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Digital Banking and Sustainable Finance: A Topic Modeling Study

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ABSTRACT

The nexus of green finance and digital banking is transforming the world financial system on the twin pillars of environmental sustainability and technological innovation. Topic modeling is utilized in this study to examine nascent trends on the basis of a corpus of around 481 records of the Web of Science database. Six leading topics are: (1) Digital Financial Inclusion and Sustainable Development, (2) Green Finance and Digital Innovation, (3) Fintech and Sustainable Financial Services, (4) Climate and Environmental Sustainability Digital Banking, (5) Blockchain and Transparency in Sustainable Finance, and (6) AI and Big Data in Sustainable Financial Decision-Making. Digital banking is enabling financial inclusion, especially in rural villages, and supporting the United National Sustainable Development Goals (SDGs). Fintech technologies such as mobile banking, blockchain, and AI are propelling access to green financial products, transparency, and climate risk analysis. Blockchain is providing traceability of green bond issuance, while AI-based tools are offering real-time analysis of sustainability risk. Fintech innovation such as ESG-driven robo-advisors are giving access to sustainable financial services to everyone and facilitating decentralized investment in clean energy projects. Yet, issues like digital literacy deficits, cyber-attacks, and the environmental cost of blockchain mining persist. Regulatory schemes must continue to change and meet these to facilitate the promotion of inclusive access to sustainable financial services. This essay points out the necessity of harmonized ESG reporting mechanisms, AI transparency in governance, and inclusive regulation for facilitating the incorporation of sustainability in electronic banking. The findings point out the transformative potential of digital technologies in remoulding sustainable finance with significant implications for financial institutions, regulators, and academics. Subsequent work must take note of developing technology like quantum computing and decentralized finance (DeFi) to continue advancing sustainable financial innovation.

Keywords: Green finance, Digital banking, Fintech, Blockchain, AI, Financial Inclusion, ESG, Climate risk, Topic modeling.

INTRODUCTION

The global financial landscape is undergoing a fundamental transformation with the twin momentum of sustainability and digitalization. While the world is fighting the increasing menace of climate change, natural resource depletion, and social injustice, the finance sector has become the primary engine of sustainable development (Nicholls 2021). With it comes, though, the rapid pace of electronic technology evolution, revolutionizing the way people bank, presenting unprecedented opportunities for enhanced efficiency, convenience, and accessibility (Gomber et al., 2018). Within the pathway of convergence lies the development of sustainable finance within e-banking, a developing field of scholarship interested in utilizing innovative electronic techniques towards ecologically oriented as well as socially aligned financial behavior (Arner et al., 2020). This research paper is a humble effort to study the trends in green finance emerging with online banking through the technique of topic modeling for detecting latent patterns and conclusions from a corpus of literature based on academic literature and industry reports.

Sustainable finance refers to the integration of ESG considerations into financial choices with an aim of building long-term value for investors and society in general (Eccles & Serafeim, 2013). The trend has seen massive speed in the last decades with greater awareness of the need to move towards a low-carbon economy and deal with urgent social issues. Since 2020, the Global Sustainable Investment Alliance (GSIA, 2021) put total global

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sustainable investment assets at $35.3 trillion, which is 15% higher compared to the past two years. This heightened appetite has been orchestrated by a burst of sustainable financial products and services, ranging from green bonds and social impact bonds to ESG-themed mutual funds and exchange-traded funds (ETFs) (Boffo & Patalano, 2020).

Digital banking, however, involves the broad range of technologies and channels by which financial services can be delivered online. Mobile banking applications, web-based payment systems, blockchain-based platforms, and artificial intelligence-based financial planning tools are some of the examples (Boot et al., 2020). Not only has the banking sector transformed how financial services are provided under digitalization but has created new ways through which sustainability can be enhanced. For example, if the internet can mobilize funding towards green projects, increase financial transactions' transparency and accountability, and enable consumers to make more sustainable and informed financial choices (Dorfleitner et al., 2017).

Despite heightened activities in green finance and internet banking, relatively few studies have touched on the subject of overlap between these two topics holistically. Sustainable finance or digital banking has been the subject of previous literature, with virtually no consideration for the trade-offs and synergies that exist when these two phenomena converge (Arner et al., 2020). This information deficiency is especially important within the trend space of emergence in which the speedy rate of technology growth and evolving regulatory conditions intersect a dynamic and complicated landscape to navigate (Gomber et al., 2018).

To bridge this gap, this paper utilizes topic modeling—a computational text-mining method—to examine a relevant body of scholarly and industry writing on sustainable finance and e-banking. Topic modeling is an application of unsupervised machine learning to find underlying thematic patterns in a set of documents such that researchers can reveal trends and patterns that might not be readily visible through qualitative analysis per se (Blei et al., 2003). Through the use of this method to a representative population of texts such as journal articles, industry reports, and policy briefs, this research hopes to find the dominant themes and nascent trends that define the nexus between sustainable finance and digital banking.

This research will be expected to contribute a number of points to the academic literature. In the first instance, they will provide an equitable perspective on the finance art of the time for sustainable finance by digital banking research, and the most significant themes and issues. Secondly, they will provide comments on how synergies or problems of combining sustainability factors with digital banking operations are likely to be anticipated. Lastly, they will provide some recommendations on the future of this discipline, identifying the most worthwhile areas of research and innovation.

In addition to its contribution to theory, the study has important policy and practice implications for policymakers and practitioners. As financial institutions become more inclined towards embracing digital technologies to enhance their competitiveness and customer relations, they are required to deal with the imperative of aligning their operations and strategies into coherence with sustainability goals (Nicholls, 2021). This requires an adult understanding of how digital banking can be leveraged to enable sustainable finance and the trade-offs and risks entailed. Based on data-driven analysis of future trends, this study aims to inform strategy and policy-making that will result in a more sustainable and inclusive financial system.

The intersection of digital banking and sustainable finance offers a fertile ground for research and innovation where the potential to create social and environment value is matched with the efficiency and reach of financial services. This article tries to contribute to this new horizon through the application of topic modeling to identify the most significant themes and trends that will shape the future of sustainable finance in digital banking. It attempts to establish the foundation for more research and influence the practitioners' practice and policymakers' practice as they attempt to navigate through this complex and ever more dynamic landscape.

LITERATURE REVIEW

The convergence of sustainable finance and digital banking has been an area of growing attention in recent years, as they have evolved side by side and influenced each other. This literature review summarizes pioneering research articles that examine the theoretical underpinnings, empirical findings, and emerging patterns of sustainable finance and digital banking, with particular emphasis on where they meet. The report is organized in three broad categories: (1) sustainable finance, (2) digital banking, and (3) overlap of digital banking and sustainable finance.

Sustainable Finance

Sustainable finance has evolved as a field of important studies initiated by increased awareness of the financial sector's role in dealing with issues of environment and society. Eccles & Serafeim (2013) started research toward developing insights into environment, social, and governance (ESG) metrics integration into finance in order to secure sound finance decisions. This article also highlighted integration of firm strategy with sustainability is conducive to long-term value creation. In the same vein, Nicholls (2021) gives a detailed explanation of sustainable finance and its ability to bring about positive social and environment impacts alongside financial returns Sustainable finance, according to the author, is a paradigm shift in finance that necessitates new structures and metrics for the measurement of ESG performance.

Empirical studies have also examined the extent to which sustainable finance can impact financial performance. Friede et al. (2015) meta-analyzed over 2,000 studies to examine the relationship between ESG factors and the financial performance of firms. The study uncovers a positive relationship, wherein sustainable investments provide competitive returns with no exposure to risk. Similarly, Khan et al. (2016) constructed a materiality framework for testing the financial materiality of ESG issues. As they conclude in their research, the companies that engage in material ESG outperform industry peers for both stock return and profitability.

The use of financial products in promoting sustainability has also been researched. Boffo and Patalano (2020) offer an in-depth examination of ESG investing, such as green bonds, social impact bonds, and ESG-themed mutual funds. They note that the acceleration of development in sustainable financial products and the limitation in terms of harmonizing ESG metrics and reporting. In another research, Flammer (2021) examines the effect of green bonds on a company's environment performance. The findings show that, besides funding environment-friendly projects, green bonds positively affect the reputation and stakeholder behavior of companies.

Digital Banking

Financial digitization has transformed the banking sector, opening new avenues to efficiency, access, and innovation. Gomber et al. (2018) offer a comprehensive explanation of digital finance and FinTech with a focus on principal technologies driving this revolution, including blockchain, artificial intelligence (AI), and mobile banking. They see the digital banking opportunity to promote greater financial inclusion in addition to reduced cost of transaction, especially for the underpenetrated markets.

Boot et al. (2020) describe the part played by digital banking in intermediation finance. Digital technology, they argue, is transforming the traditional banking business model and making it possible to provide new peer-to-peer lending, crowdfunding, and rabo-advisary services. The authors also address the regulatory aspect of digital banking like data privacy, cyber-security, and consumer protection. Arner et al. (2020) also pen about how digital banking promotes financial inclusion. Their efforts pave the way for mobile banking and electronic payment networks to provide financial products and services to the unbanked and the underbanked, particularly in the third world.

The influence of internet banking on money decision-making and consumer behavior has also been researched. Dorfleitner et al. (2017) present the adoption of digital banking and its impact on customer satisfaction and loyalty. They conclude that online banking increases customer engagement and satisfaction, particularly if complemented with personalized financial counsel. In a related study, Thakor (2020) focuses on the strengths of machine learning and AI applications in financial areas. The writer's argument is that the technologies enhance risk calculation, asset management, and credit grading, among others, resulting in effective and cheaper financial mechanisms.

Convergence of Sustainable Finance and Digital Banking

The area of sustainable finance and e-banking is a new but fast-evolving collection of literature. Arner et al. (2020) offer an initial overview of the intersection, underlining the revolutionary potential of digital technologies to change sustainable finance. According to them, digital banking promises greater transparency, accountability, and efficiency in green and social sustainable financial flows and in green and social finance mobilization. The authors also more explicitly explain the challenges of online banking in embracing the sustainability concerns with the use of conventional ESG metrics and policy frameworks.

Dorfleitner et al. (2017) outline how online platforms facilitate sustainable investments. They discuss green and social enterprise crowdfunding platforms and view their potential to facilitate democratization of access to

sustainable finance. They also refer to success drivers for such platforms, including transparency, simplicity, and good governance. Similarly, Bollaert et al. (2021) outline the use of blockchain technology in sustainable finance. They are confident that blockchain will bring more elevated degrees of traceability and transparency to green finance transactions, reduce room for carrying out greenwashing, and heighten investor trust.

Deployment of AI and big data analytics for sustainable finance has also been discussed in recent research. Hughes et al. (2021) describes how AI can be utilized to screen and analyze ESG data and influence sustainable investment decisions. The author describes the challenge of data availability and quality along with the need for strong algorithms to provide unbiased and credible analysis. In another pertinent study, Begenau et al. (2018) examine the application of big data in making climate risk estimates. From their study, the use of big data processing can enhance the precision of the estimates to help financial institutions make informed decisions.

Finally, the regulatory and policy dimension of the relationship between sustainable finance and digital banking has come under investigation in recent research. Nicholls (2021) analyzes the need for regulation systems to promote integration of sustainability into digital banking. The regulatory systems, as argued by the author, are supposed to provide room for transparency, accountability, and consumer protection in addition to innovation and competition. Likewise, Arner et al. (2020) note the suitability of international cooperation in developing internationally standardized ESG metrics and reporting regimes, especially in digital banking.

Literature review indicates the growing body of research studies on sustainable finance and digital banking, with emerging trends at their intersection. Though tremendous progress has been achieved in understanding building blocks of these domains, additional research studies are required to investigate their synergies and trade-offs. Green finance and digital banking convergence can be a key driver for environmentally friendly and social beneficial impacts but is also a source of concern from data quality, regulatory framework, and consumer protection points of view. Future work must get to terms with digital banking models and methods for quantifying contribution to sustainable finance and the promise of new technologies such as AI and blockchain in supporting sustainability.

RESEARCH METHODOLOGY

Research Design

Research design employed in this study is aimed at analyzing the new trends of sustainable finance via digital banking using topic modeling, a text-mining computer program. The research design is organized into five phases: research design, data collection, data preprocessing, topic modeling, and analysis and interpretation. It uses the mixed-methods approach by using quantitative text-mining methods combined with qualitative thematic content analysis. The short-term goal is to find and condense the dominant themes and trends behind the interaction between sustainable finance and digital banking. Unsupervised machine learning, topic modeling, is employed as the anchor analytical method with the aim of uncovering latent thematic structures from a big corpus of trade and scholarly literature. Outputs are subsequently interpreted and contextualized through qualitative analysis to drill down ever deeper and deeper to uncover insights into the emergent trends.

Data Collection

The study data are drawn solely from the Web of Science (WoS) database, a credible and authoritative source of academic research. Utilizing WoS guarantees access to high-quality, peer-reviewed journal articles that are stringently screened and indexed, offering a sound basis for the analysis. To identify relevant studies, a systematic search is employed using keywords of "Digital Banking" OR "Online Banking" OR "Fintech" OR "fintech" OR "Financial Technology" AND "Sustainable Finance" OR "Green Finance" OR "green finance" OR "ESG Investing" OR "Impact Investing". The rationale for using the keywords is to attempt to capture the extent of scholarship at the intersection of sustainability and digitalization for the financial system. The retrieval strategyis selected to capture articles between the past decade, so the dataset covers base and present-day research in this field. The third dataset contains around 481 documents that were selected very meticulously to be representative and relevant. Filters were then invoked by publication year (2012-2025), language (English), and document type (Article), in a bid to limit the search parameters, and a refined and useful dataset ensued. Limiting the study to WoS guarantees academic standards to be prioritized, based on sound and peer-reviewed publications for analysis, with a solid foundation for the identification of sustainable finance trends occurring through digital banking.

Data Preprocessing

Before the process of topic modeling, the gathered data undergoes a series of preprocessing operations to get it ready for analysis. The text loses punctuation, digits, and special characters. Stop words like "the," "and," and "is" are also removed to concentrate on significant words. The text is tokenized by breaking the text into words or phrases (tokens) for processing. Lemmatization brings words to their base or root with consistency without redundancy. Term Frequency-Inverse Document Frequency (TF-IDF) is used to assign weight to the significance of the terms in the corpus so that very significant terms for specific documents can be ascertained.

Topic Modeling

Topic modeling is done using Latent Dirichlet Allocation (LDA), a widely used probabilistic model to identify underlying topics in a collection of texts. The best number of topics (k) is found by employing coherence scores, which reflect the interpretability and semantic coherence of the topics. A grid search is employed to determine the optimal number of topics. The pre-processed corpus is trained upon to acquire the LDA model where a probability distribution of the discovered topics is assigned to every document and the topics are represented with a word distribution. Interpretation is done through examination of top words per topic and examination of sample documents. Qualitative analysis is employed in this phase to check for the validity of relevance and meaning of the discovered topics.

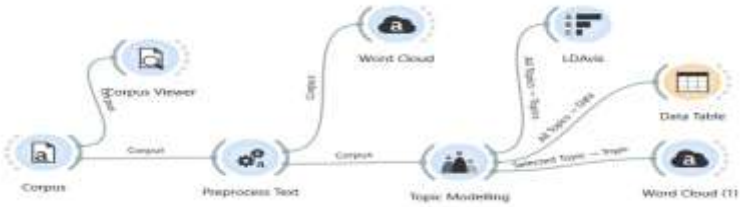

Figure 1: Text-mining workflow.

Analysis and Interpretation

The final step is to analyze the topic modeling results and interpret the results in the context of digital banking and sustainable finance. All the topics have been named based on the most significant and related words. For instance, a theme characterized by the terms "green bonds," "ESG," and "sustainability" could be identified as "Sustainable Financial Instruments." Trends in emergence are determined through analysis of shifts in the frequency and direction of themes over time, comparing topic coverage over years and sources. These findings are corroborated using qualitative analysis, such as reading of pivotal documents and expert interviews, in an effort to offer validity and reliability of the results. The implications of the research for policymakers, practitioners, and academics are considered, including implications for harnessing digital banking to enable sustainable finance and addressing potential issues.

RESULTS

Based on the observations gained through the word clouds, suggest at least six topic titles relevant to the most significant concerns emerging through this textual analysis.

Topic 1: Digital Financial Inclusion and Sustainable Development

The topic, with keywords like mobile banking, sustainable development, fintech, and financial inclusion, emphasizes the significance of digital banking in enabling financial inclusion, especially in rural areas (Figure 1). Mobile financial technologies are facilitating access to green financial services such as microloans for renewable energy initiatives in the rural regions. This coincides with the greater emphasis on optimal use of digital technologies towards attaining the United Nations Sustainable Development Goals (SDGs). Digital banking platforms are also emerging as a key force behind financial inclusion, particularly in the less penetrated markets, through mobile banking, fintech solutions, and blockchain technology. These technologies enhance access to financial services and reduce poverty and economic stability (Demirgüç-Kunt et al., 2020). Mobile banking has grown significantly in poor banking infrastructure developing economies. Empirical evidence has shown that

mobile money services such as Kenya's M-Pesa improved household incomes and small business formation, improving financial inclusion (Jack & Suri, 2016).

Additionally, digital banking promotes sustainable development goals (SDGs) through the promotion of green financial products. Evidence indicates that fintech-oriented solutions, including digital credit scoring and risk evaluation through artificial intelligence, grant microloans to environmentally sustainable businesses (Ozili, 2021). Additionally, blockchain technology promotes transparency in financial dealings, minimizing fraud and guaranteeing funds find their way to their targeted sustainable development projects (Hussain et al., 2024).

Although these advantages exist, the digital literacy disparities and security concerns have the potential to overshadow the potential of digital financial inclusion (Shen et al., 2021). The future research agenda must be directed toward finding ways of reconciling digital banking with the regulatory systems to enable balanced financial access.

Figure 2: Word cloud for topic 1

Topic 2: Green Finance and Digital Innovation

In figure 12, keywords like green bonds, renewable energy, blockchain, and sustainability run the day here. The report indicates that fintech innovations, especially blockchain, are revolutionizing green finance through improved transparency and traceability of green bond issuance. Blockchain platforms are used to monitor the application of proceeds of green bonds and reduce the likelihood of greenwashing. Green finance, triggered by technological advancements, has been instrumental in sustainable investment, especially selling green bonds and investing in green power ventures. Green finance application of blockchain and AI has improved efficiency, accountability, and transparency in the management of green investments. Proof indicates predictive analysis using AI enables climate risk analysis, thus allowing investors to channel funds wisely into environmentally friendly ventures (Yue et al., 2020).

Figure 3: Word cloud for topic 2

Online platforms have also facilitated the application of green bonds by enhancing monitoring systems and proceeds channeling to environmental initiatives (Ehlers & Packer, 2017). Blockchain's function in building trust

and integrity in green finance has been extensively reported, and case studies have proven its capacity to reduce greenwashing risks.

However, the sudden emergence of digital technology in green finance requires strong regulatory controls to avoid potential misuse. Evidence shows that regulatory issues, such as the absence of uniform ESG metrics, impede the efficient application of digital innovations in green finance (Fatemi & Fooladi, 2013).

Topic 3: Fintech and Green Financial Services

The topic of this study is fintech innovation being incorporated into sustainable financial services. Some of the catchphrases are fintech, mobile payments, cryptocurrency, and adoption, reflecting an increased move towards utilizing digital means in making things more sustainable (figure 4). Fintech, for instance, is providing ESG-focused robo-advisory services that render sustainable investment a reality for retail investors. Fintech transformed sustainable financial services by spurring digital banking uptake, mobile payments, and blockchain transactions. There is evidence that fintech-enabled financial services have increased economic stability and financial inclusion, especially in low-income economies (Arner et al., 2020). Cashless transactions have made it easier to eliminate environmental expenses of physical banking infrastructure.

Blockchain transactions have become a sustainable option compared to the conventional financial system through minimizing the transaction cost and maximizing security. Additionally, the use of cryptocurrencies in financial systems has opened new channels for decentralized sustainable finance (Goodell, 2020).

Figure 4: Word cloud for topic 3

Although sustainable finance is promising in fintech, energy-intensive blockchain mining and regulatory risk remain concerns. Studies indicate that green fintech product development, including carbon-neutral blockchain, can alleviate the environmental issues of digital finance (Truby, 2018).

Topic 4: Environmental and Climate Sustainability through Digital Banking

In the figure 5, the phrases climate, environmental sustainability, carbon emissions, and renewable energy capture the function of digital banking in combating climate change. Digital technologies are also utilized to finance renewable energy projects as well as induce environmentally sustainable consumption. Some examples include mobile phone bank applications that are empowering consumers to monitor their carbon footprint and make green money choices. Internet banking plays an important part in addressing climate change through the utilization of green financial products and investment in green energy firms. Results from research findings show that banks making use of internet technology are introducing green lending to their strategies, investing in environmentally friendly businesses (Campbell-Verduyn, 2018). Financial technologies like artificial intelligence-poweredcarbon calculators help in monitoring and managing environmental contamination by individuals and institutions.

In addition, online banking has facilitated crowdfunding for green initiatives, enabling decentralized funding of climate initiatives. It can be seen from research that online lending platforms have made financing of renewable energy start-ups possible, ensuring sustainable development in the emerging economies.

Nevertheless, access to green financial products and digital divide is a cause of concern. Facts reveal that regulative intervention and facilitative policies must be ensured in a manner that digital banking products reach societal segments without discrimination (Saraf & Kayal, 2022).

Figure 5: Word cloud for topic 4

Topic 5: Blockchain and Sustainable Finance Transparency

This topic, encapsulated with words such as blockchain, transparency, ESG, and green bonds, is regarding the potential of blockchain technology to enhance transparency in green finance (figure 6). Blockchain technology is used, for example, to create irreversible traces of ESG transactions to enhance the integrity and accountability of ESG reporting and green bond issues. Blockchain technology has revolutionized sustainable finance by increasing the transparency, traceability, and accountability of ESG reporting and green bond issuance. Research has established that green finance blockchain technologies minimize information asymmetry, enabling investors to verify the sustainability credentials of financial products (Lee & Jeong, 2022). Addition, blockchain technology-enabled smart contracts facilitate green bond trading by automating compliance with sustainability standards (Macchiavello et al., 2022).

Figure 6: Word cloud for topic 5

Empirical evidence shows blockchain enhances ESG reporting by immutable accounts of corporate sustainability behavior. Overconsumption of energy by blockchain mining and regulatory uncertainty, however, hinder widespread use. Academics demand eco-friendly blockchain technology, such as proof-of-stake algorithms, for the lower risk of pollution (Rauchs et al., 2018).

Topic 6: Big Data and AI in Sustainable Financial Decision-Making

Best keywords for this topic are AI, big data, ESG scoring, and climate risk assessment. The outcome is that digital banking is being embraced with the application of AI and big data analytics for more sophisticated ESG scoring and climate risk assessment (figure 7). For instance, AI solutions are providing real-time data to investors about sustainability risks so they make informed decisions. Artificial intelligence and big data analysis have revolutionized sustainable financial decision-making by offering improved ESG scoring, climate risk management, and sustainable investment strategies. The study shows that machine learning models improve predictive models in sustainable finance, enabling more accurate risk estimation of green investments (Fatica & Panzica, 2021). AI-based sentiment analysis has also been employed to gauge firm corporate sustainability reporting, indicating hints about how much priority the companies place on ESG (Broadstock et al., 2021).

Figure 7: Word cloud for topic 6

Moreover, financial inclusion has been enabled by big data analytics that can empower alternative credit scoring mechanisms to the advantage of underbanked consumers. There is evidence that AI and digital banking usage underpin personalized sustainable investment decisions, which reconcile financial objectives with environmental and social objectives (Musleh Al-Sartawi et al., 2022).

However, concerns around data privacy, bias in algorithms, and moral considerations of AI-driven financial decisions still remain. Experts recommend embracing open AI governance frameworks to promote equitable and responsible decision-making for sustainable finance (Berg et al., 2020).

CONCLUSION

This research examine the intersection of green finance and digital banking and determines major themes and trends using topic modeling. The findings of this study uncover the game-changer function that digital banking technology in the guise of blockchain, artificial intelligence (AI), and data analytics has in green finance. Green finance innovation, sustainable fintech services, the role of digital banking towards climate action, the role of blockchain in financial transparency, AI-powered financial decision-making, digital financial inclusion are some of the major areas identified by this research. Together, all these digital innovations have reached far in making financial services more accessible, efficient, and transparent, as well as aligning with global sustainability goals. But regulatory disparities, cyber intrusions, information chasms, and discriminatory algorithms are afewproblems which need to be addressed to capitalize on these advances.

One of the greatest contributions of this ongoing research is the contribution to digital financial inclusion towards sustainable development. Digital banks now take a prime position in increasing the geography of money, specifically targeting the excluded groups of marginalized communities of developing countries. Fintech-driven mobile banking accounts and microcredit facilities bridged the access gap by enrolling individual consumers and micro-enterprises into the formal sector of banks, increasing economic growth, and poverty reduction(Demirgüç-Kunt et al., 2020). Most notably, such operations as Kenya's M-Pesa illustrate the way in which mobile banking increases the incomes of households and financial well-being (Jack & Suri, 2016). Along with capital accessibility, e-banking extends green financial products, including renewable energy project microloans, to reach, which promotes finance resilience to support sustainable development (Ozili, 2021). Yet, challenges of digital illiteracy deficits and cybersecurity continue to be addressed through more robust financial education policy and supervisory infrastructure to enable safe and accessible digital banking entry (Shen et al., 2021).

The second important trend that is identified is the convergence of green finance and digital innovation. Research establishes that AI, blockchain, and fintech innovations are central to greater transparency, accountability, and efficiency in green investments. Blockchain-based platforms have facilitated the listing and trading of greenbonds significantly, enabling greater traceability and lower risks of greenwashing. The online platforms justify the allocation of green finance by providing investors with reliable information on sustainability projects (Tang & Zhang, 2020). Predictive analytics through AI also improve green finance by making it possible to assess climate risks, thus guiding investors in making well-informed decisions through intelligent and sustainable investments (Yue et al., 2020). While the above type of progress, a challenge such as scarce harmonized ESG indicators constitute a pertinent barrier to the use of digital technology for green finance (Fatemi & Fooladi, 2013). Regulatory vulnerabilities must be filled while taking investors' trust along with pushing financial markets' convergence towards global sustainability frameworks.

Green finance fintech development is a critical trend. Fintech innovations, such as digital payments, blockchain transactions, and decentralized finance (DeFi), have contributed to the sustainability of financial activities through more efficiency and less operational cost (Arner et al., 2020). Digital payment systems have contributed towards the decrease in cash usage via cashless payments, decreasing environmental expenses related to traditional banking infrastructure. Furthermore, blockchain technology has enhanced the security and transparency of finance transactions and thus established trust in sustainable finance. Cryptocurrencies have even been proposed as financial instruments of last resort potentially capable of aiding decentralized sustainability activity (Goodell, 2020). Yet, doubts surround the energy demands of blockchain mining, especially for proof-of-work, on the environmental sustainability of certain fintech (Truby, 2018). There must be a transition towards carbon-neutral blockchain technology and more regulatory oversight of fintech activities in an effort to balance technological innovation with environmental responsibility.

The research also points out the role of digital banking towards environmental and climate sustainability. Digital banking companies are now incorporating sustainability into their activities through inclusion of instances of climate risk assessment models, offering funding to renewable energy initiatives, and advocating sustainable consumption practices (Campbell-Verduyn, 2018). Carbon footprint estimators powered by artificial intelligence (AI) assist companies and individuals in monitoring their climate footprint, which promotes a culture of sustainability-aware financial practices. In addition, online lending websites enable crowdfunding for green energy start-ups, and decentralized investment in climate businesses. Conversely, there is a barrier in the provision of green financial services, particularly in low-income economies. There is a requirement for inclusive policies and intervention to provide digital banking facilities to all segments of society in order to establish social equality in the green finance system (Saraf & Kayal, 2022).

The biggest impact of the research is perhaps that transparency in green finance has become possible due to blockchain. Blockchain-based ESG reporting and green bond issuance have increased financial data integrity, reducing information asymmetry as well as encouraging investor trust in green finance (Lee & Jeong., 2022). Smart contracts ensure compliance with sustainability laws automatically without paperwork and expenses (Macchiavello et al., 2022). Nevertheless, in the absence of its prospectivity, green finance applications of blockchain continue to be hampered by energy consumption and regulatory uncertainty issues. It is essential that research must be targeted towards developing energy-efficient blockchain technology, such as proof-of-stake algorithms, thereby allowing such limitations to be minimized (Rauchs et al., 2018).

Ultimately, the study recognizes the use of big data analytics and artificial intelligence in the development of sustainable financial choices. The algorithms of machine learning of AI improved the climate risk analysis predictive model, allowing finance institutions to optimize the use of resources in sustainability investment (Fatica & Panzica, 2021). The application of sentiment analysis powered by artificial intelligence has been a significant factor in gauging corporate ESG engagement, keeping sustainability disclosures clear (Broadstock et al., 2021). Alongside, big data analytics supported various credit-scoring activities to augment the financial inclusivity of financially excluded people. Data privacy, algorithmic transparency, and moral concerns surrounding AI-driven decision-making are yet to be in focus. Transparent open AI governance through institutions that can help facilitate fairness and accountability when utilizing sustainable finance is what is being advocated by researchers (Berg et al., 2020).

IMPLICATIONS, LIMITATIONS AND FUTURE DIRECTION

The findings of this research have far-reaching implications to policymakers, researchers, and financial institutions. Financial institutions can gain from this research the future of next-generation digital banking technologies like blockchain, AI, and big data analytics in facilitating sustainable finance. Using these technologies, banks can increase transparency, efficiency, and inclusiveness in their operations while propelling global sustainability goals. Blockchain technology, for instance, improves traceability in green finance because it guarantees that money channeled into green schemes goes as per plans and hence decreases the possibility of greenwashing. ESG scoring models that are created using artificial intelligence also improve financial decisions by improving climate risk assessment and sustainable investment policy (Fatica & Panzica, 2021). In addition, mobile banking and fintech apps facilitate greater financial inclusion, particularly in less penetrated economies, so that it is convenient to buy green financial products and sustainable lines of credit (Demirgüç-Kunt et al., 2020).

To policymakers, this research proposes the implementation of robust regulating structures that are sustainability-informed for online banks. Currently, there is the lack of the existence of universally adopted Environment, Social, and Governance (ESG) and reporting systems that lead to lack of congruity in analyzing sustainable financial offerings (Fatemi & Fooladi, 2013). Policymakers have a responsibility of building generic standards for ESG so that uniform analysis of sustainability exists. Also, as electronic banking goes even deeper in the developing economies, policy makers need to make sure that they fill the digital divide by means of programs increasing digital literacy and awareness about cybercrime. Policy actions also have to address the issue around AI and big data ethics, wherein concerns over biases built into algorithms do not have negative effects primarily on the marginalized masses (Berg et al., 2020).

For researchers, the research offers an opportunity for learning on digital banking convergence and sustainable finance. Topic modeling offers a new approach to analyzing large corpora of academic literature, allowing researchers to reveal underlying patterns that may not be obvious through traditional qualitative approaches. There are other topics where research could explore deeper the impact of new financial technologies such as quantum computing and decentralized finance (DeFi) on sustainable finance. Interdisciplinary research that fuses fintech adoption and behavioral economics is another topic where research could learn valuable lessons on consumer decision-making in sustainable banking.

Limitations

In as much as this study has potential, it also has a number of limitations that must be highlighted. To start with, data is only obtained from Web of Science (WoS) database, which may not be comprehensive of all research on sustainable finance and e-banking studies, although it is highly reputable. Future research can include additional databases like Scopus, Google Scholar, or repository systems within institutions to augment the dataset. Second, although topic modeling using Latent Dirichlet Allocation (LDA) is a great method for revealing themes, it is hampered by its base in statistical probability instead of semantic insight. Topics therefore might meet or need further explanation, especially in multifaceted realms like sustainable finance. Hybrid methods can be investigated in future research that combines machine learning with human judgment to expand thematic labels.

Third, this research is based mainly on academic literature and possibly may not represent actual industry trends and practical applications. A lot of financial innovation driven by sustainability is found in the corporate world, central bank supervision, and fintech companies, which are not necessarily well-documented in academic research. Future research can include industry reports, case studies, and interviews with practitioners to present a more comprehensive view of sustainable digital finance. Fourth, regional differences in digital banking adoption are not factored into this study. The adoption of digital banking is considerably different for emerging and developed economies because of varying levels of financial infrastructure, regulation, and culture (Saraf & Kayal, 2022). Comparative regional analysis should be done in further studies to monitor how digital banking promotes sustainability across different economic contexts.

Lastly, although this research analyzes present trends, it does not evaluate the long-term contribution of digital banking innovations to sustainability. Most fintech innovations are in their early stages, and the extent to which they can help achieve sustainability is uncertain. Longitudinal studies tracking the development of digital banking solutions over time would be useful in evaluating their long-term contribution to sustainability. Follow-up research has to examine behavioral economics and consumer uptake of green digital finance. Digital banking is good for sustainability, but consumer participation is an issue. Research has to examine the effect of behavioral nudges, incentives, and gamification on sustainable financial choice. For example, individualized carbon footprint

monitoring in mobile bank apps might make environmentally friendly spending more likely. Cross-regional analyses of the effect of digital banking on sustainability might uncover best practices, accounting for differences in policy, economic development, and technology.

Future Research

AI-based sustainable finance raises governance and ethical issues, including algorithmic bias, data privacy, and ethical governance. AI governance mechanisms that provide credit rating equity and investment need to be explored by the future research agenda. Fintech-based financing of climate resilience projects needs to be explored. Climate risk can be reduced in vulnerable areas by blockchain-based green bonds and AI-based climate insurance schemes. Longitudinal data for the long-term effects of digital banking innovations on sustainability are needed. Most fintech-promoted sustainability initiatives are nascent and monitoring their progression can tell us about their ability to establish climate resilience, financial inclusion, and economic stability.

This research adds to digital banking and green finance scholarship in that it identifies future trends using topic modelling. Although digital finance has huge potential, regulatory vulnerabilities, cyber threats, and digital inclusion are issues that need to be addressed. Financial institutions, policymakers, and researchers alike all need to ensure digital financial innovations are sustainable, inclusive, and ethical and can contribute to developing a resilient global financial architecture.

AUTHOR DECLARATIONS

CRediT Author Statement / Author contributions

Rahisha: Conceptualization; Methodology; Formal Analysis; Investigation; Writing – Original Draft; Visualization.
Mohammed Jamshed: Conceptualization, Supervision; Project Administration; Writing – Review & Editing; Resources.

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