Review
UDK 316.422:330.322
DOI 10.7251/BLCZR0723203H

INFLUENCE OF TECHNOLOGICAL INNOVATIONS ON ESG INVESTING: TRENDS AND FUTURE DIRECTIONS

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SUMMARY

This paper looks at how technological advancements in big data, blockchain, artificial intelligence (AI), the Internet of Things (IoT), and fintech are changing sustainable finance, especially in ESG invesment. Thanks to these technological advancements, ESG data is now more accessible, transparent, and accurate, allowing investors to make better-informed decisions that support sustainable development objectives. Even if new technologies like 5G networks and quantum computing have a lot of promise, their quick adoption comes with drawbacks, such as problems with data quality, complicated AI models, and the possibility of technology-driven greenwashing. The paper makes the case that standardizing reporting, fostering cross-industry collaboration, and striking a balance between technology advancements and social responsibilities are essential to the future of ESG investment.

KEYWORDS: *Artificial Intelligence (AI), Big data, ESG investment, financial investment, Sustainable Development Goals (SDGs), greenwashing, Internet of Things (IoT).*

UTICAJ TEHNOLOŠKIH INOVACIJA NA ESG ULAGANJE: TRENDOVI I BUDUĆI PRAVCI

SAŽETAK

Ovaj rad razmatra kako tehnološki napredak u velikim podacima, blockchainu, umjetnoj inteligenciji (AI), Internetu stvari (IoT) i fintechu mijenjaju održivo financiranje, posebno u ESG ulaganjima. Zahvaljujući ovom tehnološkom napretku, ESG podaci sada su dostupniji, transparentniji i tačniji, omogućujući ulagačima da donose bolje informirane odluke koje podržavaju ciljeve održivog razvoja. Čak i ako nove tehnologije kao što su 5G mreže i kvantno računarstvo puno obećavaju, njihovo brzo usvajanje dolazi s nedostacima, kao što su problemi s kvalitetom podataka, komplikovani modeli umjetne inteligencije i mogućnost tehnološkog zelenašenja. U radu se tvrdi da su standardiziranje izvještavanja, podsticajne međuindustrijske saradnje i uspostavljanje ravnoteže između tehnološkog napretka i društvene odgovornosti ključni za budućnost ESG ulaganja.

KLJUČNE RIJEČI: *Umjetna inteligencija (AI), big data, ESG ulaganja, finansijska ulaganja, ciljevi održivog razvoja (SDGs), greenwashing, internet of things (IoT).*

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INTRODUCTION

In the world of international finance, the incorporation of Environmental, Social, and Governance (ESG) factors into investment choices has quickly progressed from a specialized technique to a common practice. Statistics shows that over 90% of S&P 500 businesses provide ESG reports (McKinsey, 2023). A growing number of investors understand how important it is to include ESG variables in their portfolios in order to improve long-term financial success as well as to comply with moral principles. Business activities that support the Sustainable Development Goals (SDGs) account for 49% of the income of the world's largest 1,200 firms and 53% of the revenue of the top 500 US enterprises (Keyesg, 2024). With the increasing demand for sustainable investing solutions, technology advances are also having an increasingly significant impact on the ESG environment.

The methods for gathering, evaluating, and using ESG data in investment decision-making are being completely transformed by technological advancements (ESG Research Pro, 2024). The financial sector is seeing a significant change in how it approaches sustainability, from the use of big data and artificial intelligence (AI) to the use of blockchain technology and the Internet of Things (IoT). These developments help investors make more meaningful and informed decisions while also enhancing the openness and integrity of ESG reporting.

This study aims to investigate the impact of technology advancements on ESG investment, highlighting significant patterns propelling this change and projecting future developments in this quickly developing area. This paper will give a thorough review of how emerging technologies like blockchain, artificial intelligence, and fintech platforms are influencing ESG investing strategies and what the future holds for technology-driven sustainability in finance.

The following important queries will be the focus of the study: How is ESG investment being driven by technology innovations? And what more innovations may be made in the future to better combine technology and ESG principles? The paper's goal is to better comprehend the dynamic interaction between technology and sustainable finance by offering pertinent insights to policymakers, investors, and finance professionals through this study.

LITERATURE REVIEW

The idea of ESG investment emerged from the larger trend of socially responsible investing (SRI), which is gaining traction as investors start to weigh moral principles in addition to financial gains is a subject that has drawn the attention of several scholars. In his history and development of ESG analysis, Roselle (2016) examines the transition from conventional financial measures to a more all-encompassing strategy that takes ESG factors into account. According to Drei and colleagues (2023), ESG investment is expanding quickly and may be viewed as a buffer against potential risks such as regulatory fraud, taxes linked to pollution, and other hazards. Similarly, according to Martínez (2021), Covid-19 had an impact on the evolution of ESG investing. This study also demonstrated that compared to other investment categories, ESG investments are less volatile and safer during a crisis.

In terms of technology development, Vangala (2024) finds out that the rise of fintech firms and the expansion of digital platforms have altered the way individuals invest their

money, making it easier, less expensive, and more effective than in the past. Chua (2023) discoveres in his study that behavioral intents to accept AI-based suggestions, trust in AI, and perceived accuracy of AI are all positively correlated with current investors' views about AI. Vedapradha and Hariharan (2018) drew attention to the role that technology plays in the banking industry, highlighting how AI-based solutions not only assist information storage but also uphold and enhance operational openness. Wilhelmina and other researchers (2024) also discuss the role that AI would play in the market. By incorporating AI, algorithms will be able to learn and adapt in real time, enabling them to design and optimize strategies based on market circumstances.

Macpherson (2021) concludes that AI capabilities have shown promise for ESG investment. This type of investing usually depends on self-disclosed business information that is produced periodically and is subject to biases and inherent data difficulties. On the contrary, concerns about AI ethics and the proper usage of AI systems are also brought up by Minkkinen (2024). Mori (2023) also highlights the advantages of AI for financial institutions as a whole, including rating services and ever-stronger assistance for asset managers.

The convergence of technology and ESG investing is attracting more and more attention in academic research, which examines how advancements in blockchain, AI, and data analytics might improve the performance of sustainable investment strategies. Research has indicated that the incorporation of technology in ESG investment can result in enhanced precision in evaluating a firm's long-term sustainability and feasibility, along with more effective and transparent reporting protocols.

TECHNOLOGICAL INNOVATIONS DRIVING ESG INVESTING

With the ability to handle and evaluate vast volumes of ESG-related data, big data and analytics have gained significance in the field of ESG investment. An extensive picture of a company's environmental, social, and governance initiatives is offered by the deluge of data coming from many sources, including social media, corporate filings, and independent ESG rating organizations.

Big data facilitates more accurate reporting, enhances risk management, fosters competitive differentiation, and generates long-term value—all of which are critical components of ESG (environmental, social, and governance) programs (ESG Summit Europe, 2023). Businesses may identify important ESG KPIs, monitor their progress, and communicate openly with stakeholders by using sophisticated analytics. Additionally, by offering a thorough grasp of possible dangers, big data assists businesses in managing ESG-related risks like supply chain problems or reputational harm. Businesses who successfully use big data to prioritize ESG stand out from the competition and make wise decisions that benefit the environment and their company in the long run.

Additionally, ESG investment has greatly improved thanks to AI and Machine Learning, which automate the examination of complicated and unstructured data. With the use of these technologies, it is possible to evaluate non-traditional data sources for ESG performance assessment, including sentiment analysis from social media, satellite imagery, and employee reviews. AI algorithms are able to identify businesses that are expected to score highly on ESG criteria and forecast future ESG trends. Incorporating non-financial data

into investment choices and offering deeper insights are two ways that artificial intelligence (AI) has the potential to change ESG investing.

ESG investment is also being revolutionized by blockchain technology, which increases accountability and transparency. The decentralized and unchangeable ledger structure of blockchain guarantees the accuracy, verifiability, and resistance to manipulation of ESG data. In the fight against "greenwashing", which occurs when businesses inflate their ESG results in an attempt to draw in investors, this is particularly crucial. Blockchain also provides an answer to environmental problems when the system may offer automatic reporting of any quantity of data points pertinent to an organization's ESG tracking, as well as unchangeable certification (Forbes, 2022).

Blockchain technology may be used by businesses to trace the origin of commodities and guarantee that they are supplied responsibly and ethically. Blockchain is the perfect technology to solve some of the issues that are specific to green finance, such the need for more open and accountable funding channels and the risk of "greenwashing," because it can provide safe, transparent, and immutable transaction records (Udeh *et al*, 2024). Blockchain technology may boost investor trust and encourage more investment in green efforts by guaranteeing that green projects are actually sustainable and that cash flows are precisely recorded and reported.

Another important factor that is becoming more and more important in ESG investment is the Internet of Things (IoT), which offers real-time data on resource management, energy efficiency, and environmental effect (IoTNow, 2023). A company's environmental performance may be evaluated by looking at a number of environmental parameters that IoT devices can track and report on, including waste management, water use, and carbon emissions. Real-time tracking of energy use and emissions by IoT sensors in industrial facilities helps businesses lower their carbon footprint and raise their ESG scores (Reddy, 2023). As a result, investors might use this data to evaluate the sustainability of their investments.

Financial technology advancements have made ESG investing more accessible, especially through platforms that provide retail investors with ESG-focused investment alternatives (Finance Magnates, 2023). These platforms frequently use AI and big data to offer individualized ESG portfolios, which make it simple for people to match their financial goals with their principles. ESG investing has expanded as a result of the emergence of robo-advisors, which employ computers to manage client portfolios and include sustainability standards into automated investment plans.

Generally, the development and sophistication of ESG investment are mostly being driven by technological developments. Investors may achieve their sustainability goals by making more educated, impactful, and transparent investment decisions by utilizing big data, AI, blockchain, IoT, and fintech. These innovations not only make ESG investment more successful, but they also open up new avenues for sustainable finance advancements in the future.

FUTURE DIRECTIONS: OPPORTUNITIES AND CHALLENGES

Emerging technologies like advanced AI, 5G networks, and quantum computing have the potential to significantly change ESG investment as technology develops. Quantum

computing, for instance, has the potential to completely transform data processing by handling intricate ESG data sets that are difficult for existing technology to handle. This would make ESG analysis much more precise and thorough. It is at this critical juncture, when our world faces urgent ecological and socioeconomic concerns, that quantum computing gives humanity a potent instrument (Safonov, 2024). It is essential to take advantage of this chance and incorporate this state-of-the-art technology into a number of business domains, particularly in the ESG field.

The Internet of Things (IoT) might benefit from 5G technology as it would allow for quicker and more dependable data transport and communication (Nexusgroup, 2024). Applications in ESG monitoring follow as a result of its improved connectivity and real-time data capabilities. This would make it possible to monitor environmental factors, such as energy usage and carbon emissions, continuously and in real time along the whole supply chain. Real-time ESG data might lead to more dynamic and responsive investing strategies that better align portfolios with ongoing sustainability activities.

Technology and finance will probably work together more in the future when it comes to ESG investment. Fintech firms with expertise in AI, blockchain, IoT, and data analytics are well-positioned to collaborate with financial institutions to create more advanced ESG platforms and tools. Such partnerships may result in the development of cutting-edge ESG investment products, more innovation in sustainable finance, and more potent responses to the world's sustainability problems.

There is a chance to broaden the scope of ESG investing to cover more inventive and diverse industries as awareness of ESG problems rises. For instance, new opportunities for ESG investments are created by the development of green technology, sustainable agriculture, and the circular economy. Furthermore, as investors focus more on topics like corporate governance, diversity and inclusion, and labor rights, social and governance aspects are becoming more and more significant. The creation of new investment products and strategies may result from this expansion of the ESG framework, which would further propel the rise of sustainable finance.

Standardized ESG data and reporting systems are one of the most potential future advances in ESG investment. The process of standardizing ESG data would enhance its dependability and comparability, hence simplifying the process for investors to evaluate and contrast the sustainability achievements of various businesses. The Global Reporting Initiative (GRI) and the International Financial Reporting Standards (IFRS) Foundation are two organizations that are attempting to create international standards for ESG reporting.

The quality and consistency of ESG data continue to be major obstacles in ESG investment, notwithstanding the benefits brought about by technology. Differences in the information utilized to guide investment decisions may result from the absence of dependable and uniform ESG reporting frameworks. Investors find it challenging to fairly evaluate and contrast ESG performance across industries and businesses as a result.

Moreover, the application of AI and machine learning in ESG investment frequently depends on data that is unstructured or of inconsistent quality, which might introduce bias into the research. Investor trust in the dependability of these technologies may be damaged as a result of erroneous or deceptive ESG evaluations. To tackle these obstacles, persistent endeavors to enhance data quality and institute uniform reporting guidelines would be necessary.

The complexity of AI and machine learning models is rising, making it more challenging for stakeholders and investors to comprehend and analyze them. Since AI-driven ESG policies may include opaque decision-making processes, this complexity raises questions regarding accountability and transparency. If investors are unable to comprehend the underlying logic or rationale behind investing decisions, they may find it difficult to trust AI models.

The goal of explainable AI (XAI) models, which attempt to increase the transparency and interpretability of AI-driven judgments, is to overcome this difficulty. To guarantee that AI can be successfully incorporated into ESG investing without compromising transparency, further research is required to find the ideal balance between model complexity and interpretability, which continues to be a major difficulty.

The use of cutting-edge technology in ESG investment also brings up moral and societal issues. AI and big data, for instance, may be used to track or evaluate social and governance variables, which might result in privacy violations or misuse of personal information. Furthermore, the usage of IoT devices for environmental monitoring may give rise to worries about data collection and possible abuse as well as surveillance.

It's critical to strike a balance between the need to pursue innovation and uphold ethical norms, openness, and data integrity as technology advancements continue to influence ESG investment. The financial sector can propel significant advancements in sustainable finance and guarantee that ESG investing stays an effective instrument for advancing social responsibility and global sustainability by tackling the obstacles and grasping the opportunities brought about by developing technology.

CONCLUSION

An important shift in the way investors see sustainability has occurred with the confluence of ESG investment and technology innovation. In addition to increasing the precision and openness of ESG research, technologies like big data analytics, AI, blockchain, IoT, and fintech platforms have made it easier for people to access sustainable investing options. These developments have made it possible for investors to make better judgments, match their values with their portfolios, and support more general objectives related to social justice, environmental sustainability, and corporate governance.

The ESG investment space offers enormous potential as well as formidable difficulties as it develops further. The incorporation of cutting-edge technologies like 5G networks and quantum computing has the potential to further revolutionize ESG investment by offering more advanced instruments for data analysis and real-time tracking. Investor confidence may be increased by considerably increasing the comparability and reliability of ESG measures through the standardization of ESG data and reporting standards.

There are some challenges in store, though. Careful management is required when it comes to issues with data quality, AI model complexity, hazards associated with technology-driven greenwashing, and ethical considerations about technology deployment. To guarantee that technology is applied in ESG investing in a way that preserves the values of accountability, transparency, and ethical responsibility, financial institutions, technology providers, regulators, and stakeholders must work together to address these issues.

In conclusion, even if technology advancements are propelling substantial advancements in ESG investment, the sector's capacity to strike a balance between innovation and responsibility will determine its future viability. Through surmounting the obstacles and leveraging the prospects brought about by these advancements, ESG investing may maintain its pivotal role in molding a future that is both egalitarian and sustainable.

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