Digital Transformation of Sustainable Finance: A Review of FinTech Applications in ESG Scoring, Climate Risk, and Green Bonds

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ABSTRACT- Sustainable finance is booming globally. Investors, governments and institutions are now demanding environmentally responsible, socially responsible, and good governance financial systems. These goals are generally quantified using environmental, social and governance (ESG) indicators. However, traditional finance systems can have issues like poor quality of data, lack of transparency and slow reporting and lack of trust in ESG scores. These issues are causing it to be difficult to measure sustainability in a reliable way.

Financial technology (FinTech) is revolutionizing sustainable finance. New digital tools like artificial intelligence (AI), machine learning, big data and blockchain are now being used to collect, process and analyse ESG and climate related information. These tools are used to help investors and policymakers to make better and faster decisions.

This review paper provides an overview of recent research on how FinTech can contribute to sustainable finance. It is focused on three main areas; ESG scoring and measurement AI-based climate risk assessment and digital platforms for green bonds and other sustainable debt instruments. The study is based on integrative approach of narrative review with a clear and transparent search process of the literature. Academic articles and important institutional reports that were published in the recent years are reviewed.

The findings reveal that FinTech contributes to more efficiency, better data coverage and accessibility to sustainability information. At the same time, important challenges remain such as biased algorithms, unclear AI models, weak regulation and the risk of greenwashing. This review highlights these issues and suggests directions for future research to improve trust, transparency and ethical use of digital technologies in sustainable finance.

KEYWORDS- Sustainable Finance; FinTech; ESG Scoring; Climate Risk; Green Bonds; Artificial Intelligence; Digital Finance

I. INTRODUCTION

Sustainable finance has become an important part of modern financial systems [1]. Governments, investors and financial institutions are paying more attention to the way that money is used and where it flows. The goal is not only to make a profit, but also support environmental protection, social well-being and good governance [2]. These ideas are often condensed under the umbrella of environmental, social, and governance and referred to as ESG. As conditions of climate change, social inequality and failure of governance have escalated, the contribution of finance in addressing these issues has become more visible [3] .

According to Zheng et al. [4], financial markets currently offer a variety of products aimed at achieving sustainability objectives. In recent years, there has been sustainable finance has grown rapidly. These include green bonds, social bonds, sustainability bonds and sustainability linked bonds. At the same time, the policies of the countries in the world have changed and so have the expectations of the investors. As such, sustainable finance is no longer an esoteric field. It is becoming part of the normal financial system.

This growth is due to a number of reasons. Climate related risks have now come to affect economic stability and financial performance. Extreme weather events, damage to the environment and energy transitions are new risks for firms and investors [5]. Social issues such as labor rights, inequality and access to basic services also impact on the long run economic outcomes [6] . Weak governance can result in corruption, bad management and financial loss. As a result of these risks, investors begin to take into consideration ESG factors as a part of risk management and not simply a matter of preference for ethics [7].

Policy initiatives also have played an important role. International agreements and national regulations for encouraging the adoption of sustainability in financial decision taking [8] . Governments are looking for help from the financial markets for long-term development targets and climate targets. Financial institutions are increasingly come under pressure to report on ESG related information and more care of their sustainability related risks [9]. These policy signals have helped to increase the nexus between finance and sustainability.

At the same time there have been some active investors. Large institutional investors are now asking for improved ESG data from the firms and making it clear how the sustainability strategies are to be implemented [10]. Many investors believe that companies with good ESG performers are better prepared for the future risk. This belief has boosted the demands of sustainable investment

products [11]. Firms who have strategies that sounds like the tenets of ESG often get favorable access to capital.

Together, these trends suggest that sustainable finance is changing the face of financial systems. However, explosive growth of finance based on ESG is also facing new challenges. Measuring sustainability performance, risk evaluation of climate risks and trust in green financial products are as yet difficult tasks. Such challenges indicate a need for better tools, clarity and transparency in standards. This is the context in which the role played by the digital technologies and FinTech have become increasingly important in the field of sustainable finance.

### A. Origin of ESG and Sustainable Finance

The increase of sustainable finance has been robust in the last decade. More capital is now directed to projects that help with clean energy, climate adaptation, social development and responsible business practices [12]. Green bonds and other forms of sustainable debt instruments have helped a lot in this growth. These instruments can help to finance projects of governments and companies with clear environmental or social benefits. This change has been met by public policy playing a major part. International agreements such as the Paris Agreement have sparked the countries with the process of monitoring the carbon emission and also the risks of climate change [13]. The United Nations Sustainable Development Goals (SDGs) has also called for the governments and financial institution to provide for the support for sustainable development [14]. These global frameworks have resulted

in the pressure increasing on financial markets to align their investment decision to long-term goals for the environment and social goals. As a result of this, the consideration of sustainability in the financial sector has become more and more visible in the area of financial regulations and policy discussions.

The behaviour of investors has changed as well. Many institutional investors such as pension funds insurance companies and asset managers are now taking ESG factors into consideration when making investments [15]. They see sustainability as not only being an ethical issue, but a financial one too. Climate risks and social conflict, and lack of good governance can lead to financial losses [16]. Due to this, investors are demanding better ESG information as a prerequisite before making an investment decision. Companies that do well on ESG issues often get access to capital.

The emergence of sustainable bond markets clearly reflects this tendency. Global issuance of sustainable bonds has been on the rise year on year, even during times of economic uncertainty. As can be seen in Figure 1, the global holdings of sustainable bond issuance have reached an all-time high of USD 1.05 trillion in 2024. Cumulative issuance since 2019 has run to close to USD 5 trillion, despite short-term market volatility. This rapid rate of growth underlines the increasing importance of sustainable finance in the global capital markets and it explains why this is an important topic that should be carefully reviewed by academics.
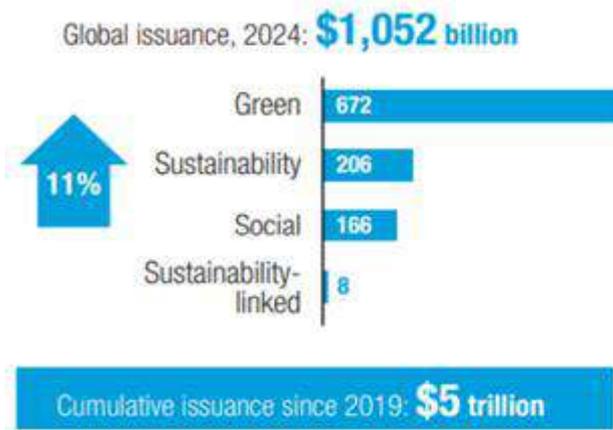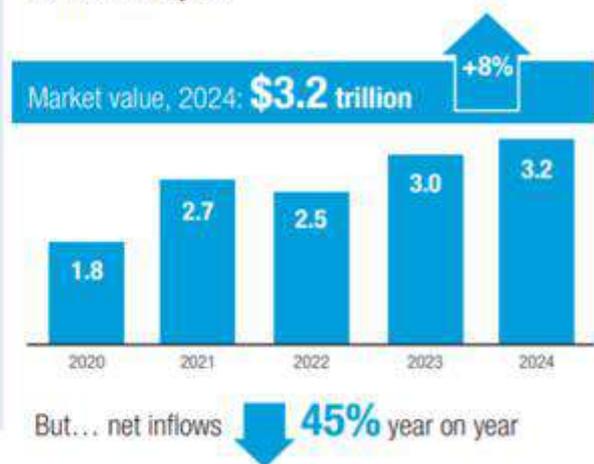

Figure 1: Global Growth of the Sustainable Bond Market (2020–2024)

B. Challenges of Fragmentation and Credibility of ESG

Despite the fact that ESG-based finance is an emerging field, it faces several serious challenges. One of the largest problems is inconsistency of ESG scores [17]. Different rating agencies are likely to often have very different ESG scores for the same company. This makes it hard for the investors to compare different firms and have confidence in the ESG data [18]. The methods of calculating ESG scores are typically not transparent and vary greatly from provider to provider. Another major issue is greenwashing. Some companies claim to be sustainable and make no actual changes to their business practices [19]. They might use

vague words or selective information to present a positive image. This leads to low trust in the ESG products and can mislead the investors. Where greenwashing is common it undermines the credibility of the entire sustainable finance market. Data opacity is also a huge concern. Data of environmental, social, and governance (ESG) is often self-reported company data. This data may be incomplete, delayed and/or biased. In many cases, there is no apparent process for verification [20]. As a result, it is very difficult for investors and regulators to measure the actual performance of firms in terms of sustainability. These problems are indicative of the fact that there is still a lack

of transparency, standardisation and reliability in traditional ESG systems.

C. FinTech and AI in the Sustainable Finance

Financial technology, known as FinTech, has started to make changes in the way sustainable finance functions [21]. Digital tools are now available which allow more rapid data collection, processing and analysis. Technologies like big data analytics, artificial intelligence, and automation are progressively being used in financial decision-making [22]. These tools are useful for dealing with large amounts of complex information which traditional systems do not deal with easily. Artificial intelligence is having a central role in this transformation. AI tools can analyze large datasets and identify patterns and generate insights in real time [23]. In the realm of sustainable finance, AI is applied to the processing of ESG data, articulation of climate risks, and to track sustainability performance [24]. Natural language processing to assist in the analysis of company reports and news. Machine learning models are useful for predicting environmental and financial risk. Explainable AI tools are also being developed to better transparency.

Figure 2 shows the key AI techniques in ESG assessment. It demonstrates the support of machine learning, natural language processing, predictive modeling, and explainable AI for environmental, social, and governance analysis. The increasing adoption of these tools demonstrates the move towards data-driven and automated approaches in sustainable finance.
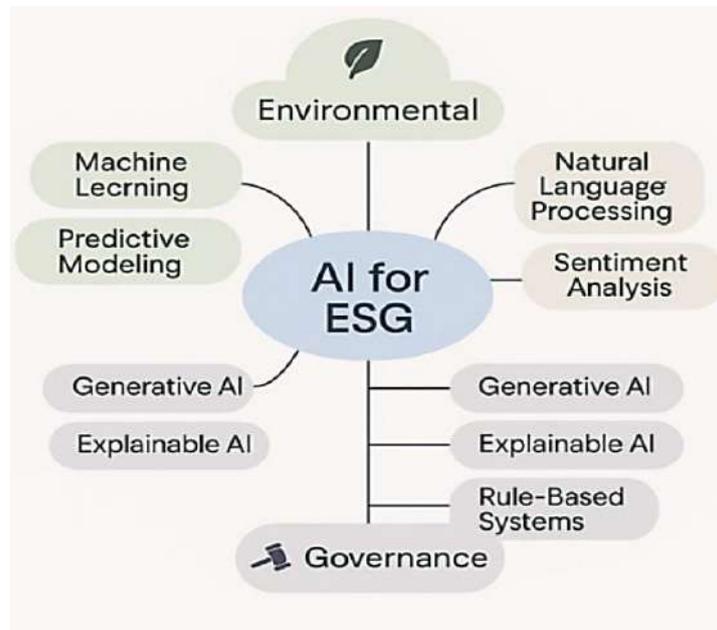

Figure 2: Structure of AI Applications in ESG Assessment

D. Research Gap and Review objectives

Although there has been a rapid increase in research on ESG, sustainable finance and FinTech, current research is fragmented. Many papers focus on one aspect only, such as ESG scoring, climate risk or green bonds. Few reviews include an integrated perspective on the connection of digital technologies with these areas. In addition, some of the reviews do not clearly say how they did it or do not discuss the ethical and governance challenges.

This review is aimed at addressing these gaps. It offers a transparent and structured overview of FinTech applications in ESG scoring, AI-based climate risk assessment and digital green bond platforms. By synthesizing existing research, this study reveals key trends, challenges, and research directions for future research. The goal is to better understand how digital transformation can help support more credible, transparent and effective sustainable finance systems.

II. METHODOLOGY

This study adopts an integrative narrative review approach. This type of review is appropriate for topics that are broad and interdisciplinary. Sustainable finance, ESG and FinTech are topics which cover finance, technology, policy and ethics. The existing studies apply different methods and use different types of data. Due to this diversity, it is inappropriate to use a statistical meta-analysis. The selected approach enables studies using different designs to be reviewed in a unified and organized manner.

A systematic and transparent search process was applied to gather relevant literature. A number of academic databases were chosen to obtain a broad coverage of quality research. Some of these databases are Web of Science, Scopus, ScienceDirect, Google Scholar, and SSRN. These sources have been chosen based on their content of peer-reviewed articles and widely cited research articles in finance, sustainability and technology. In addition, reports by major international organizations were included. These organizations include the World Bank, the United Nations, the Organization for Economic Cooperation and Development (the so-called "OECD"), and the Climate Bonds Initiative. Such reports are important because they affect policy and market practices on sustainable finance.

The search of literature was guided by predefined keywords. The primary keywords used were "sustainable finance," "ESG," "environmental social governance," "FinTech," "financial technology," "artificial intelligence," "machine learning," "climate risk," "green bonds" and "digital finance." Different combinations of these terms

were used in order to capture a broad range of relevant studies. Only publications that were written in English were considered. The search was conducted on studies published between 2014 and 2025. This time period shows the tremendous growth of ESG investing and digital finance in recent years.

Clear inclusion and exclusion criteria were used to identify the final selection of studies. Studies were included if they focused on the measurement of ESG, climate-related financial risks, green bonds or sustainable bonds, or the use of digital technologies in sustainable finance. Peer-reviewed journal articles, conference papers and reports from well-known institutions were included. Studies were excluded if they were not on the topic of finance and/or sustainability. Papers that were purely technical and with no clear financial link were also excluded. Opinion articles, news articles and non-academic sources were excluded.

The process of screening was based upon principles similar to PRISMA guidelines for review studies. First of all, all the records that were found were collected and checked for duplicate. Duplicate records were removed. Second, titles, abstracts were read to find relevant studies. Third, the full texts were reviewed to ensure whether the studies met the inclusion criteria. Studies that did not meet the criteria were excluded. The reasons for exclusion were recorded, to ensure transparency.

After the screening process, the final set of studies was reviewed in depth. Key information was extracted from each study. This information consisted of the major topic, data sources, methods used and key findings. The studies were then categorised in to three main themes. These themes are ESG scoring and measurement, AI-based climate risk assessment and digital platforms for green bonds and sustainable finance. This thematic grouping helped with the organization of the results and allowed the comparison of the results by study.

The analysis was focused on finding common finding, major differences and research gaps. Attention was made to the strengths and the weaknesses of the existing studies. Ethical issues, data quality issues and regulatory issues were also identified where applicable. This approach helped to ensure that the literature was reviewed in a balanced and critical manner.

Overall, this methodology provides a clear and credible foundation for the review. The use of defined search terms and selection criteria and an open screening process improves the quality of the review. This way the findings can be updated in the future as new research becomes available. It also helps to achieve the purpose of ensuring a clear and structured understanding of FinTech applications to sustainable finance.

III. RESULTS AND THEMATIC SYNTHESIS

This section presents the key finding of the review. The results are presented in three major themes. These themes are the fields of application of FinTech in sustainable finance, and the most common. The first theme is FinTech Tools to Score ESG. The second theme is focused on the use of artificial intelligence on climate risk assessment. The third theme is associated with digital platforms for green bonds and other sustainable finance instruments. Together, these themes provide a clear picture about the impact of digital technologies on sustainable finance.

A. *FinTech Tools for Scoring ESG*

A large part of the reviewed literature focuses on the usage of FinTech tools in ESG scoring and measurement. ESG scoring is important because it helps the investors to gauge the performance of the sustainability of various firms [25]. Many of the traditional methods of scoring ESG metrics include manual data collection and self-reported information. These methods are slow and may be not accurate [26]. FinTech tools aim to improve such a process by using technological tools that collect and analyse data through automated methods [27].

Many studies discuss ESG data platforms in terms of big data and digital analytics. These platforms gather information from a variety of sources [28]. These sources include company reports, financial statements, news articles, social media and satellites data. By combining various forms of data, FinTech platforms are able to provide more in-depth ESG profiles. Several studies suggest that the use of automated methods of data collection enhances both the speed and coverage of ESG assessments [29].

Another tool discussed in the literature is Blockchain technology. Blockchain is applicable for improvement of transparency of data and traceability [30]. In the case of ESG scoring, blockchain can be used to store information related to sustainability in a safe and tamper-resistant manner [31]. Some research references the use of blockchain to help verify some environmental data, such as carbon emissions or the practices of the supply chain. This verification process helps to limit the risks of data manipulation and false reporting [32]. As a result, the usage of blockchain is often considered as a way to solve the trust problems of the ESG markets. One of the main advantages of the ESG systems based on FinTech is automation. Automated ESG scoring cuts down on the amount of manpower and money. It enables ESG data to be updated more frequently [33]. Real-time or near real-time update, which can help investors to respond quickly to sustainability risks Several studies report the improvement of the efficiency and consistency of ESG measurement with automated systems [34]. These benefits are particularly crucial for large institutional investors who have a large number of assets in different markets. Despite these benefits, however, there are some serious challenges, which are also identified in literature. One of biggest issue is scores for ESG divergence. Different ESG data providers often come up with very different scores on the same company [35]. This occurs because they draw on different indicators, data sources and weighting methods. Even when FinTech tools are applied, these differences do not go away. Some studies reveal that automation may boost the amount of data but it cannot resolve the fundamental methodological disagreements.

Another concern is data quality and bias. Automated ESG systems rely on the quality of input data. If the data is incomplete or biased, the output will also be biased [36]. Some studies caution that alternative sources of data, such as social media or news, may indicate public attention and not actual performance on sustainability. This can lead to an inaccurate representation of ESG scores and mislead investors.

Overall, the findings indicate that FinTech tools have been used to make ESG scoring better in many ways. They improve speed, data coverage, and automation. However,

issues concerning the divergence of scores, data bias, and non-standardization have not been solved. These issues imply that technology alone is not capable of solving ESG credibility issues comprehensively.

B. Artificial Intelligence and the Risk Assessment of Climate

The second major theme in the literature concerns the application of artificial intelligence in climate risk assessment. Climate risks are being recognized as financial risks. These are risks to asset values, insurance costs and long-term investment returns [37]. Traditional risk models are often unable to represent the complexity of climate-related threats [38]. AI tools are used to fill in this gap.

Many works are done on physical climate risks. These risks include floods, heatwaves, storms and rising sea levels. AI models are used to study climate data, satellite images, and historical records of losses [39]. Machine learning techniques are useful in identifying the patterns and predicting effects. Several studies show that the use of AI improves the accuracy of physical risk estimates at a local and regional scale [40]. This is especially useful to banks and insurers.

Another set of studies is concerned with transition risks. Transition risks are the risks arising from the effect of changes in policies, technologies and market response to climate action [41]. AI models are used to analyze the effects of carbon pricing, energy transitions, and regulation on firms and industries [42]. Such models help investors to understand which assets may lose value in the transition to the low carbon economy.

Stress testing is also much talked about in the literature. Financial institutions are utilizing AI-based stress tests in order to model various climate scenarios. Such scenarios are extreme weather events or failing policy changes fast [43]. In addition, AI facilitates the ability of stress tests to have more variables and more complex interactions. This leads to more comprehensive risk assessments compared to traditional models [44].

However, explainability is a big problem in AI-based climate risk tools. Many AI models are complex and difficult to understand [45]. This poses problems for regulators and decision-makers If the users do not understand how a model works, they may not trust the results [46]. A number of studies emphasise the importance of explainable AI in climate finance. Explainable models help to improve transparency and accountability.

The reviewed literature also highlights the role of institutional quality. AI tools function better in environments that have good governance, good data systems, and good regulations. In the context of weak institutional settings, AI can lead to a rise in inequality or to the perpetuation of existing problems [47]. Figure 3 conceptually illustrates the non-linear, or "U" shaped nature of the relationship between FinTech adoption and climate adaptive capacity. This relationship is affected by institutional quality and governance structures. The figure is useful to understand why digital tools do not yield same results in all circumstances.
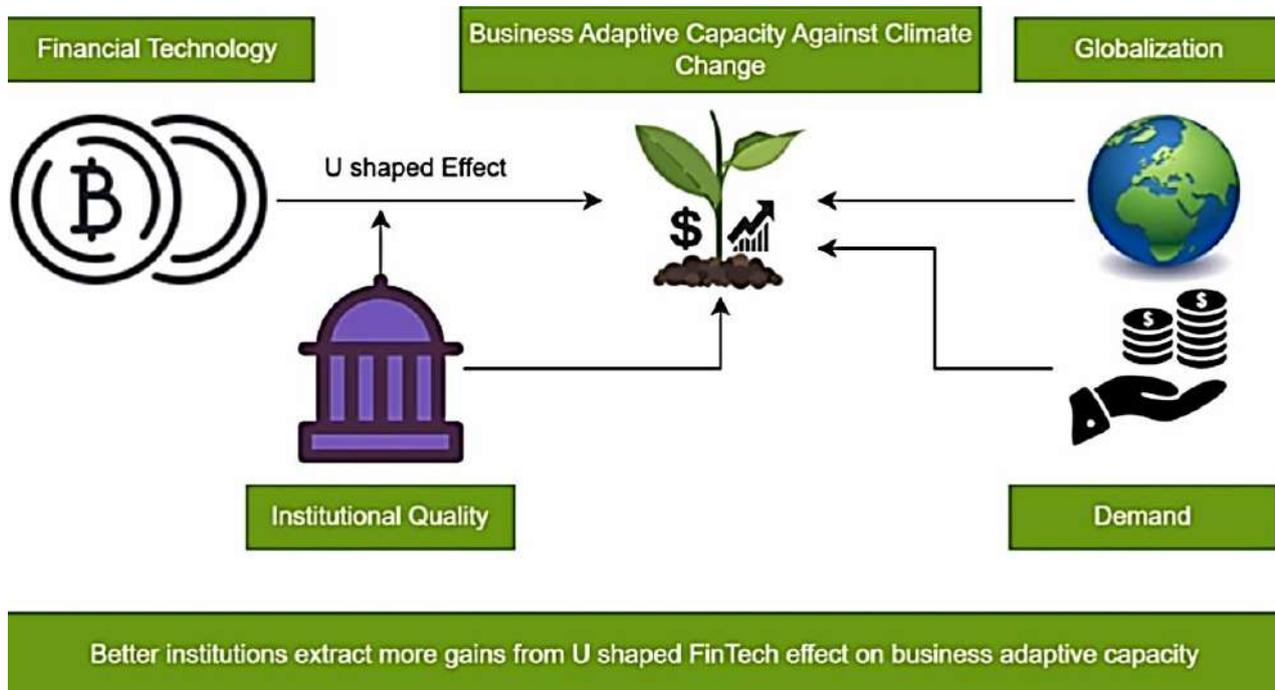

Figure 3: FinTech, Institutional Quality, and Climate Adaptation: A Conceptual Mechanism

In summary, AI has improved climate risk assessment because of its ability to create more power and predictive capacity to analysis. At the same time, issues relating to transparency, governance and institutional capacity make it difficult to be effective. These findings have shown that AI needs to be supported by strong institution and have set rules.

C. Green Bonds and Digital Sustainable Finance Platforms

The third theme is centred around green bonds and digitization platforms in sustainable finance. Green bonds refer to debt instruments which are used to finance projects that contribute to environmental goals [48]. In recent years, digital platforms have revolutionized the process of issuing, tracking, and trading these bonds. These changes have been

useful for the betterment of efficiency and access into the sustainable finance markets.

Corporate engagement in the sustainable bond markets has been increasing and have been growing at a constant rate over time [49]. Both financial and non-financial companies are currently using green and sustainability-related bonds as a funding strategy [50]. This is because of the growing demand and acceptance of sustainable finance instruments by investors. As is shown in Figure 4, the share of sustainable corporate bond issuances increased from less than 1% of all corporate bonds in 2015 to about 7% in 2024. The growth can be observed for both financial and non-financial companies, which hints on the fact that sustainable finance has stopped being a niche market and has entered the sphere of mainstream corporate finance.
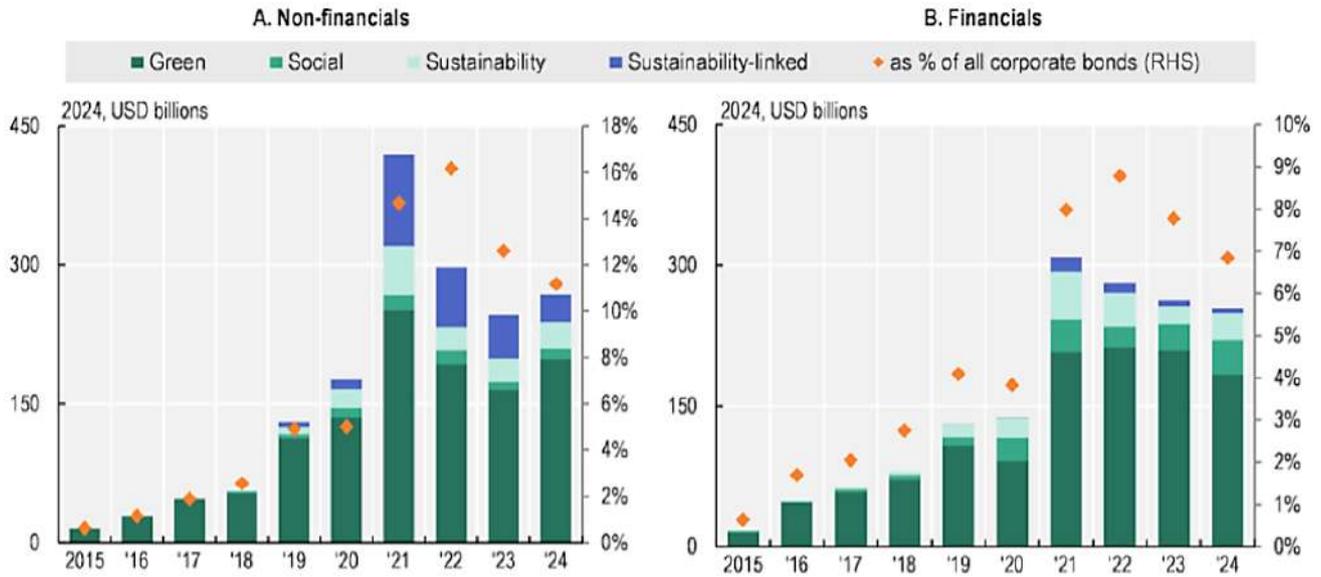

Figure 4: Growth of Sustainable Corporate Bond Issuance by Financial and Non-Financial Firms (2015–2024)

Several studies highlight the role of digital issuance platforms in this expansion. These platforms eliminate the paperwork and speed up the time it takes to issue bonds. They also decrease the transaction costs [51]. By making the process of issuance easier, digital systems make it easier for smaller issuers to get into sustainable finance markets. This helps to facilitate a wider participation in green finance and build deeper markets.

Tokenization is another important development which is discussed in literature. Tokenization involves blockchain tech can be used to represent the bonds in the form of digital tokens [52]. These tokens are easier to trade and are done with more transparency. Some studies suggest that tokenization helps in increasing the liquidity and access to investors [53]. It may also facilitate partial ownership of green assets, which may attract a wider range of investors. Market transparency is one of the major benefits of digital platforms. Blockchain based systems provide a detailed tracking of use of bond proceeds [54]. Investors are able to review the investment of funds into approved green projects. This helps to increase accountability and decrease the possibility of greenwashing [55]. Several studies have found positive gains on investor confidence when there are transparent digital tracking mechanisms.

In spite of these improvements, the trust of investors is a major concern. While the use of digital tools makes things more transparent, trust is also about having clear standards and being able to reliably verify. Unless there is a clarity and consistency of defining the green bonds, technology alone is not sufficient to solve the problems of credibility [56]. The literature is mixed in terms of if digital platforms alone are enough in developing long-term trust.

These concerns are reflected in the latest trends in the market. In the below Figure 5 shows, issuance of green bonds dominated sustainable debt issuance with a decline in sustainability-linked bonds. This decrease is a cause of concern in terms of product design and credibility. It also suggests that investors are more trustworthy of more clear rules and structures of the use-of-proceeds instruments
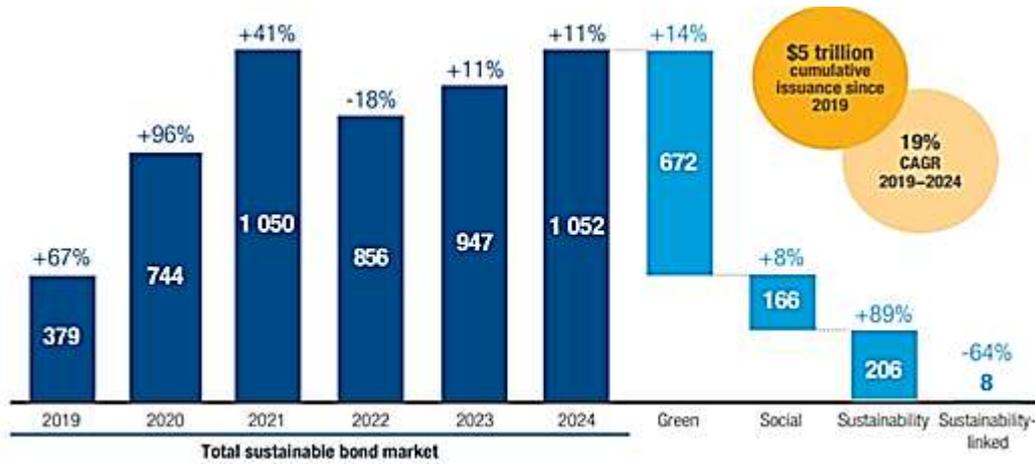
Figure 5: Reveals the sustainable bond issuance (by category) in 2024 (Source: UNCTAD, based on information from Climate Bonds Initiative) (Abbreviation: CAGR Compound Annual Growth Rate)

All in all, the reviewed studies make it clear that digital platforms have led to improvements in the efficiency, transparency, and access of green bond markets. However, technology cannot replace good governance. Clear standards, effective oversight, and credible verification are essential to the long-term success of sustainable finance.

IV. DISCUSSION

This section provides an interpretation of the major findings of the review. It links the three themes discussed above and describes their broader meaning. The discussion also points to the issues of ethics, governance and regulation. It then identifies gaps in the current research and draws implications for practice and policy.

A. Integrated Interpretation Across Themes

The results indicate that there is a close relationship between ESG scoring, AI-based climate risk assessment, and green bonds. These areas do not function independently. Instead, they constitute portions of the same sustainable finance system. ESG scoring is a way to obtain information about the firm behavior and sustainability performance [57]. Climate-related risks that can impact future financial outcomes are analyzed by AI tools. Green bonds and other sustainable instruments then use this information to help direct capital towards sustainable projects.

FinTech plays a linking role in these areas. Digital tools gather huge datasets of ESG data. AI systems take this data and help to find risks and trends. Digital platforms then support the issuance and tracking of the green financial products [58]. Together, these tools help to better support decision-making in sustainable finance. Investors can have a better sense of risks. Issuers can demonstrate the use of funds. Regulators are able to monitor the market behavior better.

However, the findings also indicate that the FinTech is an enabler and not a guarantee. Technology brings faster, larger and wider access to information. It does not necessarily guarantee quality, fairness or trust [3] . For example, enhanced data collection does not address differences on the definition of ESGs. More complex AI models do not eliminate uncertainty in climate predictions.

Digital platforms do not mean that poor product design is prevented.

The effectiveness of FinTech is dependent on its usage. Effective governance, clear standards and reliable oversight are required [59]. Without these conditions, digital tools can be exacerbating existing problems. This is why similar technologies achieve different results from market to market and region to region. FinTech has its role in sustainable finance but it cannot substitute sound institutions and clear rules.

B. Ethical, Governance and Regulatory Implications

The use of FinTech in sustainable finance raises important ethical and governance issues. One of the most important problems is algorithmic bias. AI systems are trained on existing data. If this data is incomplete or biased, this will cause the results to be biasedIn the case of ESG scoring, this could result in giving preference to firms operating in regions with better disclosure practices [60]. Firms from developing countries could be unfairly rated. This leads to inequity of access to sustainable finance.

Another big concern is about the use of black box AI models. Many systems that use AI are hard to comprehend. Users might not be aware of the way choices are made, and what variables are significant [61]. This lack of transparency leads to lack of trust. It also causes issues for regulators, who have a need to understand an explanation in order to assess risk models [62]. Explainable AI is a solution that is often suggested, but this is not widely used yet.

Regulatory lag is also a serious problem. FinTech innovation is at a higher pace than the pace of financial regulation [63]. Many digital ESG tools and green finance platforms are operating in murky regulatory environments. Rules vary from country to country, region to region. This means uncertainty among firms and investors. It also opens up to risk of regulatory arbitrage and greenwashing.

To provide a balanced picture, Table 1 summarises the key opportunities, limitations and ethical risks of FinTech-enabled sustainable finance. The table indicates that although digital tools have clear positive aspects there are also a number of challenges that need to be carefully managed.

Table 1: Opportunities, Limitations, and Ethical Risks of FinTech-Enabled Sustainable Finance

Area	Key Opportunities	Main Limitations	Ethical and Governance Risks
ESG Scoring	Faster data collection and wider coverage	Inconsistent methods across providers	Algorithmic bias and unfair ratings
AI Climate Risk	Better prediction of physical and transition risks	Limited model transparency	Black-box decision-making
Green Bonds	Improved tracking of fund use	Dependence on standards and definitions	Risk of greenwashing
Blockchain Systems	Higher transparency and traceability	High technical and energy costs	Unequal access and digital divide
Digital Platforms	Lower costs and wider market access	Regulatory uncertainty	Weak oversight and accountability

In the above Table 1, it helps prevent over-optimism in technology. "It demonstrates that the ethical and governance issues will need to be addressed alongside innovation."

C. Methodological and Evidence Gaps

The review also indicates that there are important gaps in the current research. One of the major gaps is the absence of longitudinal studies. Many of the studies have brief time periods. This makes it hard to define long-term impacts of FinTech on sustainability outcomes. More long-term data will be required to get a better idea of whether the use of digital tools is actually enhancing environmental and social performance [64].

Another limitation is the use of proprietary models and data. Many ESG scores and AI tools are in the ownership of private companies. How they did this is not entirely revealed. This makes it less transparent and reproducible [65]. Frequently researchers cannot test or compare these models for themselves. This does not help the scientific nature of some findings.

There is also a huge geographical imbalance. Most of the research is conducted in developed economies. There is little evidence from developing countries and emerging markets. These regions experience varying institutional conditions and constraints to the availability of the data. Without more coverage, the relevance of existing research at global level is incomplete.

D. Implications for Practice and Policy

The findings have a number of practical implications for practice and policy. Regulators should develop more specific and consistent rules on the ESG data, the use of AI and green finance products. This includes standards for transparency and accountability. Regulators should also support explainable AI in order to build trust. Investors must use FinTech tools with a grain of salt. Digital systems can be used to support better decisions, but they should not

be considered to be as completely objective or neutral. Investors should be aware of model limitations and sources of data.

Universities and research institutions should fund interdisciplinary research. Collaboration between finance, data science, ethics and policy is crucial. Education programs should also equip the future professionals to utilise FinTech responsibly. FinTech companies should develop tools that value transparency and fairness. Ethical considerations must be factored in at the beginning stages of development. This will help build trust and support long-term adoption.

V. FUTURE RESEARCH DIRECTIONS

This review identifies a few areas for which future research is needed. While FinTech has improved various aspects of sustainable finance, there are services and aspects that are still left unanswered. Addressing these gaps can help to improve the credibility, fairness and effectiveness of ESG-based financial systems.

One important direction of future research is development of standardized ESG metrics Current measures of ESG are very different from provider to provider [66]. This creates confusion among investors and makes it less comparable between firms and markets. Future studies should be focused on constructing common frameworks for ESG measurement. These frameworks should set out clear indicators, data sources and the weightings in a clear manner. Standardized metrics would reduce the variation of scores, and lead to the ratification of ESG ratings. Research should also be on the adaptation of global standards to local situations, without compromising on consistency. Explainable artificial intelligence is also one more area of importance for future research. Many AI models that are currently being used around ESG scoring and climate risk assessment models are hard to understand [67]. This puts a cap on their acceptance by the regulators as well as the users. Future studies should investigate ways of making models more transparent without losing their predictive power. Research should also investigate how explainable AI can help in winning trust of investors and regulatory approval. Clear explanations of AI decisions are imperative to the responsible use of AI in finance. At the intersection of regulatory technology or RegTech and ESG systems is also receiving more attention. For example, RegTech tools can be used to monitor ESG disclosures, climate risks and green finance products by regulators on a real-time basis [68]. The future studies should examine the efficacy of digital reporting systems and automatic supervision on compliance and reduction of greenwashing. Studies should also address the role that RegTech can have in facilitating cross-border given the nature of sustainable finance markets. Another field of research is ethical AI-governance. As FinTech tools continue to grow in power, ethical hazards are also increasing [69]. Future research should be done on how to introduce ethical principles in ESG algorithms and digital platforms. This includes fairness and accountability as well as data protection. Research should also be focused on who is to blame when AI systems come up with harmful or biased results. Strong governance frameworks are required to help guide ethical uses of technology in sustainable finance. Finally, more interdisciplinary research has to take place. Sustainable

finance is an intersection between finance, technology, environmental science, ethics and public policy. As well, future studies should consider the need to pull together the experts in these fields. Interdisciplinary approaches can be used to solve complex problems impossible to solve by a discipline. Such collaboration can lead to realistic models and better design of policies and better linkages between financial innovation and sustainability outcomes in the world.

VI. CONCLUSION

This review outlined the disruption FinTech is having on sustainable finance. It focused on three key areas: ESG scoring and AI-based assessment of climate risks and green bonds, utilizing digital platforms. The findings show that digital technologies play an important role in improving data collection, analysis and transparency in sustainable finance markets. FinTech is important as this is useful to solve the credibility problems in ESG systems. Automated data platforms, AI models and blockchain tool for better speed, scale and monitoring. These tools have enabled easier and better investment decisions to be made as well as to increase access to information about sustainability. However, the review also shows technology is not all there is to it. Problems such as divergence of ESG scores, algorithmic bias and lack of clarity in standards exist to this day. FinTech may be able to provide support to sustainable finance but cannot substitute good governance and clear rules.

This review contributes to academic literature since it provides an integrated view of FinTech applications in the ESG scoring, climate risk and green finance instruments. Unlike the many studies currently in existence, it integrates these areas and draws focus to their interaction in the same financial system. The review also provides a well-balanced judgment on the article both for advantages and disadvantages. With the gaps in the research and ethical issues, it gives a good way for future studies.

The results also have policy as well as practical implications. This evidence can be used by regulators to develop improved standards and oversight mechanisms. Investors can have an improved idea of the limitation of digital ESG tools. Universities and FinTech companies can leverage these insights to promote responsible innovation. Overall, this review shows that FinTech is a powerful enabler for sustainable finance but its success is dependent on transparency, ethics and effective regulation.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

[1] Dev, D., G. D. Sharma, M. Gupta, and A. K. Tiwari, "Sustainable finance in action: A comprehensive framework for policy and practice integration," *International Review of Economics & Finance*, vol. 103, pp. 104511–104511, 2025. Available from: https://doi.org/10.1016/j.iref.2025.104511

[2] Christine, A. F., D. F. Hakam, Y. A. Nainggolan, S. K. Wiryono, and L. I. Hakam, "Environmental, social, and governance (ESG) impact on corporate financial strategy of energy and utilities companies worldwide," *Energy Strategy Reviews*, vol. 62, p. 101916, 2025. Available from: https://doi.org/10.1016/j.esr.2025.101916

[3] Wang, M., and H. Njangang, "The unexpected outcomes: How does climate finance affect corruption in developing countries?" *Journal of Environmental Management*, vol. 389, p. 126065, 2025. Available from: https://doi.org/10.1016/j.jenvman.2025.126065

[4] Zheng, M., L. Wu, G.-F. Feng, and C.-P. Chang, "The impact of green finance on sustainable development: An investigation into national ESG performance," *Journal of Applied Economics*, vol. 28, no. 1, 2025. Available from: https://doi.org/10.1080/15140326.2025.2528672

[5] Migliorelli, M., "Climate change, environmental sustainability, and financial risks: Are we close to an understanding?" *Current Opinion in Environmental Sustainability*, vol. 65, pp. 101388–101388, 2023. Available from: https://doi.org/10.1016/j.cosust.2023.101388

[6] Lee, J.-Y., "Economic inequality, social determinants of health, and the right to social security," *Health and Human Rights*, vol. 25, no. 2, p. 155, 2023. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC10733760/

[7] Hussain, I., S. Zhonggen, J. Aman, and S. Alam, "Impact of environmental, social, and governance risks and mitigation strategies of innovation and sustainable practices of host country on project performance of CPEC," *Sustainability*, vol. 17, no. 15, pp. 6861–6861, 2025. Available from: https://doi.org/10.3390/su17156861

[8] Moses, V., A. Narula, N. Chetan, C. Vidya, M. Sarode, and P. L. Muralidhara, "International agreements and government initiatives on policy regulatory frameworks for clean energy," in *Biotechnology Innovations for a Sustainable Future*, pp. 2323–2344, 2026. Available from: https://doi.org/10.1007/978-981-97-9859-9_113

[9] Chau, L., L. Anh, and V. Duc, "Valuing ESG: How financial markets respond to corporate sustainability," *International Business Review*, vol. 34, no. 3, p. 102418, 2025. Available from: https://doi.org/10.1016/j.ibusrev.2025.102418

[10] Ali, N. B. M., H. A. A. Ali Hussin, H. M. F. Mohammed, K. A. A. H. Mohmmed, A. A. S. Almutiri, and M. A. Ali, "The effect of environmental, social, and governance (ESG) disclosure on the profitability of Saudi-listed firms: Insights from Saudi Vision 2030," *Sustainability*, vol. 17, no. 7, p. 2977, 2025. Available from: https://doi.org/10.3390/su17072977

[11] Herman, A., Ž. J. Oplotnik, and T. Jagrič, "The impact of ESG on business performance: An empirical analysis of NASDAQ–NYSE-listed companies," *Sustainability*, vol. 17, no. 21, pp. 9683–9683, 2025. Available from: https://doi.org/10.3390/su17219683

[12] Ahmad, F., A. Boumaiza, A. Sanfilippo, and L. Al-Fagih, "A comprehensive review on green finance and its impact on net zero energy transition: From the perspective of renewable energy development," *Energy Strategy Reviews*, vol. 62, p. 101948, 2025. Available from: https://doi.org/10.1016/j.esr.2025.101948

[13] UNFCCC, "The Paris Agreement," United Nations Climate Change, 2025. Available from: https://unfccc.int/process-and-meetings/the-paris-agreement

[14] UNDP, "Sustainable development goals," United Nations Development Programme; United Nations, 2025. Available from: https://www.undp.org/sustainable-development-goals

[15] McCahery, J. A., P. C. Pudschedl, and M. Steindl, "Institutional investors, alternative asset managers, and ESG preferences," *European Business Organization Law Review*, vol. 23, no. 4, pp. 821–868, 2022. Available from: https://doi.org/10.1007/s40804-022-00264-0

[16] D'Orazio, P., "Climate risks and financial stability: Evidence on the effectiveness of climate-related financial policies," *International Review of Financial Analysis*, vol. 105, p. 104304, 2025. Available from: https://doi.org/10.1016/j.irfa.2025.104304

[17] Bao, X., M. Sadiq, W. Tye, and J. Zhang, "The impact of environmental, social, and governance (ESG) rating disparities on corporate risk: The mediating role of financing constraints," *Journal of Environmental Management*, vol. 371, no. 1, p. 123113, 2024. Available from: https://doi.org/10.1016/j.jenvman.2024.123113

[18] Liu, R., D. Wang, S. Zheng, and N. Cai, "The retrospective and predictive effectiveness of ESG ratings: Evidence from China," *Sustainability*, vol. 17, no. 11, pp. 4819–4819, 2025. Available from: https://doi.org/10.3390/su17114819

[19] Sneideriene, A., and R. Legenzova, "Greenwashing prevention in environmental, social, and governance (ESG) disclosures: A bibliometric analysis," *Research in International Business and Finance*, vol. 74, p. 102720, 2025. Available from: https://doi.org/10.1016/j.ribaf.2024.102720

[20] Shi, Y., and T. Yao, "ESG rating divergence: Existence, driving factors, and impact effects," *Sustainability*, vol. 17, no. 10, p. 4717, 2025. Available from: https://doi.org/10.3390/su17104717

[21] Galeone, G., S. Ranaldo, and A. Fusco, "ESG and FinTech: Are they connected?" *Research in International Business and Finance*, vol. 69, pp. 102225–102225, 2024. Available from: https://doi.org/10.1016/j.ribaf.2024.102225

[22] Polireddi, N. S. A., "An effective role of artificial intelligence and machine learning in banking sector," *Measurement: Sensors*, vol. 33, pp. 101135–101135, 2024. Available from: https://doi.org/10.1016/j.measen.2024.101135

[23] Haleem, A., M. Javaid, M. A. Qadri, R. P. Singh, and R. Suman, "Artificial intelligence (AI) applications for marketing: A literature-based study," *International Journal of Intelligent Networks*, vol. 3, no. 3, pp. 119–132, 2022. Available from: https://doi.org/10.1016/j.ijin.2022.08.005

[24] Liu, Y., J. Song, B. Zhou, and J. Liu, "Artificial intelligence applications and corporate ESG performance," *International Review of Economics & Finance*, vol. 104, p. 104559, 2025. Available from: https://doi.org/10.1016/j.iref.2025.104559

[25] Aydogmus, M., G. Gulay, and K. Ergun, "Impact of ESG performance on firm value and profitability," *Borsa Istanbul Review*, vol. 22, no. 2, pp. S119–S127, 2022. Available from: https://doi.org/10.1016/j.bir.2022.11.006

[26] Liu, Y., J. Osterrieder, B. H. Misheva, N. Koenigstein, and L. J. Baals, "Navigating the environmental, social, and governance (ESG) landscape: Constructing a robust and reliable scoring engine," *Open Research Europe*, vol. 3, pp. 119–119, 2023. Available from: https://doi.org/10.12688/openreseurope.16278.1

[27] Offiong, U. P., K. Szopik-Depczyńska, K. Cheba, and G. Ioppolo, "FinTech as a digital innovation in microfinance companies – systematic literature review," *European Journal of Innovation Management*, vol. 27, no. 9, pp. 562–581, 2024. Available from: https://doi.org/10.1108/ejim-04-2024-0462

[28] Li, Y., L. Zheng, C. Xie, and G. Sun, "Big data development and enterprise ESG performance: Empirical evidence from China," *International Review of Economics & Finance*, vol. 93, 2024. Available from: https://doi.org/10.1016/j.iref.2024.05.027

[29] Lee, H., S. H. Lee, H. Park, J. H. Kim, and H. S. Jung, "ESG2PreEM: Automated ESG grade assessment framework using pre-trained ensemble models," *Heliyon*, vol. 10, no. 4, p. e26404, 2024. Available from: https://doi.org/10.1016/j.heliyon.2024.e26404

[30] Gómez, C., and B. Garbinato, "Blockchain technology to improve traceability in the coffee supply chain: A systematic literature review," *International Journal of Information Management Data Insights*, vol. 5, no. 2, p. 100359, 2025. Available from: https://doi.org/10.1016/j.jjimei.2025.100359

[31] Gong, X., X. Tao, M. Zhang, Y. Xu, H. H. L. Kwok, J. Dai, and J. C. P. Cheng, "Secure environmental, social, and governance (ESG) data management for construction projects using blockchain," *Sustainable Cities and Society*, vol. 114, pp. 105582–105582, 2024. Available from: https://doi.org/10.1016/j.scs.2024.105582

[32] Bhatt, G. D., and A. Emdad, "Blockchain's role in environmental sustainability: Bibliometric insights from Scopus," *Green Technologies and Sustainability*, vol. 3, no. 4, p. 100236, 2025. Available from: https://doi.org/10.1016/j.grets.2025.100236

[33] Tronstad, J., "The role of FinTech in sustainable finance and ESG investing," *S&P Global Market Intelligence*, 2025. Available from: https://doi.org/10.2139/ssrn.5182517

[34] Yu, X., L. Fan, and Y. Yu, "Artificial intelligence and corporate ESG performance: A mechanism analysis based on corporate efficiency and external environment," *Sustainability*, vol. 17, no. 9, p. 3819, 2025. Available from: https://doi.org/10.3390/su17093819

[35] Li, J., and Y. Zhang, "Does ESG rating divergence affect the disclosure behavior of key audit matters?" *International Review of Economics & Finance*, vol. 103, p. 104591, 2025. Available from: https://doi.org/10.1016/j.iref.2025.104591

[36] Alotaibi, E. M., and A. M. Alwathnani, "AI-enabled ESG compliance audit for stakeholders," *Sustainability*, vol. 17, no. 21, pp. 9513–9513, 2025. Available from: https://doi.org/10.3390/su17219513

[37] Ángel, L., A. van Klyton, A. Rojas, and J. Muñoz, "Climate risk and its impact on the cost of capital—A systematic literature review," *Sustainability*, vol. 16, no. 23, pp. 10727–10727, 2024. Available from: https://doi.org/10.3390/su162310727

[38] Vogl, M., M. Kojić, and S. Schlüter, "Decrypting the triad of climate policies, macroeconomic interdependencies and quantitative modelling: A literature review on quantifying climate risks," *Regional Science Policy & Practice*, vol. 17, no. 11, p. 100229, 2025. Available from: https://doi.org/10.1016/j.rspp.2025.100229

[39] Olawade, D. B., O. Z. Wada, A. O. Ige, B. I. Egbewole, A. Olojo, and B. I. Oladapo, "Artificial intelligence in environmental monitoring: Advancements, challenges, and future directions," *Hygiene and Environmental Health Advances*, vol. 12, pp. 100114–100114, 2024. Available from: https://doi.org/10.1016/j.heha.2024.100114

[40] Pimenow, S., O. Pimenowa, P. Prus, and A. Niklas, "The impact of artificial intelligence on the sustainability of regional ecosystems: Current challenges and future prospects," *Sustainability*, vol. 17, no. 11, p. 4795, 2025. Available from: https://doi.org/10.3390/su17114795

[41] Zhou, Q., J. Ni, and C. Yang, "Climate transition risk and industry returns: The impact of green innovation and carbon market uncertainty," *Technological Forecasting and Social Change*, vol. 214, p. 124056, 2025. Available from: https://doi.org/10.1016/j.techfore.2025.124056

[42] Wu, Q., and P. Zhou, "How does artificial intelligence change carbon emission intensity? A firm lifecycle perspective," *Applied Economics*, pp. 1–18, 2025. Available from: https://doi.org/10.1080/00036846.2025.2482927

[43] Weber, O., "Climate stress testing in the financial industry," *Current Opinion in Environmental Sustainability*, vol. 66, pp. 101401–101401, 2024. Available from: https://doi.org/10.1016/j.cosust.2023.101401

[44] Huang, L., Q. Duan, Y. Liu, Y. Wu, Z. Li, Z. Guo, M. Liu, X. Lu, P. Wang, F. Liu, F. Ren, C. Li, J. Wang, Y. Huang, B. Yan, M.-A. Kioumourtzoglou, and P. L. Kinney, "Artificial intelligence: A key fulcrum for addressing complex environmental health issues," *Environment International*, 2025. Available from: https://doi.org/10.1016/j.envint.2025.109389

[45] Saarela, M., and V. Podgorelec, "Recent applications of explainable AI (XAI): A systematic literature review,"

Applied Sciences, vol. 14, no. 19, pp. 8884–8884, 2024. Available from: https://doi.org/10.3390/app14198884

[46] Ahn, D., A. Almaatouq, M. Gulabani, and K. Hosanagar, "Will we trust what we don't understand? Impact of model interpretability and outcome feedback on trust in AI," *arXiv*, Nov. 15, 2021. Available from: https://doi.org/10.48550/arXiv.2111.08222

[47] Vitor, P., B. Belchior, N. C. Chaves, R. M. Chaves, C. E. Barbosa, and Jano, "The future of AI in government services and global risks: Insights from design fictions," *European Journal of Futures Research*, vol. 13, no. 1, 2025. Available from: https://doi.org/10.1186/s40309-025-00253-9

[48] European Environment Agency, "Green bonds," Apr. 28, 2023. Available from: https://www.eea.europa.eu/en/analysis/indicators/green-bonds-8th-eap

[49] Bajra, U. Q., and N. Wagner, "Analyzing the impact of eco-friendly bond on economic growth and environmental sustainability," *Borsa Istanbul Review*, vol. 24, no. 4, 2024. Available from: https://doi.org/10.1016/j.bir.2024.04.003

[50] Khan, M. A., and S. Vismara, "Green bond issuance and corporate environmental and financial performance: A meta-analysis," *International Review of Economics & Finance*, vol. 102, p. 104313, 2025. Available from: https://doi.org/10.1016/j.iref.2025.104313

[51] Narong Kiettikunwong and W. Sangsarapun, "G-token implications and risks for the financial system under state-issued digital instruments in Thailand," *Journal of Risk and Financial Management*, vol. 18, no. 10, pp. 555–555, 2025. Available from: https://doi.org/10.3390/jrfm18100555

[52] Layosa, J., "Reassessing blockchain in global development: Tokenization of infrastructure, social impacts, and the Axie Infinity case in the Philippines," *Social Sciences & Humanities Open*, vol. 13, pp. 102340–102340, 2025. Available from: https://doi.org/10.1016/j.ssaho.2025.102340

[53] Tanveer, U., S. Ishaq, and T. G. Hoang, "Tokenized assets in a decentralized economy: Balancing efficiency, value, and risks," *International Journal of Production Economics*, vol. 282, p. 109554, 2025. Available from: https://doi.org/10.1016/j.ijpe.2025.109554

[54] Agi, M. A. N., and A. K. Jha, "Blockchain technology for supply chain management: An integrated theoretical perspective of organizational adoption," *International Journal of Production Economics*, vol. 247, p. 108458, 2022. Available from: https://www.sciencedirect.com/science/article/pii/S0925527322000570

[55] Wu, D., and X. Zuo, "Curbing financial greenwashing: Policy tools, legal mechanisms, and corporate responsibility for sustainable development," *International Review of Economics & Finance*, vol. 103, p. 104480, 2025. Available from: https://doi.org/10.1016/j.iref.2025.104480

[56] Schilke, O., and M. Reimann, "The transparency dilemma: How AI disclosure erodes trust," *Organizational Behavior and Human Decision Processes*, vol. 188, p. 104405, 2025. Available from: https://doi.org/10.1016/j.obhdp.2025.104405

[57] Tayan, B., D. Larcker, E. Watts, and L. Pomorski, "ESG ratings: A compass without direction," *The Harvard Law School Forum on Corporate Governance*, Aug. 24, 2022. Available from: https://corpgov.law.harvard.edu/2022/08/24/esg-ratings-a-compass-without-direction/

[58] Dhar, B. K., M. M. Roshid, S. Dissanayake, U. Chawla, and M. Faheem, "Leveraging FinTech and GreenTech for long-term sustainability in South Asia: Strategic pathways toward Agenda 2050," *Green Technologies and Sustainability*, vol. 4, no. 1, p. 100263, 2025. Available from: https://doi.org/10.1016/j.grets.2025.100263

[59] Ferilli, G. B., Y. Altunbas, V. Stefanelli, E. Palmieri, and V. Boscia, "Fintech governance and performance: Implications for banking and financial stability," *Research in International Business and Finance*, vol. 70, pp. 102349–102349, 2024. Available from: https://doi.org/10.1016/j.ribaf.2024.102349

[60] Kokina, J., S. Blanchette, T. H. Davenport, and D. Pachamanova, "Challenges and opportunities for artificial intelligence in auditing: Evidence from the field," *International Journal of Accounting Information Systems*, vol. 56, no. 1, p. 100734, 2025. Available from: https://doi.org/10.1016/j.accinf.2025.100734

[61] Hassija, V., V. Chamola, A. Mahapatra, A. Singal, D. Goel, K. Huang, S. Scardapane, I. Spinelli, M. Mahmud, and A. Hussain, "Interpreting black-box models: A review on explainable artificial intelligence," *Cognitive Computation*, vol. 16, no. 1, pp. 45–74, 2023. Available from: https://doi.org/10.1007/s12559-023-10179-8

[62] Hassan, R., N. Nguyen, S. R. Finserås, L. Adde, I. Strümke, and R. Støen, "Unlocking the black box: Enhancing human-AI collaboration in high-stakes healthcare scenarios through explainable AI," *Technological Forecasting and Social Change*, vol. 219, p. 124265, 2025. Available from: https://doi.org/10.1016/j.techfore.2025.124265

[63] Khan, H. H., S. Khan, and A. Ghafoor, "Fintech adoption, the regulatory environment and bank stability: An empirical investigation from GCC economies," *Borsa Istanbul Review*, vol. 23, no. 6, 2023. Available from: https://doi.org/10.1016/j.bir.2023.10.010

[64] Tumpa, R. J., L. M. Naeni, F. Afzal, and A. N. Ghanbaripour, "Leveraging digital technology to improve environmental, social, and governance performance of infrastructure projects," *Management Decision*, vol. 63, no. 13, pp. 455–496, 2025. Available from: https://doi.org/10.1108/md-04-2024-0818

[65] Laviola, F., and N. Cucari, "From promise to concern: Public perceptions of AI in ESG frameworks over time," *Technology in Society*, vol. 85, pp. 103219–103219, 2026. Available from: https://doi.org/10.1016/j.techsoc.2026.103219

[66] Anselmi, G., and G. Petrella, "ESG ratings: Disagreement across providers and effects on stock returns," *Journal of International Financial Markets, Institutions and Money*, vol. 100, p. 102133, 2025. Available from: https://doi.org/10.1016/j.intfin.2025.102133

[67] Pei, P., "Artificial intelligence in ESG investing: A scoring model for accuracy and accountability," *SHS Web of Conferences*, vol. 225, p. 03017, 2025. Available from: https://doi.org/10.1051/shsconf/202522503017

[68] Bagherifam, N., S. Naghdi, V. Ahmadian, A. Fazlzadeh, and M. Baghalzadeh Shishehgarkhaneh, "Digital regulatory governance: The role of RegTech and SupTech in transforming financial oversight and administrative capacity," *International Journal of Financial Studies*, vol. 13, no. 4, p. 217, 2025. Available from: https://doi.org/10.3390/ijfs13040217

[69] Bu, Y., X. Du, H. Li, X. Yu, and Y. Wang, "Research on the FinTech risk early warning based on the MS-VAR model: An empirical analysis in China," *Global Finance Journal*, vol. 58, pp. 100898–100898, 2023. Available from: https://doi.org/10.1016/j.gfj.2023.100898