\alpha \rightarrow F(z) = 0$$

$$for\ z \geq VaR_\alpha \rightarrow F(z) = \frac{F(z) - \alpha}{1 - \alpha}$$

Defined X as a random variable for returns, q is the confidence level for CoVaR and p the confidence level for VaR, the probability of the system's return to be lower than CoVaR when the condition of the institution's return to be equal to its VaR is satisfied, is equal to the confidence level q. In notation:

$$P\left(X_t^{sys} \leq CoVaR_{q,t}^i \mid X_t^i = VaR_{p,t}^i\right) = q$$

As a result, CoVaR represents the maximum potential systemic loss when an institution is under distress for a determined confidence level. A high CoVaR suggests that the system is more vulnerable and will bear significant losses with probability q when the institution's return is equal to its VaR. In the same way, due to the distribution of returns, as q becomes very high (or very low), the condition on tail risk becomes more stringent, leading CoVaR to cause a higher level of systemic loss. Thus, in order to represent the system in its "normal" conditions, the considered value for q is the value that divides the returns' distribution in half, the median value q=0,5.

Finally, to measure a company's contribution to systemic risk, Delta CoVaR is computed as the difference between the CoVaR computed assuming the company experience the distress state (q=0,95) and CoVaR computed in the median state.

As stated by Bianchi and Sorrentino (2019), there are several alternative methods to compute CoVaR and thus Delta CoVaR:

- Factor Based Quantile Regression that, after choosing state variables (or factors), performs a quantile regression to model the return of the single institution and the return of the system based on their response to the state variables. Based on these regressions, another quantile regression is performed to derive VaR and CoVaR (Bianchi and Sorrentino, 2019). The issue with this approach is the overdependence of the informative power of Delta CoVaR depends solely on the explanatory power of the state variables, thus making it less precise in.
- Non-parametric method runs a quantile regression of the system's returns against the returns of the institution to estimate a coefficient beta. Then, it estimates the q-th and the 0,5 quantiles of the distribution, namely the Value at risk for the q quantile state and the median state (Bianchi and Sorrentino, 2019). Finally, it computes Delta CoVaR as the estimated coefficient beta times the difference between the VaR:
$$\Delta CoVaR_{q,t}^{i} = \beta * (VaR_{q,t}^{i} - VaR_{0,5,t}^{i})$$
- GARCH-Type closed form formula: as stated before GARCH models allow to capture the time varying nature of institutions' variance. The same models can be used to compute the covariance between each institution and the system. Consequently, by using a GARCH model with Constant Conditional Correlation (CCC) it is possible to derive CoVaR as:
$$CoVaR_{q,p,t}^{i} = \phi^{-1}(q) * \sigma_t^{sys}\sqrt{1 - {\rho_t^{i}}^2} + \phi^{-1}(p) * \rho_t^{i} * \sigma_t^{sys}$$
Where $\phi^{-1}$is the inverse of the cumulative distribution function of a standardized normal variable, ρ_t^i is the correlation between residuals of institution i and the system and σ_t^{sys} is the volatility of the system. Both ρ_t^i and σ_t^{sys} are extracted from the GARCH model. Note that in the standardized normal distribution N (0,1), quantile for p=0,5 that divides observations in half is the mean (0), thus the second term of the CoVaR formula for the median state would be null.

Since, then, Delta CoVaR is the difference between CoVaR when p is equal to q and when p is equal to 0,5, the formula for Delta CoVaR stands:

$$\Delta CoVaR_{q,t}^{i} = CoVaR_{q,q,t}^{i} - CoVaR_{q-0,5,t}^{i}$$

$$\Delta CoVaR_{q,t}^{i} = \phi^{-1}(q) * \sigma_t^{sys}\sqrt{1-\rho_t^{i^2}} + \phi^{-1}(q) * \rho_t^i * \sigma_t^{sys} - \phi^{-1}(q) * \sigma_t^{sys}\sqrt{1-\rho_t^{i^2}}$$

Ultimately resulting in:

$$\Delta CoVaR_{q,t}^{i} = \phi^{-1}(q) * \rho_t^i * \sigma_t^{sys}$$

According to Bianchi and Sorrentino's empirical comparison (2019), the GARCH Formula has been revealed as the preferred method due to its increased informative power. Being characterized by persistence, meaning that institutions tend to conserve their systemic relevance over time and by the ability of capturing the time varying volatility of logarithmic returns, the closed form formula remains unaffected by exogenous issues that might compromise the model's informative power.

3.4 PANEL REGRESSION

Once obtained and regularized all the data for the systemic risk measures, the final part of the study is to perform a regression to understand the dynamics between variables.

Since the data is defined by more than one dimension, namely a temporal dimension (date) and a transversal dimension (different companies), the chosen model is a panel regression. As previously said, panel regression is a widely used technique to observe the behaviour of different variables in time, as it accounts for both variability among variables (inter-variability) and within the same variable (intra-variability).

Panel regression models can furtherly be declined in fixed effects models and random effect models.

In the former, the unique characteristics of each company do not change over time and can influence the dependent variable. In the latter, idiosyncrasies can change over time in a random way, not being correlated to independent variables. In order not to overcomplicate the analysis by introducing the specific random factor, the fixed effect model has been preferred.

The notation for a panel regression model stands as follows:

$$Y = \alpha + \beta_1 * X_1 + \beta_2 * X_2 + \cdots + \beta_n * X_n + \varepsilon_{it}$$

In essence, the dependent variable Y is defined by the combination of the specific fixed effect α and by the coefficient beta times the independent variable X.

In this specific case three variables are chosen:

1. ESG SCORE is the main explanatory variable
2. TOTAL ASSET is a proxy for size of the company. It represents the total of all short and long-term assets reported on the balance sheet. To limit heterogeneity and favour data stationarity, this variable undergoes a logarithmic transformation. Usually, large firms have more funds and resources to be invested for reducing the riskiness of operations and have abundant capital to resist the impact of external shocks. However, the fact that larger companies attract more investors and are subject to greater media coverage increases the likelihood of a shock to spread through investment relationships, increasing exposure to systemic risk.
3. FINANCIAL LEVERAGE RATIO is a way to measure a firm's exposure to debt risk. It is defined as the ratio between average assets and average total common equity. In general, it is impossible for a firm to only rely on its own to carry out its activity; it is thus reasonable to seek for external financing, debt. The heavy usage of external financing can be useful in periods of economic prosperity, when the company is experiencing a rapid growth. In general, the more the debt the more the exploitable resources to generate profits. As long as the return on assets (ROA) remains higher than the cost of debt, the company experiences a boost in the profitability of its equity (ROE), since profits have increased, and its equity has remained constant. Yet, in a less favourable scenario, when profits do not exceed the cost of debt, the company's financial risk has increased. For example, the company might no longer be able to repay the debt or would lose shareholders due to not distributing dividends. Furthermore, with its asset "locked" by external financing, the company might not be able to invest in new opportunities or else to pay its suppliers. Therefore, financial leverage ultimately can reduce a company's

financial structure flexibility, leaving it more vulnerable to external shocks and more likely to cause them.

Consequently, defining the dependent variable Y as the systemic risk measure, firstly SRR then SRE and finally Delta CoVaR, and adding the independent variables as the control variables and the core variable ESG score, the model is further defined as:

$$SYS = \alpha + \beta_{ESG} ESG + \beta_{size} SIZE + \beta_{LVRG} LVRG$$

To test the hypothesis of an inverse relationship between the core variable ESG score and the dependent variable SYS, the coefficients for β_{ESG} shall be negative with a low p-value. In such way, the value for the correspondent variable falls in the null hypothesis rejection region with high confidence level.

CHAPTER 4: RESULTS

This chapter presents the results of the research, beginning with an initial representation of Delta CoVaR and Spillover Networks.

Both approaches are analysed in their ability to capture and potentially forecast periods of financial stress due to their sensitivity to macroeconomic events. Differences and similarities are then pointed out in an initial comparison. The analysis then shifts to an examination of top contributors and central nodes within the network, emphasizing the distinction between the most influential entities under each method.

Tracing back to portfolio analysis in Chapter 2, the paragraph provides initial insight on the inclusion of top contributors in banks' equity portfolios.

After that, sectorial aggregation analysis highlights the key contributors to systemic risk from a sectorial perspective, while exploring measures of sectorial interconnectedness.

The chapter proceeds with a discussion of panel regression outcomes exploring the impact of ESG performance on systemic risk and its statistical significance.

Concluding the chapter, final considerations for managers and regulators emphasize the critical role of ESG factors in mitigating systemic risk and fostering financial resilience.

4.1 COMPARATIVE ANALYSIS

4.1.1 DELTA COVAR

The Delta Conditional Value at Risk (CoVaR) approach is a widely used measure for assessing systemic risk within financial systems. Developed as an extension of the traditional Value at Risk model, Delta CoVaR captures how the risk profile of an institution affects the overall risk of the financial system. Specifically, delta CoVaR measures the change in the system's risk when a particular institution moves from a normal state (median) to distress. This makes it a fundamental tool for understanding a company's contribution to broader market instability.

As discussed in chapter 3, the procedure for deriving Delta CoVaR begins with tail risk estimation with Value at Risk. VaR represents the maximum potential loss a company or an asset can face over a specific time interval with a specified confidence level. Therefore, it determines the worst possible loss without considering market conditions, but solely on the individual asset's conditions with a predetermined probability.

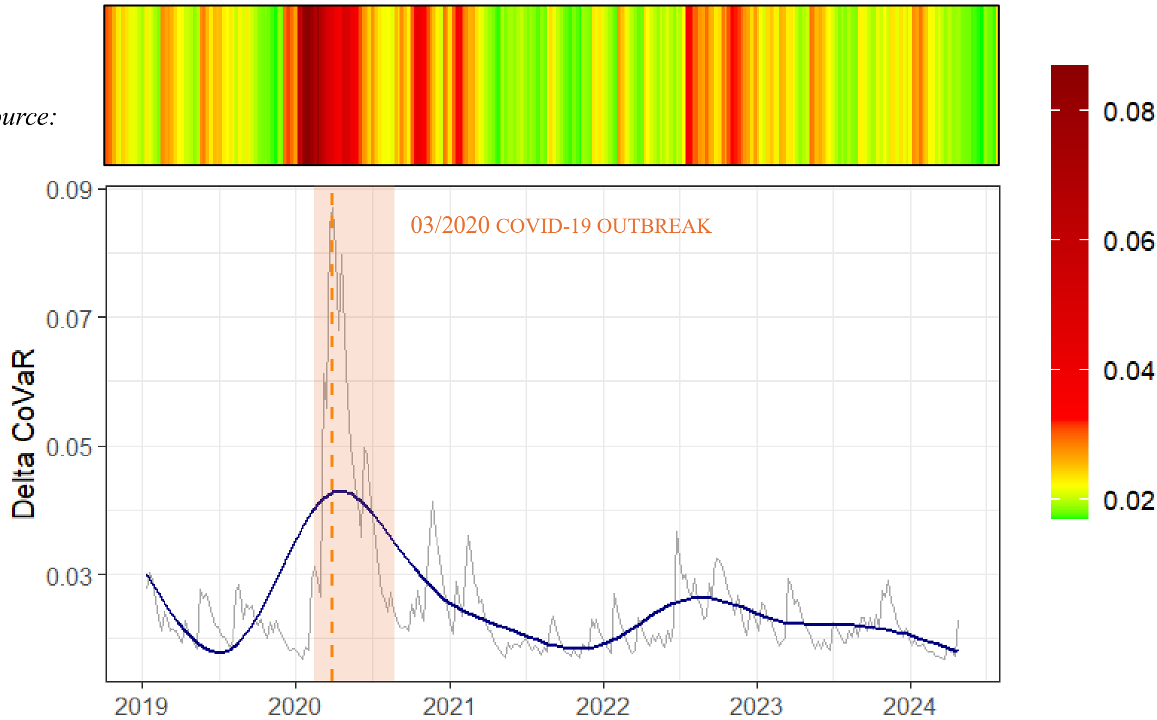
Conditional Value at Risk (CoVaR) extends this concept, incorporating market conditions to capture the risk of an institution conditional on systemic instability. CoVaR measures the maximum potential loss an asset or an institution can incur when the entire financial system is in distress. In this context, the term "system" refers to an aggregate of all other institutions or companies in the sample. Thus, CoVaR gives valuable insights into an individual company's risk in its relationship with the collective state of all others, rather than representing interconnectedness between each pair of companies.

Delta CoVaR is finally obtained by computing the difference between CoVaR under two different scenarios: one where the system is in the median (normal) state and the other where the system is experiencing distress. Consequently, Delta CoVaR is a measure for residual tail risk, quantifying the additional risk caused by the institution during periods of systemic distress.

A preliminary analysis of all companies' Delta CoVaR over time has revealed a noteworthy pattern: almost every company in the sample exhibits similar behaviour. This uniform behaviour suggests that the systemic risk contributions of individual companies, as captured by Delta CoVaR, follow a common trajectory across the financial system.

Potential explanations for this pattern lie on the high interconnectedness of the network, that is to remember is composed of supply chain relationships and the presence of major systemic events like financial crises that affect all companies in the same manner, regardless of their individual characteristics. Picture 5 depicts the overall behaviour of delta CoVaRs. This pattern also supports the notion that financial systems are interconnected, leading to synchronized risk behaviour across institutions in times of financial distress.

Picture 6. Delta CoVaR trend over time and heat map (2019-2024)



Source: Bloomberg's data elaboration

Picture 6 captures significant shifts in systemic risk, with notable peaks during key periods. The pronounced spike in early 2020 coincides with the onset of the COVID-19 pandemic, which triggered significant financial distress globally. The sharp increase in Delta CoVaR during this period reflects the substantial rise in systemic risk, since many companies had experienced heightened stress increasing their spread with the median state. Other than exposing companies to the same risk factors, the pandemic likely increased interconnectedness between institutions within the system causing the shock to propagate very quickly across the whole system.

The subsequent period of gradual stabilization suggests that the system was able to absorb the shock, potentially because of effective regulatory intervention or market adjustments that helped mitigating companies' contribution to systemic risk. However, this period is characterized by high volatility and fluctuations, indicating that the system remained vulnerable to external shocks.

Delta CoVaR approach can be useful to identify the highest risk contributors relative to the system, by comparing institutions with the highest Delta CoVaR level. The top 10 institutions based on the average contribution to systemic risk are showcased by Table 8. In the chart, the Industrials sector appears as the riskiest, with 5 representatives in the top 10 contributors, followed by Consumer Discretionary with 3 representatives.

To conclude with this initial valuation, it seems Delta CoVaR effectively captures the dynamic nature of systemic risk, highlighting periods of extreme financial stress and their subsequent recovery.

Table 8. Top 10 ranked institutions by Delta CoVaR

SECTOR	*TICKER*	*DELTA COVAR*	*ESG SCORE*
Materials	EMN US	4,30%	4,38
Industrials	PH US	4,26%	5,21
Information Technology	APH US	4,19%	4,47
Industrials	EMR US	4,15%	5,89
Consumer Discretionary	MGA US	4,13%	4,53
Consumer Discretionary	DAN US	4,12%	5,80
Industrials	AHT LN	4,09%	2,65
Industrials	TXT US	4,03%	3,87
Consumer Discretionary	PVH US	3,97%	4,85
Industrials	WAB US	3,96%	3,59

4.1.2 RISK SPILLOVER NETWORK

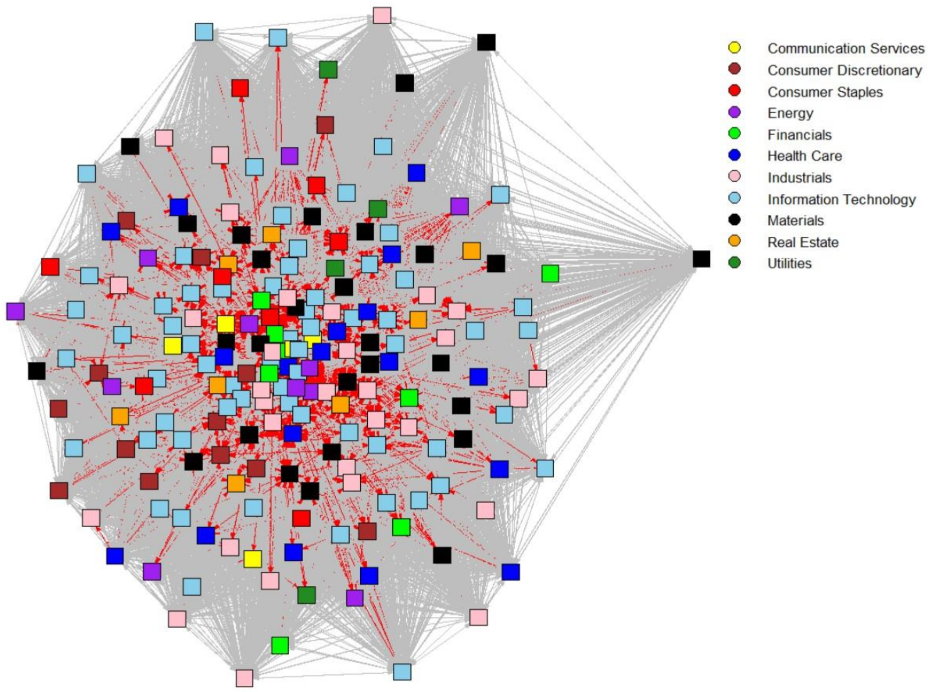
Like Delta CoVaR, Spillover networks are key tools in systemic risk analysis, as they measure and visualize the transmission of shocks or risk between institutions or sectors. In simple terms, the spillover index quantifies how much volatility of risk "spills" from one institution to another. This volatility spillover, which determines the share of a company's risk deriving from external entities, is typically computed using variance decompositions from vector autoregressive models. In this document the chosen variance decomposition method was the Generalized Variance Decomposition on a VAR model with Lasso penalization, allowing for the estimation of directional spillovers between each possible pair of companies.

Directional spillovers indicate how much risk is exchanged between pairs of institutions, both transmitted and received. They are also useful to identify systemically important institutions either because they are more vulnerable or because they are the most significant sources of risk transmission. For instance, nodes with high-weight outgoing are likely to have a strong influence on others, meaning they transmit lots of risk. Accordingly, institutions that receive many high-weight incoming edges are likely to be more vulnerable to risk, as they absorb risk from external sources.

The peculiarity of VAR models penalized with Lasso is that they are designed to set many coefficients to zero, focusing only the most significant relationship between variables. This characteristic allows for a more agile model by filtering out less relevant connections. Consequently, when applied to estimation of spillovers between institutions, many of the relationships are deemed insignificant, leading to isolated nodes in the network. These isolated nodes represent institutions with insufficient risk transmission to or from others and that can therefore be ignored in network representations. This simplified version of the spillover network is portrayed in Picture 7.

As seen in the graph for the network in chapter 2, the network can be represented with customizable layouts. For instance, in Picture 7 the colour of the nodes represents a different sector, allowing for intuitive understanding of the distribution of representatives among sectors. Additionally, the most relevant edges cam be highlighted with a different colour or thickness to emphasize the most critical pathways.

Picture 7 Spillover network representation



Source: Bloomberg's data elaboration

Given the high density of nodes in the center and the fact that each node has both an incoming and outgoing edge from all other nodes, this visualization can be confusing. Yet, it gives an initial understanding of the landscape of relationships between institutions. It appears the most significant risk emitters are concentrated in the center of the network, while the most vulnerable receivers are peripherical. The high concentration of red links among firms in the center indicates that these central firms are highly interconnected, characteristic that makes them likely to propagate risk rapidly. As a matter of fact, high level of interconnectedness increases the likelihood of risk contagion, as shocks transmitted from one institution are quickly transferred to others.

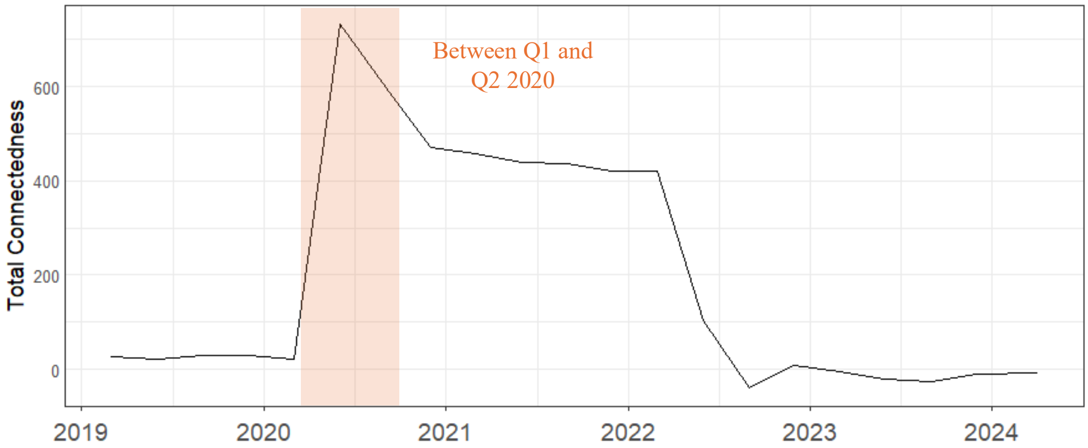
Spillover network analysis holds many important implications for regulators and risk managers, since it provides a framework for monitoring the overall health of the financial system and for identifying potential systemic distresses. In fact, by examining the interconnectedness between institutions, it is possible to predict financial instability before it materializes. Indeed, a rising level of interconnectedness is often a sign of systemic fragility.

To put this hypothesis to the test on historical data, total connectedness has been computed for each time window of spillover network with the following formula:

$$TC = \sum_{i=1}^{N} \sum_{j \neq i}^{N} D_{ij}^{w}$$

Where D_{ij}^{w} is the spillover from institution i to institution j in the window considered. Picture 8 displays the behaviour of total connectedness over time, showing how the interconnectedness in the system evolved from 2019 to 2024, data are aggregated quarterly.

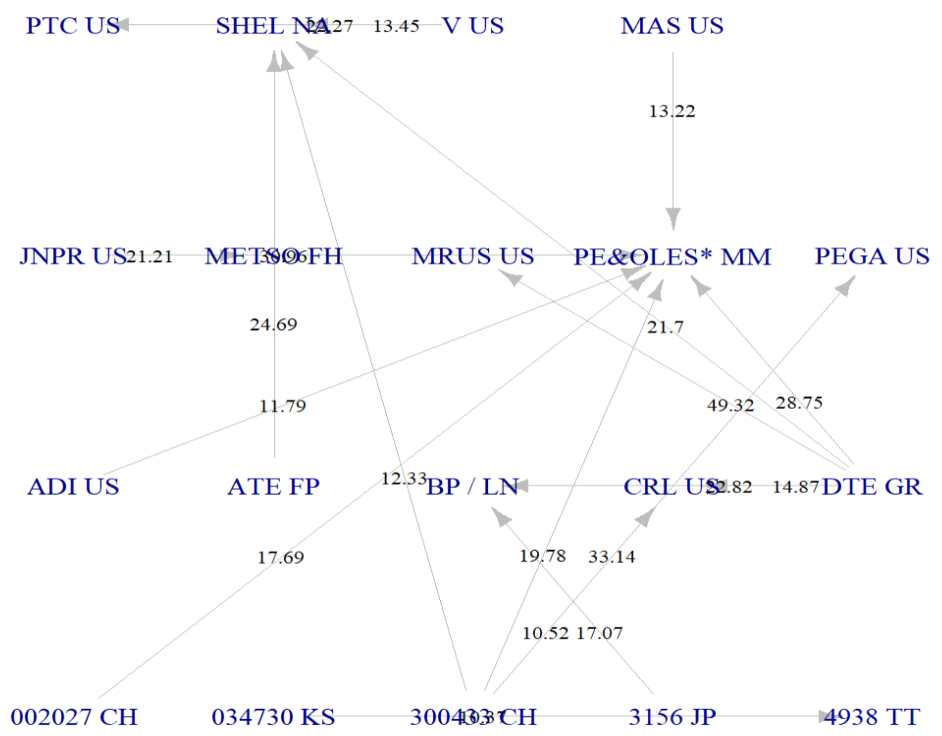
Picture 8 Total connectedness quarterly (2019-2024)



Consistent with the hypothesis that interconnectedness increases in times of financial distress, picture 10 showcases that in the period between the first and second quarters of 2020, firms tend to be highly connected with each other. As one might recall, this period aligns with the Covid-19 pandemic, which generated a systemic crisis. This spike hints that the overall spillover of risk among institutions reached its peak by the time of the crisis, supporting the idea that the financial system becomes more tightly linked in times of financial distress, thus increasing the chances of contagion.

Another noteworthy characteristic lies in the most central paths identification. By filtering once again the network to consider only the edges with the highest weight it is possible to identify the most significant relationships in terms of risk transmission. Note that these nodes are not necessarily the most significant risk transmitters or receivers, but their specific relationships with other nodes entail the highest risk exchange. Edges with the highest spillover are represented in Picture 9.

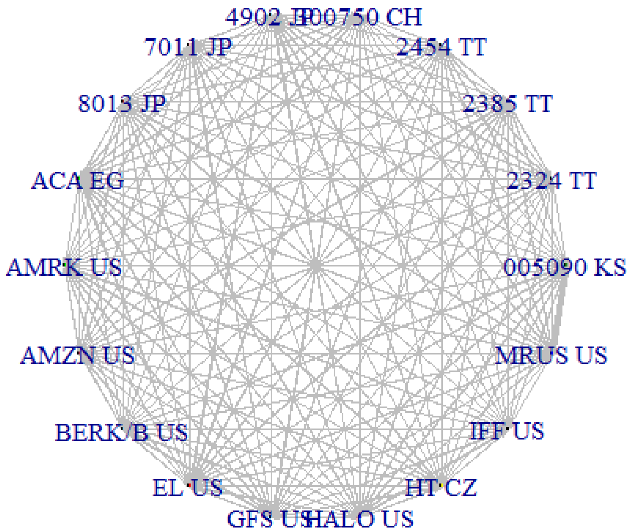
Picture 9 Highest spillover links in spillover network



Source: Bloomberg's data elaboration

While identifying nodes and edges with the highest weights can be useful to understand the network structure, it does not necessarily reveal the most influential nodes. A centrality analysis, particularly using betweenness centrality measure, might underscore the role of specific nodes within the network. As already discussed earlier, betweenness centrality highlights nodes that control the flow of information or risk, regardless of their weight, emphasizing their potential impact on overall network dynamics. This approach helps uncover key actors whose strategic position in many of the shortest paths between nodes, influences the broader system, even if their direct connections are not the strongest. Picture 10 provides a visual representation of the nodes with highest betweenness centrality.

Picture 10 nodes with highest betweenness centrality in the spillover network



Source: Bloomberg's data elaboration

Some remarks on Systemic risk contribution and vulnerability measures, namely Systemic risk Receiver and Systemic Risk Emitter, conclude this initial dissertation on the Spillover network approach. As will be showcased in Table 7 and Table 8, these measures are key to assess an institution's role in propagation and absorption of systemic risk. Table 9 represents the top ranked institutions by SRE, identifying the highest contributors to systemic risk. Table 10 displays top ranked institutions by SRR, underscoring the most vulnerable institutions.

Table 9 Top 10 institutions ranked by SRE

SECTOR	*TICKER*	*SRE*	*ESG SCORE*
Health Care	DIM FP	12330904,70	3,07
Information Technology	300433 CH	12260603,78	2,00
Information Technology	ATE FP	4264841,08	2,67
Materials	3407 JP	3831533,66	4,50
Real Estate	SPG US	3426309,27	4,04
Financials	V US	3068574,06	5,24
Communication Services	GOOG US	2658949,75	4,12
Consumer Discretionary	AMZN US	2653899,58	4,18
Information Technology	JBL US	2636381,82	4,52
Materials	FRES LN	2556622,03	4,45

Table 10 Top 10 institutions ranked by SRR

SECTOR	TICKER	SRR	*ESG SCORE*
Materials	PE&OLES* MM	10372837,59	4,08
Financials	BARC LN	5166604,58	4,32
Health Care	MRUS US	4352272,76	1,64
Energy	SHEL NA	4235983,89	6,99
Energy	BP / LN	3341715,97	6,21
Information Technology	MSFT US	2794000,54	4,98
Communication Services	GOOG US	2680125,69	4,12
Information Technology	AAPL US	2504298,82	5,62
Real Estate	DOC US	2413791,24	5,43
Information Technology	NVDA US	2050841,50	6,71

Source: Bloomberg's data elaboration

While these rankings offer valuable insights into systemic importance, it is important to note that they are substantially influenced by the initial value or size of the company. Despite lower contribution from external parties, larger institutions may inherently pose or receive greater risk, therefore they are likely to appear in higher rankings. For instance, fluctuations in companies like GOOG US are very likely to cause higher price variations on the connected companies.

Form the tables it seems that the top risk emitters have poor sustainability performance with respect to the median, and the top risk emitters appear to have high sustainability performance but are linked to sectors that embed high intrinsic riskiness and high environmental impact, like Energy and Materials. Although some conclusions on sectorial trends can be drawn from these charts, it is important to remember that these rankings reflect specific companies' behaviour within the sample and not necessarily the risk profile of their respective sectors. Risk emission and reception patterns could therefore vary with different samples or timeframes.

4.1.3 INITIAL COMPARISON

Both Delta CoVaR and spillover networks are valuable tools in systemic risk analysis, each offering valuable insights into periods of systemic fragility. Both methods, in fact, allow for detection and assessment of systemic crises, potentially foreseeing into financial instability. However, these two approaches differ in terms of focus, computational requirement and detailed captured.

Delta CoVaR is primarily a measure of residual tail risk, assessing how much additional risk an institution contributes to the system during financial distress. This approach requires a system-wide benchmark to calculate the excess risk the individual entity poses. This makes Delta CoVaR relatively simple to compute and intuitive to interpret, assessing how a particular institution's risk translates into systemic consequences.

On the other hand, spillover networks focus on direct transmission of risk between institutions by measuring the variance spillover. This method offers a more granular view of interconnectedness showing how risk propagates through the system, not just from individual companies to the aggregate, but also between each pair of institutions. While the computational charge of spillover analysis is generally higher, it can effectively reveal each underlying relationship in the system. The fact that it is possible not only to identify the most vulnerable institutions but also understand from whom this risk come from, allows spillover networks to capture dynamics that might be missed by Delta CoVaR.

To conclude, Delta CoVaR is more straightforward, both in terms of computation and interpretation, making it a useful tool when comparing the company's contribution to systemic risk relative to a broader system. Spillover networks, while more complex, provide a richer picture of systemic interdependencies, mapping how risk propagates through the system with greater detail.

4.1.4 CONSISTENCY CHECK

Adding an analytical layer to the results, a consistency test between the two approaches allows to critically examine their relationship rather than treating them in isolation. For this reason, by comparing the findings in Table 8, Picture 9, Picture 10, Table 9 and 10 alongside the previous discussion in Chapter 2 about banks' equity portfolios, valuable insights emerge into the differences and similarities between the two methods and link them to real-world dynamics.

First, a comparison of the most influential companies under both approaches reveals noticeable differences, suggesting that these methods capture different risk propagation mechanisms. In fact, companies identified as the most significant contributors by Delta CoVaR do not appear to have neither high-weight edges nor high betweenness centrality in the spillover network. This suggests that while delta CoVaR captures certain systemic risk characteristics, it may not align directly with network-based approaches.

In contrast, after computing SRE and SRR, a remarkable level of consistency can be noticed, with several of the top-ranked systemic risk Receivers and Emitters also showing up as having some of the highest-weighted edges in the network. As already discussed, the initial value of companies is shown to have substantial influence on SRE and SRR, thus justifying the fact that some very large companies appear as top ranked even though they are not among the most central nodes in the spillover network.

Considering whether institutions with central roles, under both approaches, are included in banks' equity portfolios could reconnect this analysis to the broader discussion on financial institutions' central role in managing systemic risk. Understanding these dynamics can offer banks and regulators a more comprehensive view of how their portfolio might influence or be influenced by the broader system's dynamics. When the most influential nodes in the network are included in banks' equity portfolios, their contribution or vulnerability to systemic risk directly impacts the portfolio's risk profile. Conversely, if these institutions are not central but still part of the broader network, the portfolio may be indirectly affected through their connections and the risk spillovers they propagate across the financial system. Although it appears that Delta CoVaR does not include portfolio holdings in the top ranked contributors, it is possible to trace back to the portfolio through the network of supply chain relationships, therefore it concludes that banks portfolios are indirectly influenced by high systemic risk contributors. In contrast, it appears that many Top ranked SRE and SRR companies are included in banks' equity portfolios, hinting that the portfolio both directly contributes to systemic risk and is directly vulnerable to systemic risk.

Moreover, if the banks themselves were facing times of financial distress and need liquidity, they might be forced to sell a significant portion of their equity portfolio. Given the banks' size and reputation, a large sale could send negative signals to the market. This could lead to a loss of confidence among investors, influencing investors' sentiment, triggering huge sell trends across the market. Such phenomenon, known as herding behaviour, can amplify volatility and worsen the magnitude of the market downturn for the whole system.

4.2 SECTORIAL CONSIDERATIONS

Aggregating by sector and discussing the overall trend can be a valuable expedient for regulators and risk managers, helping in sector-specific policy designing or strategic investment or divestment decisions. Over the years, various measures have been developed to highlight sectorial vulnerabilities and contributions to systemic risk. The spillover network approach stands out for its ability to distinguish every specific link in the sample, making it a more accurate tool for analysing risk transmission than the Delta CoVaR method.

Nonetheless, Table 11 provides a summary of average systemic risk measures for each sector, including Delta CoVaR, SRE and SRR. It is important to note once again that, while these averages offer valuable insights, results might be influence and biased by the value of each sector's individual component. For these reasons, a deeper and more detailed analysis of cross-sector risk transmission is provided to complement such findings and give a complete picture of systemic risk dynamics.

Table 11 Average systemic risk measures summary

SECTOR	AVERAGE DELTA COVAR	AVERAGE SRE	AVERAGE SRR
Communication Services	2,090%	-2277291	468891
Consumer Discretionary	2,860%	232457	111465
Consumer Staples	1,666%	91439	193110
Energy	2,812%	148956	280748
Financials	2,749%	461023	344934
Health Care	1,702%	478443	237274
Industrials	2,827%	74361	6187
Information Technology	2,545%	402638	10867
Materials	2,714%	116167	216967
Real Estate	3,036%	442029	162959
Utilities	2,474%	219266	-3993

According to the Delta CoVaR column, Consumer Staples appears as the sector with the lowest systemic risk profile, confirming its attractiveness as discussed in chapter 2. Healthcare and Communication Services also rank lower in systemic risk, suggesting that companies within these sectors are generally less exposed or more resilient to shocks. On the other end, Real Estate, Consumer Discretionary, Industrials and Energy appear to be the most exposed. These findings are consistent with previous considerations on the overall risk profile of these sectors, often considered more volatile or riskier due to the nature of their activity.

With regards to SRE and SRR, the Financials sector appears to be one of the main systemic risk emitters and the second highest risk receiver. This finding indeed aligns with general expectations, given the high degree of connectedness of financial institutions through lending and investment, which often amplifies their role in systemic risk propagation. Financial institutions, through their vast network of dependencies, are often critical for risk transmission, that is why they are addressed by more stringent regulatory requirements.

The Information Technology sector and Utilities sector appear to show unexpected behaviours. Whereas they appear as some of the most influential risk emitters, they show low vulnerability to systemic risk in terms of SRR. A closer look at variation coefficients reveals a significant skew in the data, suggesting that outliers with very high performance influence the average.

The Real Estate sector confirms its unattractiveness. The high cyclicality, combined with its sensitivity to macroeconomic shocks, makes it more prone to emitting and receiving risk, making it a dangerous player in the system.

4.2.1 ISS, OSS and SCS

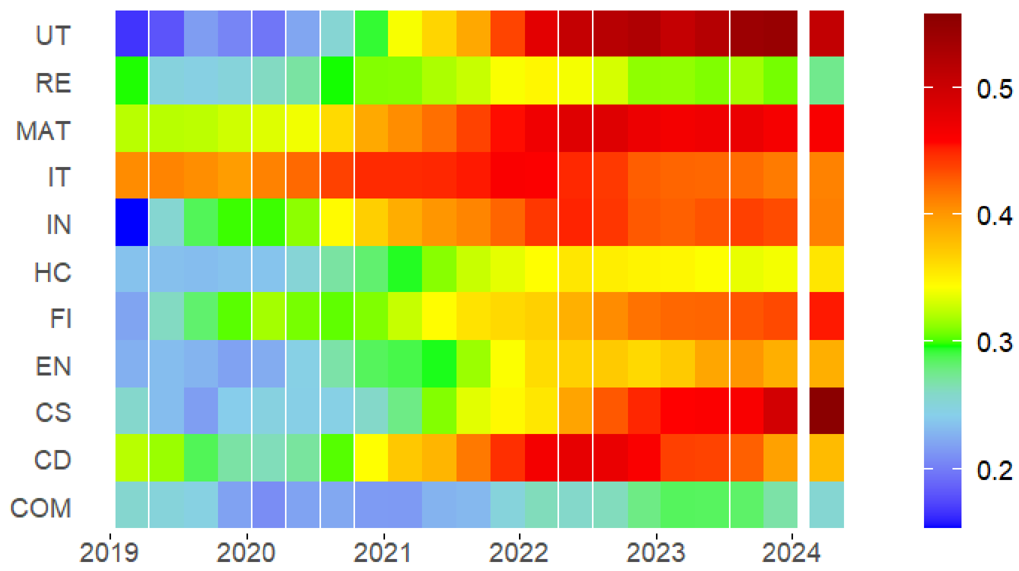
In order to further explore systemic risk transmission at sectorial level, three key interconnectedness measures are introduced: In-Strength-Sector, Out-Strength-Sector and Cross-Strength-Sector. These metrics help quantify risk flows within and between sectors, providing deeper insight into sector-specific relationships.

In-Strength-Sector connectedness quantifies the total risk that the sector receives from all other sectors, reflecting the vulnerability of a sector to external shocks and highlighting how exposed it is to risk generated elsewhere. In-Strength sector is computed as the sum of all incoming edges of the network for a specific sector, discounted for the number of components of the sector.

$$ISS = \frac{1}{N_m} \sum_{j \in V_m} \sum_{i=1, i \neq j}^{N} D_{ij}^{w}$$

in this formula N_m is the number of components of sector m, V_m is the set vertices that belong to sector m, D_{ij}^{w} is the spillover or edge weight that goes from firm i to firm j. Picture 11 shows a heatmap of ISS for each sector and its evolution over time.

Picture 11 ISS heatmap



Source: Bloomberg's data elaboration

According to the ISS heatmap, sectors like Utilities (UT) Materials (MAT) and Consumer Discretionary (CD) emerge as more vulnerable to systemic shocks. These sectors are more exposed to risk transmission, making them vulnerable during periods of financial stress.

Information Technology's high vulnerability can be attributed to its significant representation in the sample, that ultimately can influence the results.

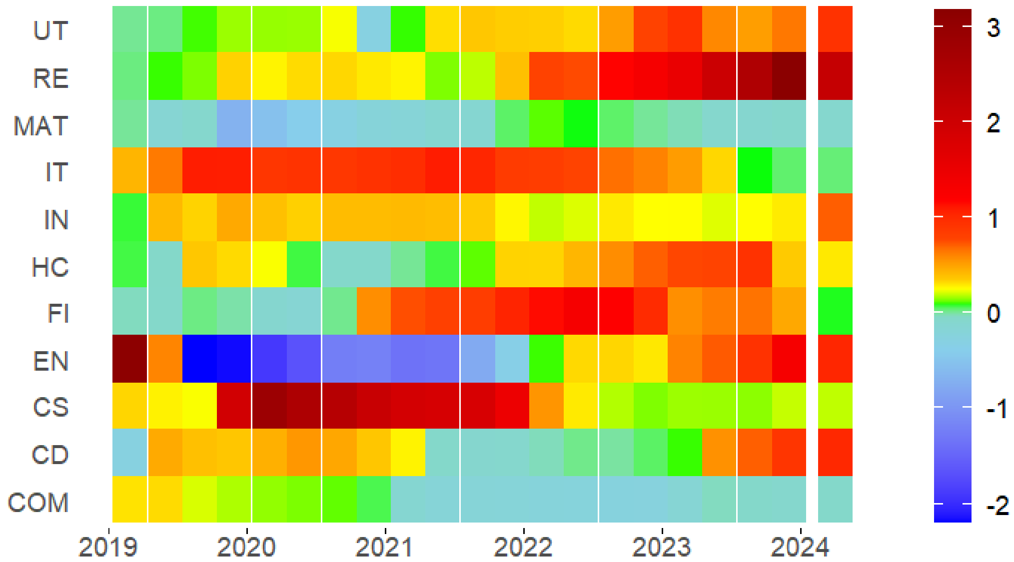
On the other end of the spectrum, Health Care (HC) and Communication Services (COM) show the least vulnerability. This can be explained by their relatively weaker of fewer connections to other sectors, making them less likely to absorb or transmit risk.

Out-strength sector connectedness measures the total risk that stems from the sector towards every other sector, reflecting how much a sector contributes to spread risk across the financial system. Out-strength-sector connectedness is computed as the sum of all outgoing edges for the specified sector, discounted for its number of components.

$$OSS = \frac{1}{N_m} \sum_{i=1, i \neq j}^{N} \sum_{j \in V_m} D_{ij}^{w}$$

Where, again, N_m is the number of components of sector m, V_m is the set vertices that belong to sector m, D_{ij}^{w} is the spillover or edge weight that goes from firm i to firm j. Picture 12 shows the heatmap of OSS for each sector in the specified time interval.

Picture 12 OSS heatmap



source: Bloomberg's data elaboration

The OSS heatmap highlights Information Technology, Financials and Consumer Discretionary as the most central contributors to systemic risk. These sectors stand out due to their high number of connections with other sectors, indicating that a disruption in any of these industries is likely to have significant spillover effects.

Interestingly, Industrials and Materials, despite being fundamental sectors providing input for the economy, appear to have a more limited impact than expected. This suggests that their risk influence is concentrated in fewer sectors rather than having wide spillover potential.

Lastly, Cross-Strength-Sector connectedness measures the intensity of risk spillover between sectors. SCS from sector m to sector n is defined as the sum of all edges that start from a firm that belongs to sector m and arrive to a node that belongs to sector n, all discounted by the multiplication of the number of components of both sectors.

$$SCS_{m \to n} = \frac{1}{N_n * N_m} \sum_{i \in V_n} \sum_{j \in V_m} D_{ij}^{w}$$

When computing SCS of a sector with itself, $N_m = N_m - 1$, $V_m = V_n$ and $i \neq j$. To appreciate cross-sectorial contribution for each sector to every other, each sector has its own heat map of SCS, all portrayed in Picture 13.

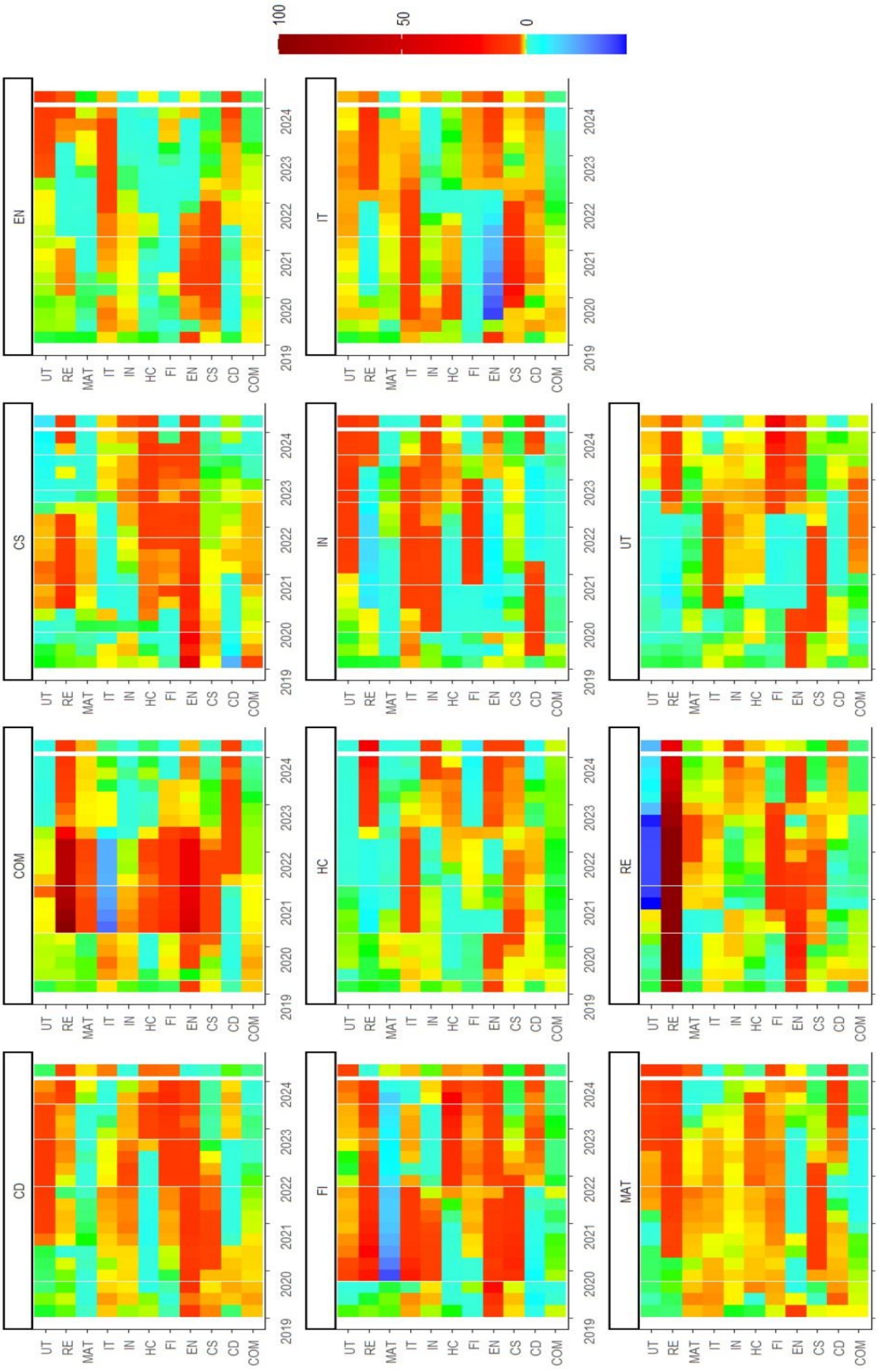
From this set of pictures, we can observe that the Energy sector consistently appears as an important risk contributors for many sectors. It exerts substantial influence on Consumer Discretionary (CD), Financials (FI) and Utilities (UT).

The Financials sector also appears deeply interconnected, displaying high level of influence across many sectors, confirming its central role in systemic risk propagation across sectors.

Utilities and Industrials show a strong mutual relationship, indicating that these sectors are closely tied in terms of risk exchange. Real estate exhibits a pronounced impact within its own sector and also influences external sectors like Financials and Energy.

These heat maps underscore that Financials and Energy act as key drivers of systemic risk. Their central roles in contagion and risk transmission require careful attention from policymakers, as they likely are pivotal in preventing or mitigating systemic shocks across the financial system.

Picture 13 Heat maps of SCS for every sector



4.3 PANEL REGRESSION RESULTS

The primary aim of this study is to evaluate the hypothesis that a stronger commitment to Environmental, Social, and Governance (ESG) principles, as represented by a higher ESG score, correlates with reduced systemic risk. To test this hypothesis, the study first calculates the spillover network and measures of systemic risk, specifically focusing on the Systemic Risk Emitter (SRE) and Systemic Risk Receiver (SRR). Following this, a panel regression analysis is employed to assess the relationship between ESG scores and systemic risk.

Panel regression models are designed to account for both cross-sectional and temporal dimensions of data, allowing to simultaneously manage multiple observations over time and across different entities, such as companies. Panel regression models are generally categorized into fixed effects and random effects regressions, each providing different insights based on the data structure and research objectives.

In the regression set up the panel regression, the dependent variable Y, is selected from systemic risk measures, namely Delta CoVaR, SRR and SRE. The independent variable of primary interest Bloomberg's ESG score, a metric that quantifies both commitment to sustainability using financial materiality and the quality of disclosure and management of these financially material issues. Additional control variables included in the analysis are the company's Size, Financial Leverage and the Sector.

In order to obtain a conclusive result to test the initial hypothesis, a negative and significant coefficient for the ESG score variable should be reported repeatedly for every regression computed. Finding an inverse relationship between ESG score and systemic risk is verified and statistically significant would imply that ESG factors have some kind of mitigation factor on systemic risk, as higher ESG score would be associated to lower systemic risk.

Picture 12 discloses the fixed effect panel regression outcome without considering the sector's influence. As one might notice the regression underscores negative coefficients for what concerns the ESG variables, showing that consistently across all three approaches, ESG is shown to mitigate both systemic risk contribution and vulnerability. Different scales in variables might justify the smaller coefficients for Delta CoVaR. Despite that, coefficients for ESG are statistically significant, with p-value lower than

0,01. As for other variables in the model, it seems that larger size companies are associated with lower risk contribution and vulnerability. Such a result can be justified by the higher opportunities for larger companies to transfer risk to others while being unaffected, diversification of risk and economies of scale might effectively reduce the company's risk exposure. Larger companies may also have more resources and better risk management practices that contribute to lower systemic risk profile.

Picture 13 Fixed effects panel regression outcome

	Dependent variable:		
	SRR	SRE	DCVAR
	(1)	(2)	(3)
ESG	-0.314***	-0.466***	-0.001***
	(0.086)	(0.085)	(0.0002)
SIZE	-0.209*	-0.224*	-0.002***
	(0.120)	(0.118)	(0.0002)
LVRG	0.00003	0.0001	0.00000
	(0.0003)	(0.0003)	(0.00000)
Observations	23,808	23,808	23,808
R^2	0.001	0.002	0.009
Adjusted R^2	-0.015	-0.014	-0.007
F Statistic (df = 3; 23433)	7.058***	14.158***	72.416***
Note:	*p<0.1; **p<0.05; ***p<0.01		

However, the model's adjusted R^2 is very low. Since it reflects the proportion of variance in the dependent variable that is explained by the independent variables, a small, adjusted R squared suggests that the model does not capture all the factors influencing systemic risk. Being a very complex and being influenced by many factors, it is likely that the current set of variables does not account for the full spectrum. Factors contributing to systemic risk can be influenced by broader economic conditions, market dynamics or even unforeseen events that the selected variables are not able to explain. These results indicate that this model is a useful starting point, but there may be many additional variables that might increase explanatory power.

This is also proven by factoring for sector and conducing a Least Squares Dummy Variable (LSDV) model, which accounts for entity-specific effects on panel data. The model provides more consistent estimates of the coefficients on the independent variable, including dummy variables for each company to account for differences in financial performance that are not explained by the considered variables, but by firm-specific attributes. A partial outcome of these models is portrayed in Table 12.

Table 12 partial outcome of Least Squares Dummy Variable model

	SRR	*p-value (<0,01)*	*SRE*	*p-value (<0,01)*	*DCVAR*	*p-value (<0,01)*
ESG	-0,3145	<0,01	-0,4664	<0,01	-0,0013	<0,01
SIZE	-0,2091	<0,1	-0,2245	<0,1	-0,0022	<0,01
LVRG	0,0000	>0,5	0,0001	>0,5	0,0000	>0,5
COM	3,3603	<0,01	8,1090	<0,01	0,0517	<0,01
CD	14,6508	<0,01	15,8979	<0,01	0,0524	<0,01
CS	10,2212	<0,01	4,6379	<0,01	0,0481	<0,01
EN	-2,7907	<0,05	12,1929	<0,01	0,0533	<0,01
FI	16,7171	<0,01	18,5579	<0,01	0,0501	<0,01
HC	13,9490	<0,01	14,8501	<0,01	0,0584	<0,01
IN	11,2813	<0,01	-2,5771	<0,05	0,0412	<0,01
IT	9,3866	<0,01	13,6532	<0,01	0,0512	<0,01
MAT	10,1097	<0,01	11,4946	<0,01	0,0535	<0,01
RE	3,2805	<0,01	14,3068	<0,01	0,0419	<0,01
UT	13,4053	<0,01	14,7309	<0,01	0,0611	<0,01
R2	0,68069		0,70943		0,86294	
Adj. R2	0,67558		0,704776		0,860755	

The increased level of R^2 is a remarkable sign for this model, yet coefficients' significance did not improve. Consistently with what previously found, the Financials sector confirms its central role in both systemic risk emission and vulnerability. Consumer Discretionary also shows strong positive contributions to systemic risk, with high coefficients across SRR, SRE and DCVAR making it one of the most critical sectors in systemic dynamics.

To conclude, systemic risk is indeed a multifaceted concept that poses many challenges on statistical models, it is therefore not uncommon to find low adjusted R^2 in complex fields as such. Moreover, data granularity can impact the model's explanatory power. The model could therefore be improved by incorporating additional data, considering more frequent observations or changing aggregation methods or measure computation's methods. However, despite the low R^2, the significant findings for ESG scores, size and leverage are still valuable. These findings suggest that the model is still able to capture some meaningful relationships which could be explored with more comprehensive data or additional variables.

4.4 IMPLICATIONS

The findings of this study emphasize the crucial role that ESG performance plays in mitigating both systemic risk emission and vulnerability and may help financial decision making in various contexts. The negative and significant coefficients for ESG scores across the different systemic risk measures reveals that firms with higher ESG performance are more resilient to systemic shocks and are less likely to contribute to the spread of risk across the broader financial system when a firm-specific shock occurs.

Therefore, integrating ESG factors into corporate strategies, firms can effectively reduce their financial risk profile. Strong governance, proper management and transparent disclosure of risks associated with environmental and social factors can minimize the likelihood of destabilizing events to occur. The integration of ESG criteria into supply chains to create a stable stream of revenues across the whole chain, often referred to as co-development, could turn out to be a successful strategy to avoid incurring in losses and protect financial stability.

Companies with strong ESG credentials tend to establish stronger relationships with stakeholders, including investors, employees and customers. The trust built with these relationships can act as a shield against market fluctuations. Specifically, sustainable investors are often characterized by a long-term investment horizon and tend to prefer a more stable value-oriented investing over aggressive growth investing. Therefore, such investors are less prone to panic selling during periods of market stress. Attracting this investor category will likely make the company more resilient to broader shocks. Moreover, sustainable investors' decisions are likely driven by non-financial motives, such as genuine concern for the environment and societal value Thus, they might tolerate lower short-term returns, if they believe the company is generating shared value in line with their beliefs. Managers should thereby be motivated to adopt sustainable practices, not only to strengthen their firm's resilience but also to attract this growing class of long-term, value-focused investors.

This study also underlines the critical influence of financial institutions in economic systems. Due to their influence on capital allocation and credit provisions, these institutions must be carefully regulated and must follow prudent approaches to both investing and lending. It is therefore strongly suggested for them to integrate ESG factors into their creditworthiness assessment procedures and their risk evaluation frameworks. Financial institutions should actively integrate ESG criteria when constructing their equity portfolios. By doing so they can enhance portfolio resilience, reduce tail risk and align with the principles of steady income, prudent, value-focused investing that emerged from the portfolio analysis. Stocks included in the portfolios that belong to sectors as Financials, Healthcare, Energy and Consumer discretionary, should be closely monitored for their high systemic risk contribution. ESG can also be seen as a non-financial risk factor that helps diversify away from traditional market risks, while simultaneously hedging against reputational damages.

Regulators should continue encouraging companies to engage in ESG practices while promoting transparent and standardized ESG disclosure, to favour comparability among institutions. Regulators should monitor large companies as they can pose greater systemic risk due to their scale and interconnectedness. The financial sector's critical role in managing potential contagion must be balanced with its responsibility to lead the sustainable transition. Financial institutions shall be aware of their prominent influence on potential contagion of systemic shocks but also of their ability to redirect capitals towards more compliant green projects. Regulators shall continue encouraging the green transition of Energy companies while spurring companies in other inherently risky sectors, such as Industrials, Healthcare and Consumer discretionary to strengthen their commitment to ESG to further mitigate potential systemic risk by offering incentives or rewards for remarkable achievements.

In summary, ESG performance emerges as a powerful tool for enhancing corporate resilience, attracting stable investors and mitigating systemic risk. Both financial institutions, regulators and other companies should prioritize ESG integration to foster a more sustainable and resilient financial system.

CONCLUSIONS

This document has explored the complex relationship between ESG performance and systemic risk within interconnected financial systems. By employing two complementary approaches, Delta CoVaR and network analysis, the research has provided insights into how ESG factors can act as a stabilizing force, particularly during periods of financial stress. The following section summarise the most important findings through the various chapters of this document and their implications for corporate risk management and regulators.

A comprehensive literature review on ESG investing has pointed out that while the evidence of increased profitability of ESG-related securities remains contextual and not entirely systematic, there is compelling evidence that ESG serves as a valuable tool for risk mitigation. Companies that strongly commit to ESG practices tend to cultivate robust trust bonds with stakeholders, which, in turn, help them hedge against financial risk. Therefore, even though ESG may not always guarantee higher profitability, its role in reducing corporate risk and attracting long-term investors is well-supported by literature.

From the analysis of major European banks' investment strategies emerged that these institutions follow prudent and value-oriented investment strategies, prioritizing risk reduction over aggressive growth. Rather than focusing on sustainability, banks seem to build their portfolios to provide a stable stream of returns by minimizing exposure to market risk. As a matter of fact, banks tend to build portfolios with very low or negative beta, effectively sacrificing potential growth to minimize risk exposure. this conservative approach underscores the importance of risk management and regulatory limitations for these kinds of institutions, whose scale and systemic importance could cause significant shifts in market sentiment and in the economic landscape in general. A key recommendation arising from this analysis is that banks should start disclosing, where present, ESG criteria they use to build their equity portfolios. In this way, they could balance financial performance with sustainability goals, thus aligning with growing regulatory pressure and stakeholders' demands for responsible investing.

Although no new findings were generated in the methodology, it is essential to acknowledge methods to compute systemic risk measures. By using time series analysis models such as Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models and Vector Autoregressive models with Lasso penalization (VAR-L) it has been possible to compute not only firm-specific information, where present observations are influenced by past observations but also system-wide information, where present observations are influenced by past observations of other entities. These models enhanced robustness and effectiveness of the analysis.

The comparative analysis of Delta CoVaR and spillover network approaches revealed both strengths and limitations in each method. Both are effective tools for detecting and potentially forecasting periods of systemic stress by looking at overall trends for Delta CoVaR and at total connectedness for spillover networks. Whereas Delta CoVaR is relatively simpler to compute, the fact that it is a benchmark-based measure, quantifying the additional risk the single company poses on the system, reduces its accuracy in capturing the magnitude of specific relationships. in contrast, the spillover network is more computationally intensive but offers deeper insights on individual relationships between firms, providing a map of risk transmissions. This makes the spillover approach particularly accurate for understanding the intricate set of financial dependencies, whereas Delta CoVaR is more suited for a comparative risk assessment.

The sectorial connectedness analysis offered critical insights into the most influential sectors with regards to systemic risk. The financial sector emerged as key transmitter and receiver, making it a priority focus for regulators aiming to regulate systemic threats. Additionally, sectors like Consumer Discretionary and Utilities emerge as highly risky and closely linked to other sectors, underscoring their importance for risk managers. The Energy sector also emerged as critical in driving risk transmission, reinforcing its risky nature due to its volatility and interdependencies with other industries.

Finally, the most important contribution of this document is the role of ESG performance in mitigating financial risk. Evidence from the panel regression underscore the inverse relationship between ESG performance (as defined by Bloomberg's financial materiality) and systemic risk transmission. Therefore, companies with strong ESG credentials tend to exhibit greater resilience to financial shocks, mostly due to stronger stakeholder relationships and sustainable investors specific characteristics. This finding is a critical insight for managers and regulators, as it highlights how incorporating ESG factors into corporate strategies and financial decision making can enhance both firm-specific and system-wide resilience.

The initial low level of statistical significance of the model highlights that a multifaceted phenomenon as systemic risks is far from being fully comprehended. There are many factors that could have influenced the results of this research that need to be acknowledged, for example, the manual data collection process for the sample could have led to overrepresentation of some sectors, compromising objectivity in the sectorial interconnectedness analysis. Having chosen a relatively short time interval with relatively low granularity (weekly data) might have led to overapproximating calculations or missing out shorter term trends that occurred farther in time. Furthermore, choosing ESG scores from a different provider might cause substantial changes in results. Model specification and the choice of control variables might have compromised the overall significance of results.

Despite all limitations, it is hoped that the findings in this document will inspire further investigation into how ESG factors can mitigate systemic risk, especially in contexts as interconnected as the actual economic landscape. Future research could build on this work by incorporating more granular data, exploring different methodologies or expanding the analysis to other sectors and other contexts, ultimately deepening our understanding of ESG's role in enhancing financial stability.

REFERENCES

1. Goldman Sachs Q1 2023 "2022 Sustainability Roundup and 2023 Outlook" https://www.gsam.com/content/dam/gsam/pdfs/common/en/public/articles/2023/2022-sustainability-roundup-and-2023-outlook-vF.pdf?sa=n&rd=n
2. UN PRI "Overview of the Principles" https://www.unpri.org/about-us/what-are-the-principles-for-responsible-investment
3. Freeman, R.E., (2010). Strategic Management: A Stakeholder Approach. Cambridge University Press. Friede, G., Busch, T., Bassen, A., 2015a. ESG and financial performance: aggregated evidence from more than 2000 empirical studies. J. Sustain. Financ. Invest. 5, 210–233. https://doi.org/10.1080/20430795.2015.1118917
4. Power, M., Scheytt, T., Soin, K., & Sahlin, K. (2009). Reputational Risk as a Logic of Organizing in Late Modernity. Organization Studies, 30(2-3), 301-324. https://doi.org/10.1177/0170840608101482
5. Jain M, Sharma GD, Srivastava M. (2019), Can Sustainable Investment Yield Better Financial Returns: A Comparative Study of ESG Indices and MSCI Indices. Risks., 7(1):15. https://doi.org/10.3390/risks7010015
6. Giglio S, Maggiori M, Stroebel J, Tan Z, Utkus S, Xu X, (April 2023), Four facts about ESG beliefs and investor portfolios, working paper 31114, National Bureau of Economic Research, http://www.nber.org/papers/w31114
7. Jansson, M. and Biel, A. (2011), Motives to engage in sustainable investment: a comparison between institutional and private investors. Sust. Dev., 19: 135-142. https://doi.org/10.1002/sd.512
8. Walter, Ingo, Sense and Nonsense in ESG Scoring (November 5, 2019). NYU Stern School of Business, Available at SSRN: https://ssrn.com/abstract=3480878 or http://dx.doi.org/10.2139/ssrn.3480878
9. Billio, M., Costola, M., Hristova, I., Latino, C., & Pelizzon, L. (2021). Inside the ESG ratings: (Dis)agreement and performance. Corporate Social Responsibility and Environmental Management, 28(5), 1426–1445. https://doi.org/10.1002/csr.2177

10. Arribas I, Espinós-Vañó MD, García F, Morales-Bañuelos PB (2019). The Inclusion of Socially Irresponsible Companies in Sustainable Stock Indices. Sustainability.; 11(7):2047. https://doi.org/10.3390/su11072047
11. Kjaer, Christina and Kirchmaier, Tom, Deceived by 'S': Corporate Scandals and ESG (April 25, 2023). Available at SSRN: https://ssrn.com/abstract=4428468 or http://dx.doi.org/10.2139/ssrn.4428468
12. Fulton, Mark and Kahn, Bruce and Sharples, Camilla, Sustainable Investing: Establishing Long-Term Value and Performance (June 12, 2012). Available at SSRN: https://ssrn.com/abstract=2222740 or http://dx.doi.org/10.2139/ssrn.2222740
13. Schanzenbach, Max Matthew and Sitkoff, Robert H., ESG Investing: Theory, Evidence, and Fiduciary Principles (October 1, 2020). Journal of Financial Planning, Available at SSRN: https://ssrn.com/abstract=3684979
14. Murè P, Spallone M, Mango F, Marzioni S, Bittucci L. ESG and reputation: The case of sanctioned Italian banks. Corp Soc Responsib Environ Manag. 2021; 28: 265–277. https://doi.org/10.1002/csr.2047
15. Karwowski M, Raulinajtys-Grzybek M. The application of corporate social responsibility (CSR) actions for mitigation of environmental, social, corporate governance (ESG) and reputational risk in integrated reports. Corp Soc Responsib Environ Manag. 2021; 28: 1270–1284. https://doi.org/10.1002/csr.2137
16. Marco Mandas, Oumaima Lahmar, Luca Piras, Riccardo De Lisa, ESG reputational risk and market valuation: Evidence from the European banking industry, Research in International Business and Finance,Volume 69, 2024, 102286, ISSN 0275-5319, https://doi.org/10.1016/j.ribaf.2024.102286
17. Chasiotis, I., Gounopoulos, D., Konstantios, D. and Patsika, V. (2024), ESG Reputational Risk, Corporate Payouts and Firm Value. Br. J. Manag., 35: 871-892. https://doi.org/10.1111/1467-8551.12745
18. Dittmar, A. and J. Mahrt-Smith (2007). 'Corporate governance and the value of cash holdings', Journal of Financial Economics, 83, pp. 599-634. https://doi.org/10.1016/j.jfineco.2005.12.006
19. Tarik Roukny, Stefano Battiston, Joseph E. Stiglitz, Interconnectedness as a source of uncertainty in systemic risk, Journal of Financial Stability, Volume 35, 2018, Pages 93-106, ISSN 1572-3089, https://doi.org/10.1016/j.jfs.2016.12.003.

20. Delpini D, Battiston S, Caldarelli G, Riccaboni M (2019) Systemic risk from investment similarities. PLoS ONE 14(5): e0217141. https://doi.org/10.1371/journal.pone.0217141
21. Markowitz, Harry M., and Harry M. Markowitz. Portfolio selection: efficient diversification of investments. J. Wiley, 1967.
22. Wolf Wagner, Diversification at financial institutions and systemic crises, Journal of Financial Intermediation, Volume 19, Issue 3, 2010, Pages 373-386, ISSN 1042-9573, https://doi.org/10.1016/j.jfi.2009.07.002.
23. Paolo Tasca, Stefano Battiston, Andrea Deghi, Portfolio diversification and systemic risk in interbank networks, Journal of Economic Dynamics and Control, Volume 82, 2017, Pages 96-124, ISSN 0165-1889, https://doi.org/10.1016/j.jedc.2017.01.013.
24. Delpini D, Battiston S, Caldarelli G, Riccaboni M (2019) Systemic risk from investment similarities. PLOS ONE 14(5): e0217141. https://doi.org/10.1371/journal.pone.0217141
25. Domenico Curcio, Igor Gianfrancesco, Grazia Onorato, Davide Vioto, Do ESG scores affect financial systemic risk? Evidence from European banks and insurers, Research in International Business and Finance, Volume 69, 2024, 102251, ISSN 0275-5319, https://doi.org/10.1016/j.ribaf.2024.102251.
26. Jang G-Y, Kang H-G, Lee J-Y, Bae K. ESG Scores and the Credit Market. Sustainability. 2020; 12(8):3456. https://doi.org/10.3390/su12083456
27. Chodnicka-Jaworska P. ESG as a Measure of Credit Ratings. Risks. 2021; 9(12):226. https://doi.org/10.3390/risks9120226
28. Devalle A, Fiandrino S, Cantino V, The Linkage between ESG Performance and Credit Ratings: A Firm-Level Perspective Analysis, International Journal of Business and Management, Volume 13, 2017, ISSN: 1833-8119 https://doi.org/10.5539/ijbm.v12n9p53
29. Adrian, T., & Brunnermeier, M. K. (2011). CoVaR'NBER Working Paper, No. 17454.
30. Financial Stability Board, (2011) Policy measures to Address Systemically Important Financial Institutions, https://www.fsb.org/2011/11/r_111104bb/
31. Our common future https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf
32. NFRD https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0095

33. Non-financial reporting directive: https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/654213/EPRS_BRI(2021)654213_EN.pdf
34. Efrag SR TEG Chairwoman presentation on ESRS https://www.odcec.napoli.it/media/commissioni/1/130/attach/download/11__October_2023_EFRAG_Presentation_Webinar_Commissione_Tutela_del_Consumo.pdf
35. Shape the new European sustainability reporting standards for SMEs https://green-business.ec.europa.eu/document/download/5bdcc13b-d00d-4c3a-a35d-a70012f2aec3_en?filename=Overview%20of%20the%20SMEs%20draft%20sustainability%20reporting%20standards_EFRAG.pdf 09/04/2024
36. CSRD https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022L2464
37. EU taxonomy https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32020R0852
38. Single-use plastic directive https://environment.ec.europa.eu/topics/plastics/single-use-plastics_en
39. Canada’s ban on Single-Use Plastics https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/reduce-plastic-waste/single-use-plastic-overview.html
40. Australia’s ban on single use plastics https://www.epa.sa.gov.au/articles/2021/02/24/ban_on_single_use_plastics_from_1_march_2021#:~:text=From%20Monday%201%20March%202021,that%20do%20not%20contain%20plastic.
41. South Korea’s ban https://www.straitstimes.com/asia/east-asia/south-korea-retracts-bans-on-disposable-cups-at-cafes-restaurants#:~:text=A%20ban%20on%20single%2Duse,have%20been%20imposed%20for%20violations. (Article 8 Nov 2023, the straits times)
42. https://www.scmp.com/week-asia/health-environment/article/3260639/india-banned-single-use-plastics-almost-2-years-ago-did-it-work (article 29/04/2024 Shaikh Azizur Rahman south china morning post) India's ban on Single-use plastics
43. UK modern slavery act table of contents https://www.legislation.gov.uk/ukpga/2015/30/contents
44. About the emission trading system https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/what-eu-ets_en
45. US Toxic Substances Control Act https://www.epa.gov/laws-regulations/summary-toxic-substances-control-act