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How Robo-Advisors Influence Green Bond Investment Behavior?

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Abstract. Green financing has become an essential way of ensuring sustainability globally, and the use of green bonds as the dominant financing instrument is essential in the implementation of sustainability in transportation, the environment, and the reduction of emissions. At the same time, the digital revolution in the financing sector has placed the use of artificial intelligence-driven robo-advisors at the forefront of financial decision-making among retail investors. This study investigates the relationship between robo-advisor attributes and individual investor behavior regarding the allocation of green bond investments, with the variables of transparency, reliability, trust, and frequency of use. With the research study adopting the quantitative research methodology and data from 401 participants, the study concludes with 70 participants, ensuring researchers assess the attributes as predictors of the proportion and amount of the entire green bond invested. The study concludes the findings as the variables of transparency and reliability being significant predictors of the allocation, while trust and frequency show no direct relationship.As a matter of influence on portfolio structure but less on the investment amount itself, that was respectively contributed to by investment experience and personal financial capabilities. Overall, the paper concludes that transparency and comprehensible recommendation logic, in combination with system reliability, is a crucial factor behind sustainable system adoption, while strategies on personalization were found to be most successful in the presence of clear information disclosure.

Keywords: robo-advisors, green bonds, investment behavior, transparency, reliability

1. Introduction

Green finance has been identified as a major sustainability driver in the world today, with green bonds being a crucial tool in green finance. On the other hand, the increased use of digitalization in the finance sector has led to robo-advisors powered by artificial intelligence emerging as a major driver of investments. An important area to understand is how robo-advisor attributes correlate to green bond investments.

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2. Literature review

2.1. Green finance and green bonds: an overview

Green finance refers to financial instruments or investments aimed at achieving environmental sustainability such as green bonds, Environmental, Social, Governance (ESG) investments, or any other type of climate-related financial instruments [1]. Green bonds are differentiated due to their usage of funds being "earmarked" towards meeting environmental aims such as renewable energy, energy conservation, green transport, or pollution reduction. Such an aspect makes it easy to track them down in comparison to any other type of green financial instruments [2].

A green bond, as a climate finance solution, facilitates public and private sectors to issue long-term debt financing, and refinance, [3,4]. The social effects of green bond initiatives include a reduction in pollution, enhancement of environment quality, creation of new jobs, and increased public awareness of a low-carbon lifestyle and green investments [5]. In the market, green bonds enhance the conversion of fossil energy sources to renewable sources, enhance innovation in green technology, and eliminate inefficient and outdated capacities [3]. To the government, green bonds enhance dual carbon strategies, ease financial burdens, and enhance international investments and policy development [6].

Green bonds typically involve a so-called greenium, where investors pay a premium, or a slight reduction in yield, in order to gain sustainability advantages [7]. However, the actual greenium is issuer- or market-dependent. Some critical concerns in green bond markets include greenwashing, which could be the tendency to exaggerate or even misrepresent issuers' environmental credentials, damaging investors' trust in green products [8,9].

2.2. AI and robo-advisors in investment decision-making

Digitalization has brought a significant change in the financial industry, with new technologies like AI contributing to a paradigm shift in investment decision-making. A Robo-advisory system is an innovative fintech solution that uses algorithms to suggest investment decisions in a way that is less reliant on human assistance [1]. The system uses Machine Learning(ML) and Big Data(BD) to analyze market trends, track risk, and offer investment decisions according to client preferences [10].

One of the key benefits associated with robo-advisors is that they improve financial inclusion because their low-cost approach supported by big data enables retail investors who lack a high level of financial education to make use of complex investment strategies [11]. Nevertheless, their use in sustainable finance is low despite their great potential in integrating ESG criteria to advise investors on green assets [12]. Transparency is a major issue here since investors would not easily comprehend how machine-learning models analyze ESG risks and opportunities .

2.3. Robo-advisors and their role in green bond investing

Robo-advisors, also known as AI-powered advisors, have also been utilized to evaluate ESG risks, maximize green bond portfolios, and offer tailored investment advice according to sustainability preferences [12]. They also counter behavioral biases associated with investment decisions, promoting green bonds not only as an ethical financial product but also a financial one to render them attractive [13].

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In spite of these advantages, investor trust remains a major factor affecting the adoption of robo-advisors for green bond investments. Investors could also have potential biases in their perception and regard for the algorithm as well as possible algorithmic mistakes concerning the sustainability provided by this platform.

2.4. Investor behavior and trust in AI-driven green investments

Several factors may affect trust in robo-advisors. However, concerns about the strength of robo-advisors and the bias of algorithms may be an issue of concern. The sustainability of robo-advisors may affect trust. According to Bennani et al., concerns regarding the reliance of robo-advisors and the bias of algorithms may be an issue of concern.

Investor behavior in sustainable financing is influenced by risk perception, ethical values, and financial performance targets . This is because investors would like to receive a reduced level of economic returns in exchange for other qualities such as sustainability, while there are also other investors who are dubious about the financial viability of green products.

AI-based robo-advisors can also be employed to reduce skepticism through insights regarding the risk-reward profile of green bonds, thus promoting investor confidence towards these funds.

Nevertheless, the major challenge that individuals will face will be the perceived opacity of their use by AI algorithms. This is because research confirms that people have greater trust in their human advisors than in machine advisors such as robos-advisors, especially with regards to complex factors as noted by Au et al., 2021.

To address this trust gap, regulatory frameworks that ensure accountability and transparency in AI-driven investment platforms could strengthen investor confidence and promote the adoption of green bonds .

3. Methodology

3.1. Research design

In this study, a quantitative research method shall be employed to explore its findings regarding robo-advisors and their effects on investment behavior for green bonds, including trust and investment attitude. This study shall provide insights into how robo-advisor attributes (transparency, reliability, and frequency of usage) can enhance investment trust in automated systems, and how this trust can lead to a positive investment attitude towards green bonds. These aspects can be deemed to have influential roles in determining investment decisions for sustainability.

3.2. Data collection

The data were gathered using an online questionnaire , which was sent via investment-related social media platforms, university finance communities, and online investor forums. Four hundred valid responses were returned by individual investors aged 18 years and above, from both novice and experienced investors. This measurement adopted established Likert-scale items that respectively assess perception about robo-advisors, trust, attitude towards investment, and the behavior or intention to invest in green bonds.

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3.3. Data analysis

After completing data cleaning and processing tasks, the number of effective samples for conducting a regression analysis became 70 due to the absence of information in critical investment factors. Descriptive statistical analysis was performed to determine the demographics and important variables used in the study. Reliability analysis and factor analysis were performed to confirm the internal consistency and sampling adequacy of constructs used in the study related to robo-advisors. Correlation analysis was performed to identify the relationship among the characteristics of robo-advisors and investment behavior. Multicollinearity tests (VIF test) were performed to confirm the absence of significant multicollinearity problems. Multiple regression analysiswas performed to identify the predictors among the characteristics of robo-advisors for green bond investment behavior (proportion and amount). An interaction model analysis, as well as a regression analysis among experienced investors, were also performed.

4. Results

4.1. Descriptive statistics

The sample population was composed of fairly knowledgeable and moderately experienced investors, with an overall mean level of green bond investment of 24.43% and an overall mean amount invested of about 14,602 SGD.

4.2. Reliability and factor analysis

The Cronbach alpha level for measures of trust, awareness, reliability, and transparency is 0.677, suggesting acceptable but low levels of reliability. The KMO measure of 0.634 indicated acceptable levels of full sample appropriateness for conducting factor analysis. The results for factor loading indicated high values for robo-reliability (-0.981) and robo-transparency (-0.773), and low values for trust and awareness, suggesting that reliability and transparency play pivotal roles in robo-advisor assessments.

4.3. Correlation analysis

The correlation analysis indicated highly positive correlations between the variables of transparency ($r = 0.839$) and reliability (r = substantial) and green bond investment proportion; nonetheless, there were weaker correlations between trust and usage frequency. The investment amount was associated with weaker correlations concerning all characteristics of the robo-advisor.

4.4. Regression results

4.4.1. Investment proportion model

In Model 1, the test to predict the investment proportion, a high degree of explanatory power was achieved (R-squared = 0.857, adjusted R-squared = 0.829). In the test, the significant predictors were the robo-reliability ($\beta = 2.324$, $p = 0.005$) and the robo-transparency ($\beta = 4.102$, $p < 0.001$). The outcome showed that investors who find robo-advisors reliable and transparent choose to invest a large number of their portfolios in green bonds. Additionally, the level of education and investment

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experience were also significantly important demographic controls in the test. Trust, awareness, and usage frequency were not significant in the test.

4.4.2. Investment amount model

Model 2 (modeling the log of investment amount) provided a lower R-squared value of 0.231, and for this model, none of the variables were found to have statistical significance. Only investment experience emerged as a significant predictor, indicating that users have been influenced by their perceptions regarding allocation but not the amount allocated.

4.4.3. Interaction and subgroup analysis

An interaction model for testing the effect of transparency by reliability demonstrated a marginally significant result for the interaction effect ($\beta = 1.035$, $p = 0.061$), indicating that transparency has a significant moderating effect on reliability in influencing users' investment decisions. Subgroup regression analysis on experienced investors ($n = 62$) had an equally high R-squared value of 0.849, further justifying the strength of the models established on experienced investors.

5. Discussion

5.1. Algorithm transparency, trust, and information symmetry

Results indicate a significant but positive impact of algorithm transparency on individual investors' portfolio composition in terms of green bonds. On the other hand, general trust in robo-advisors has no significant impact. Results indicate that trust in robo-advisory systems by investors is based on factors related to information symmetry and transparency in terms of logic and data used in making investment decisions instead of trusting automation per se.

This is in line with other research indicating transparency is an indicator of reduced perceptions of hidden biases associated with algorithms and an increase in the usage of investment advice recommended via algorithms [14] and is an essential aspect of building trust as it reduces ambiguity [15]. In sustainable finance, because of the presence of high complexity in product diversity and information asymmetry, transparency in the context of methodologies and processes is an essential aspect in confirming the Sustainable Financial-related investment recommendation [16]. The present study adds to the above-mentioned literature as it denotes sustainable investment practice as an indicator of belief in the quality of recommendation because of the non-technology-specific process of trust in AI systems [17].

5.2. Improving the matching process in personalized recommendations

Modern-day robo-analytical tools have started using AI/ML capabilities to design specific investment portfolio recommendations according to ESG requirements, risk, and behavioral characteristics to improve their acceptability ; . The importance of personalization in sustainable finance arises as green bonds are affected by boundaries of ethics, tolerance of Loss, and environmental requirements [18].

The empirical evidence confirms this view, as usage frequency and general trusting beliefs have no impact, but investment experience and educational level are highly positively correlated with green bond investment share. This means that more knowledgeable or more educated investors in the stock market are able to effectively process recommendations, suggesting that the effectiveness

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of personalization depends on the ability of the individual, rather than the platform, in processing information.

In the interaction analysis, a complementary relationship is confirmed between transparency and reliability. For instance, the integration of the concept of explanation with that of personalization is important. This is because good personalization among robo-advisors should connect green bond recommendations with the personal criteria of an investor. This would transform transparent information into a recommendation. Strategies would include measuring sustainability preference, preference updates, explanation regarding recommendations, as well as explanation according to the level of investors' experience.

5.3. Environmental-driven versus value-driven motivation: sources of behavioral differences

Investor engagement with green bonds is driven by a desire to uphold environmental values and to perform financially [19,20]. Environmental regulations and disclosures influence trust and willingness to engage with the green bond market by increasing confidence in these disclosures [3].

Findings from the study show that the transparency and reliability of robo-advisors influence investment in portfolio allocation proportion but not the total investment. The weakness in the investment amount model shown by its poor explanatory power indicates that robo-advisors influence investment in capital allocation but not investment ability and intentions. This indicated that robo-advisors increase value-based investment in the portfolio allocation process and enable investors to convert their concerns over the environment into their already fixed investment budgets. Nonetheless, the total investment amount was influenced by income and macroeconomic factors, just like in the previous study, which confirmed that environmental preferences influence investment allocations but not the total investment [20].

An increase in total volume of Green Finance therefore needs additional policies including easing entry barriers, improving liquidity, and offering fiscal incentives.

6. Conclusion

6.1. Contributions

Firstly, the research makes a significant contribution to the existing body of research that investigates the intersection of robo-advisory systems and green bond investments by establishing a solid empirical foundation with regards to the idea that a lack of transparency and unreliable recommendations impact the allocation of investments within a portfolio ($R^2 = 0.857$) on a green bond investment platform. Secondly, the research underlines the importance of explainability within personalization approaches on investment platforms when automation or high utilization intensity rates alone are not enough for a successful adoption rate related to investments.

6.2. Limitations

Several limitations for the research can be identified. Firstly, although a regression sample size ($n = 70$) is relatively large for regression models where sample sizes aren't huge with significant margins for error for robust regression models, it is still a small sample that prevents generalization for different types of financial platforms. Secondly, the research lacks a hypothetical approach with regards to analyzing the various factors for investors that influence the initial entry into a green bond investment market for a broader understanding on the research topic.

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6.3. Practical and policy implications

Robo-advisory platforms should then emphasize symmetrizing the informational asymmetry by disclosing recommendation logics, key weighting variables, data sources, and uncertainty measures of those estimates. The final personalization strategies will include explainability: both "why this investment fits you" and "what environmental impact it delivers".

From a policy perspective, measures like standardized green bond frameworks, tax incentives, and disclosure requirements have been of utmost importance for scaling the green finance market, given that robo-advisors are mainly relevant for portfolio composition, with no direct effect on the volume of investments.

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