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DETERMINANTS OF ESG SUSTAINABILITY IN FINANCIAL SYSTEMS: A FUZZY COGNITIVE APPROACH WITH A FOCUS ON GEORGIA

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Abstract. Sustainable finance has gained momentum over the last several years amid increasing environmental and social challenges. This research seeks to characterise Environmental, Social, and Governance (ESG) sustainability within the financial sector as a novel concept, identifying its core determinants, evaluating and modelling relationships among them, and subsequently analysing various scenarios for enhancing ESG Sustainability. To this end, a fuzzy cognitive map construction and modelling method was employed. Through a multi-stage process, a fuzzy cognitive map of ESG Sustainability was developed using Georgia's financial sector as a case study. The main findings identified ten fundamental factors influencing ESG Sustainability within the financial sector and evaluated the causal relationships among them. According to experts' assessments, the Local Sustainable Finance Regulatory Framework and the Involvement of International Financial Institutions are particularly important among these key fundamental factors. Additionally, the scenario analysis revealed that targeted improvements in the key factors could significantly enhance ESG Sustainability.

Keywords: Sustainability; Responsible Business Practice; Sustainable Finance; Environmental, Social, and Governance (ESG); Sustainability; Fuzzy Cognitive Map

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Additional disciplines: Sustainable Finance, ESG

1. Introduction

Sustainable finance has emerged as a critical area of focus in the financial sector amid the escalating need to address global sustainability challenges. With the intensification of climate change, resource depletion, and social inequities, the financial system must evolve to tackle these issues and support sustainable development objectives.

Climate change, biodiversity loss, and other environmental and social challenges pose significant risks to the economy and financial sector through various channels (Carney, 2015; IPPC 2018; NGFS 2019a; Somogyi & Nagy, 2022; Tvalodze, 2023; Yuan et al., 2023).

These risks can become a source of financial risks leading to financial stability risks, necessitating proper identification, assessment, and management by the financial sector (Bolton et al., 2020; NGFS, 2019a, 2019b, Monasterolo, 2020; BCBS, 2021; Tvalodze & Nikuradze, 2023). At the same time, enormous financial resources are needed to address sustainable development challenges. The financial system, through the mobilisation of financial resources to promote green, stable, and inclusive economic growth, has another crucial role to play in addressing these challenges (OECD, 2024a, 2024b, 2024c; UN, 2024; Cull et al., 2024; Kakulia, 2016). Managing climate and other Environmental, Social, and Governance (ESG) risks and reorienting financial flows to support managing these risks and contributing to a sustainable future is precisely the scope of sustainable finance (Turhan et al, 2023; Dunbar et al., 2024).

The financial sector's role in combating climate change and achieving sustainable development, on the one hand, and managing climate and other ESG risks to ensure financial stability, on the other hand, is undoubtable and internationally recognised. However, what factors determine the financial sector's ability to perform these roles effectively? In other words, what are the key factors determining the sustainability of the financial sector? How are these factors interconnected? What are the effective policies to enhance the sustainability of the financial sector? These are important questions that are not well explored in the sustainable finance literature.

This paper tries to address this research gap by introducing a novel concept of ESG Sustainability and by leveraging the Fuzzy Cognitive Map (FCM) methodology to identify key determinants of ESG sustainability in the financial sector. FCMs offer a robust participatory modelling approach that uses expert knowledge to analyse complex systems. By mapping causal relationships between key ESG determinants, this study provides a comprehensive framework for understanding the dynamics of ESG sustainability. Using Georgia's financial sector as a case study, the research identifies fundamental factors influencing ESG sustainability and evaluates their interdependencies through scenario analysis.

The rest of the paper is organised as follows: Section 2 presents a detailed description of the concept of ESG Sustainability, highlighting its importance and relevance within the sustainable finance sphere. In addition, it provides the methodological foundations, focusing on the FCM approach and its relevance to the study. Section 3 introduces a multi-stage framework for constructing a fuzzy cognitive map for ESG Sustainability and presents the development of the ESG Sustainability FCM for Georgia's financial sector, showcasing the results and key findings derived from the model. Finally, the last section offers conclusions, summarising the insights gained and discussing the implications and areas for future research.

2. ESG Sustainability – concept description and assessment methodology

In accordance with various internationally accepted definitions, sustainable finance involves integrating Environmental, Social, and Governance (ESG) issues into financial decision-making, managing corresponding risks, and redirecting financial flows toward green, inclusive, and sustainable activities. These efforts contribute to long-term economic sustainability and financial stability (EU Commission, 2018; G20, 2018; ICMA, 2020; NBG, 2023).

Despite the importance of these aspects, there are no established methodologies or frameworks for assessing the sustainable state of the financial system that comprehensively address all the above-mentioned components. Moreover, reliable, consistent, and sufficiently long-term data are lacking for a quantitative evaluation of the sustainability characteristics of the financial sector. Consequently, alternative methods are needed for such an assessment.

To address these needs, it is essential to introduce a new concept—ESG Sustainability. Based on the definition of sustainable finance presented, ESG sustainability can be defined as the financial system's ability to integrate ESG factors, manage ESG risks, and channel financial flows toward sustainable activities. Accordingly, ESG sustainability can be represented as follows:

$$ESG\ Sustainability = \varphi(I_1, I_2, I_3, \dots, I_N)$$

where $I_1, I_2, I_3, \dots, I_N$ represent fundamental factors affecting ESG Sustainability. These factors often have interdependencies and causal relationships. ESG Sustainability is a complex system, and to study this system, we need to identify indicators, measure the magnitude of their impacts, and analyse interactions between indicators.

To measure the financial system's sustainability, the framework should encompass all aspects mentioned in the definition. In other words, it should include various indicators to capture sustainable finance flows, ESG integration by financial institutions, management of ESG (including climate-related) risks, and the regulatory framework, as it may have a significant spillover effect on these indicators. With sufficient data availability, time series could be used to measure these different indicators to assess the financial sector's ESG sustainability, identify challenges, and pinpoint areas needing improvement for regulators, policymakers, and financial institutions. However, data availability is a significant challenge, especially in developing countries and emerging markets. Therefore, alternative methods and tools are necessary to assess the ESG Sustainability of the financial sector.

One such method that leverages expert knowledge in the absence of comprehensive data and can be used to analyse complex systems with multiple indicators and feedback mechanisms is Participatory Modeling, particularly Fuzzy Cognitive Maps (FCMs). FCMs, which graphically represent expert knowledge and cognitive processes, are particularly useful for modelling complex systems with various interacting elements. They depict concepts using directed, signed, and weighted arrows to represent causal relationships, forming comprehensive cause-and-effect diagrams (Kosko, 1986; Özesmi & Özesmi, 2004; Jetter & Kok, 2014).

Developing a comprehensive understanding of complex systems like sustainable finance, especially in cases of limited or absent data, requires input from various stakeholders who are part of the system. Leveraging the expert knowledge of stakeholders, which is locally relevant and contextual, can improve understanding of system dynamics and unravel complex system processes (Voinov & Gaddis, 2017; Edwards & Kok, 2021; Lui, & Zainulidin, 2024; Khamisu et al., 2024).

Using FCMs in ESG Sustainability assessments incorporates expert opinions, providing a comprehensive view of the financial system's sustainability dynamics. This approach helps to overcome data limitations, offering valuable insights into system mechanisms and enhancing decision-making in sustainable finance.

3. Building the ESG Sustainability Fuzzy Cognitive Map

Creating an FCM model involves several steps, often tailored to the research objectives and characteristics (Özesmi & Özesmi, 2004; Papageorgiou et al., 2019; Jetter & Kok, 2014; Olazabal et al., 2018). Based on the literature and research objectives, a seven-step framework for building the FCM for ESG Sustainability was developed:

1. **Determination of research objectives** - The primary objective of this research is to assess the sustainability of the financial sector through the ESG lens. This involves identifying the fundamental factors influencing ESG Sustainability, evaluating the relationships between these factors, and building a comprehensive model for scenario analysis.
2. **Selection of FCM construction method** - The construction of the FCM was based on in-depth interviews and structured questionnaires to gather expert evaluations. In particular, an expert assessment form was developed, and interviews were conducted using this form. Using an expert evaluation form simplifies the methodology for respondents and ensures that results are obtained in a consistent format, facilitating consolidation, aggregation, and further analysis.

3. **Selection of target groups and experts** - When assessing the ESG sustainability of the financial sector, it is important to consider it from various perspectives. Different market players, such as financial institutions, investors, and regulators, may have distinct views on the fundamental factors that determine the sustainability of the financial sector, the associated challenges, and potential solutions. Therefore, considering these different perspectives and analysing them both individually and collectively is crucial for developing a holistic view of ESG sustainability in the financial sector. Consequently, it is essential to involve representatives from these different stakeholders in the assessment process.

Accordingly, in the case of Georgia, three target groups were selected for expert assessment:

- financial institutions as entities that implement sustainable finance standards and regulations in practice;
- international financial institutions, as the main providers of green finance resources in Georgia and supporters of ESG standards implementation in the financial sector; and
- the National Bank of Georgia (NBG), as the country's central bank and financial sector regulator, which is responsible for developing and implementing the regulatory framework for sustainable finance in the country.

Specifically, five experts were selected from each target group, and therefore, the construction and modelling of the Fuzzy Cognitive Map of ESG Sustainability were based on the assessments of fifteen experts. The experts from financial institutions were heads of ESG/Sustainability departments, while high-level representatives from international financial institutions specialised in ESG/green finance. The experts from the NBG included heads of departments and divisions, as well as specialists responsible for developing the sustainable finance framework.

After selecting the experts, the first stage involved interviewing them to explain the research objectives, methodology, and the expert assessment form. In the next stage, the assessment form was sent to the experts, and their completed forms were collected.

4. **Receiving individual FCMs and coding into adjacency matrices** - Individual cognitive maps and the corresponding adjacency matrices were collected from fifteen experts through interviews and evaluation forms.
5. **Homogenisation and aggregation of individual FCMs into a social FCM** - After homogenisation, the individual adjacency matrices were aggregated first within each target group and then across all groups, resulting in a social FCM. This aggregated FCM represents the collective knowledge and perspectives of the experts, providing a robust model of ESG Sustainability (see Table 1).

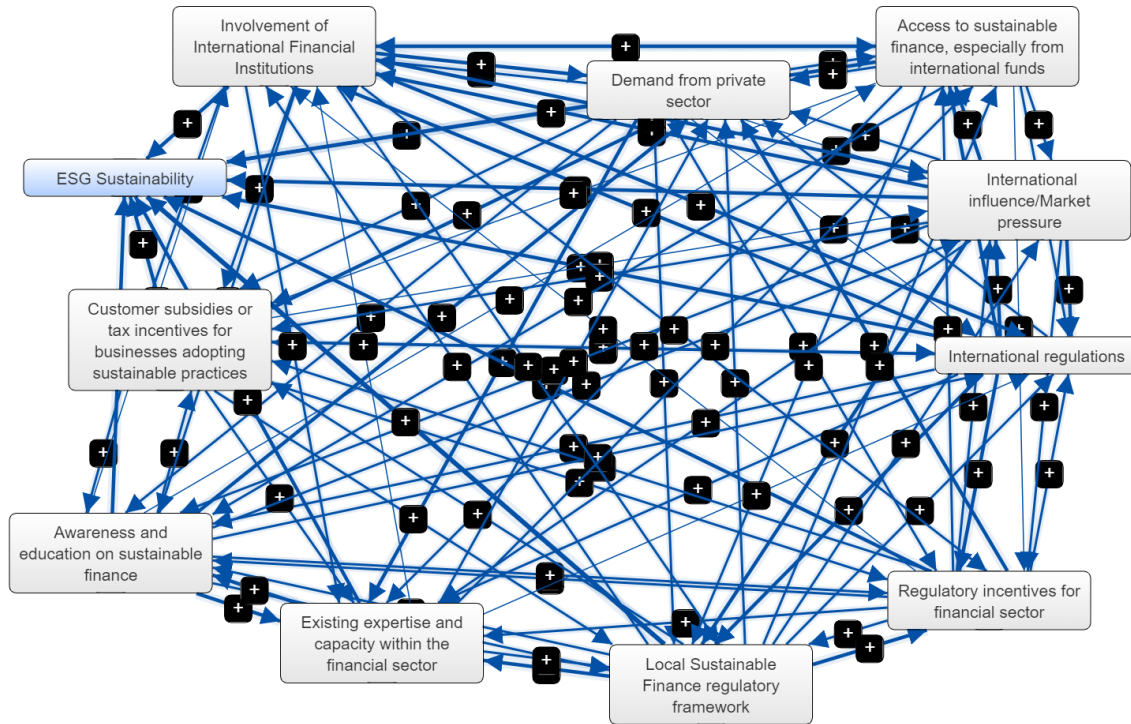


Figure 1. ESG Sustainability Social FCM

Note: Construction of FCMs, coding into adjacency matrices, and evaluation of indicators were done using the MentalModeler program, while RStudio was used to conduct simulations and scenario analysis.

Source: Authors' calculations

Table 1. Adjacency Matrix for ESG Sustainability Social FCM

	Local Sustainable Finance Regulatory Framework	Demand from private sector	Customer subsidies or tax incentives for businesses adopting sustainable practices	Regulatory incentives for financial sector	International regulations	International influence/Market pressure	Awareness and education on sustainable finance	Involvement of international financial institutions	Existing expertise and capacity within the financial sector	Access to sustainable finance, especially from international funds	ESG Sustainability
Local sustainable finance regulatory framework		0.40	0.34	0.63	0.35	0.30	0.45	0.29	0.58	0.42	0.95
Demand from private sector	0.38		0.45	0.33	0.09	0.15	0.47	0.33	0.67	0.25	0.63
Customer subsidies or tax incentives for businesses adopting sustainable practices	0.34	0.82		0.27	0.13	0.11	0.42	0.21	0.25	0.00	0.63
Regulatory incentives for financial sector	0.45	0.55	0.36		0.30	0.18	0.30	0.13	0.17	0.17	0.55
International regulations	0.77	0.40	0.38	0.52		0.67	0.33	0.75	0.33	0.50	0.67
International influence/Market pressure	0.50	0.41	0.33	0.42	0.65		0.38	0.67	0.42	0.50	0.68
Awareness and education on sustainable finance	0.33	0.57	0.37	0.27	0.25	0.20		0.13	0.67	0.08	0.70
Involvement of international financial institutions	0.42	0.50	0.38	0.17	0.63	0.71	0.33		0.67	0.25	0.88
Existing expertise and capacity within the financial sector	0.17	0.33	0.00	0.00	0.08	0.00	0.50	0.08		0.25	0.75
Access to sustainable finance, especially from international funds	0.33	0.33	0.08	0.08	0.17	0.25	0.25	0.38	0.25		0.75
ESG Sustainability											

Source: Authors' calculations

6. **Analysis of the structure of individual and social FCMs using graph theoretical indices** - Key features of the FCMs were evaluated using graph theory (see Table 2). Graph theory indices showed minimal variation between the maps of target groups and the social map, indicating consistent results. It should be noted that no transmitter variables were found in maps, while each map contains only one receiver variable. Since the number of receiver variables exceeds the number of transmitter variables in all types of cognitive maps, this suggests that the causal relationships are well-developed, and the resulting maps are complex. This is indicated by the highest complexity score in the target groups' FCM and the social FCM. According to the results, most indicators in all types of cognitive maps are ordinary variables.

The number of connections per indicator in the target groups' maps is, on average, 7 ± 0.7 S.D., while in the social map, it is 8.7. As for the density measure, it is similar across all types of maps, with an average of 0.8. The high density indicates a large number of causal connections between variables. Since this measure is similar across different types of maps, it suggests compatibility of results among the target groups.

Table 2. Graph Theory Indices for FCMs

	Social	Target Groups		
		Financial Sector Regulator	Financial Sector	International Financial Institutions
Total Components	11	11	10	9
Total Connections	96	89	73	60
Density	0.87	0.81	0.81	0.83
Connections per Component	8.73	8.09	7.30	6.67
Number of Driver Components	0	0	0	0
Number of Receiver Components	1	1	1	1
Number of Ordinary Components	10	10	9	8
Complexity Score	Highest	Highest	Highest	Highest

Source: Authors' calculations

7. **FCM Inference** - The inference process involved analysing experts' assessments and FCMs to identify fundamental factors and their relationships. The first stage of expert evaluation included identifying key fundamental factors of ESG Sustainability. Experts assigned a value between 0 and 1 to each indicator of ESG Sustainability in the financial sector.

Table 3. ESG Sustainability Core Determinants

	Core Concepts/Indicators	Experts' Initial Assessment	FCM Inference		
			Indegree	Outdegree	Centrality
C1	Local sustainable finance regulatory framework	0.95	3.69	4.71	8.40
C2	Involvement of international financial institutions	0.88	2.97	5.05	8.02
C3	Existing expertise and capacity within the financial sector	0.75	3.75	2.16	5.91
C4	Access to sustainable finance, especially from international funds	0.75	2.92	2.95	5.87
C5	Awareness and education on sustainable finance	0.70	3.43	3.57	7.00
C6	International influence/Market pressure	0.68	2.57	4.96	7.53
C7	International regulations	0.67	2.65	5.32	7.97
C8	Demand from private sector	0.63	4.31	3.75	8.06
C9	Customer subsidies or tax incentives for businesses adopting sustainable practices	0.63	2.69	3.18	5.87
C10	Regulatory incentives for financial sector	0.55	2.69	3.16	5.85
C11	ESG Sustainability		7.14	0.00	7.14

Source: Authors' calculations

From fifteen expert assessments, ten main fundamental factors determining ESG Sustainability in the financial sector were identified (see Figure 2; Table 3). Analysis of the expert assessments revealed that, at the social/aggregated level, the most significant indicator among the fundamental factors determining ESG sustainability in the financial sector is the local regulatory framework for sustainable finance (see Table 3). The second most important factor is the involvement of international financial institutions. Expertise and capacity within the financial sector, along with access to sustainable finance—particularly from international funds—are equally ranked in the third place. The lowest rating was given to regulatory incentives for the financial sector.

It should be noted that the assessment of the fundamental factors determining ESG sustainability in the financial sector is generally aligned across different target groups, although there are some differences. Notably, the most significant factors are similar among the target groups, which indicates the reliability of the aggregated results.

It is also worth mentioning that while subsidies or tax incentives for consumers in green/sustainable areas, as well as regulatory incentives for the financial sector, are considered relatively important factors by the financial sector target group, these factors received the lowest ratings from the target groups of financial sector regulators and international financial institutions. Nonetheless, the overall consistency in the assessment of fundamental factors across target groups indicates the validity and reliability of the aggregated results.

Certain indices from graph theory can be used to identify the most important concepts in the model based on specific characteristics. Three such indices, which are based on connection weights, include Indegree (weight of incoming connections), Outdegree (weight of outgoing connections), and Centrality. The first two indicate whether a concept is more of a transmitter (influential) or a receiver (dependent), while centrality shows the relative importance of a concept within the FCM structure (see Table 3).

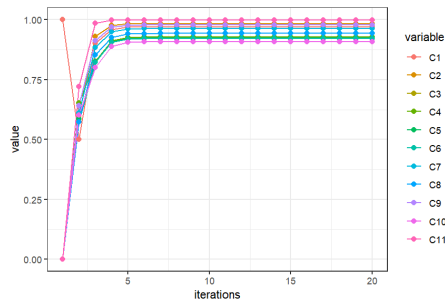
In the case of the social cognitive map, the highest centrality was observed for the local regulatory framework for sustainable finance, demand from the private sector, and the involvement of international financial institutions. Similar results are found for the target group of the financial sector regulator, while for the financial sector target group, international regulations hold the top position.

In the case of the target group of international financial institutions, awareness and education about sustainable finance are the most central. However, it should be noted that the local regulatory framework for sustainable finance is among the three most important concepts across all target groups.

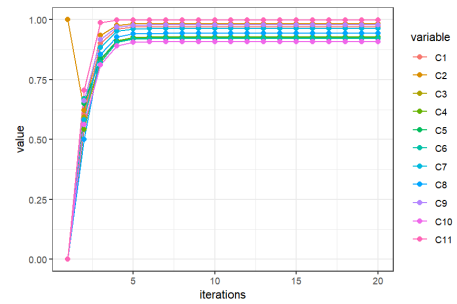
Overall, the graph theory indices showed only slight variation both among the target group maps and between these maps and the social map. This indicates compatibility and robustness of the results across different types of maps. The results also demonstrated that the experts' initial assessments align with the FCM inference determined by the Centrality indicator.

Scenario analysis, another part of FCM inference, simulated the impact of changes in each fundamental factor on ESG Sustainability. FCM-based simulations were used to understand the behaviour of concepts and their interconnections more deeply. The scenario results, using the Kosko inference function and Sigmoid transformation function (Dikopoulou et al., 2018), are presented in Figure 2.

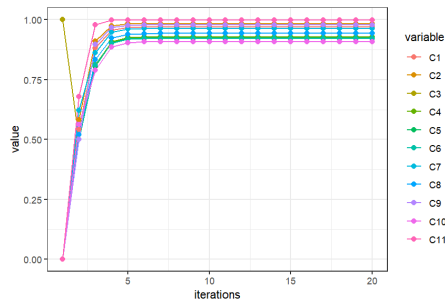
C1=1



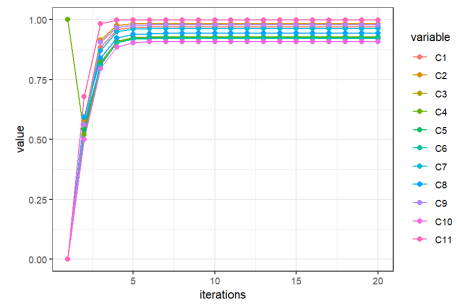
C2=1



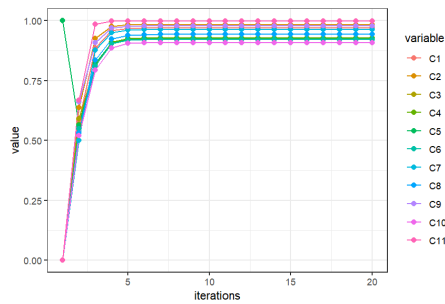
C3=1



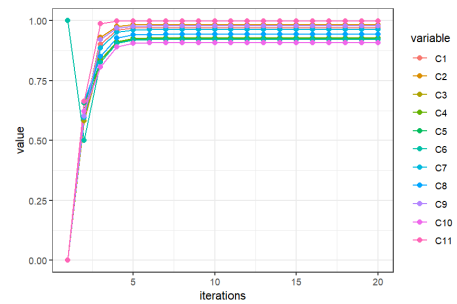
C4=1



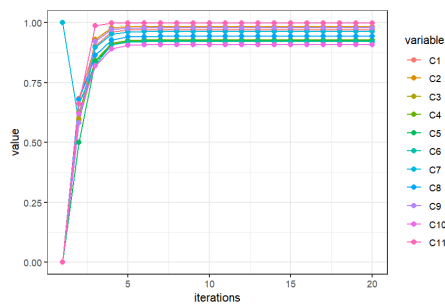
C5=1



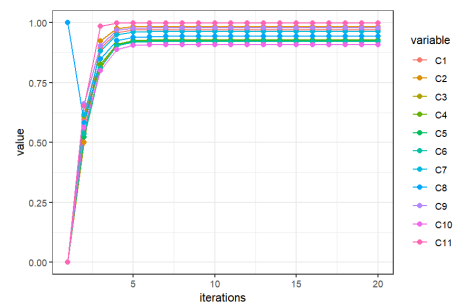
C6=1



C7=1



C8=1



C9=1

C10=1

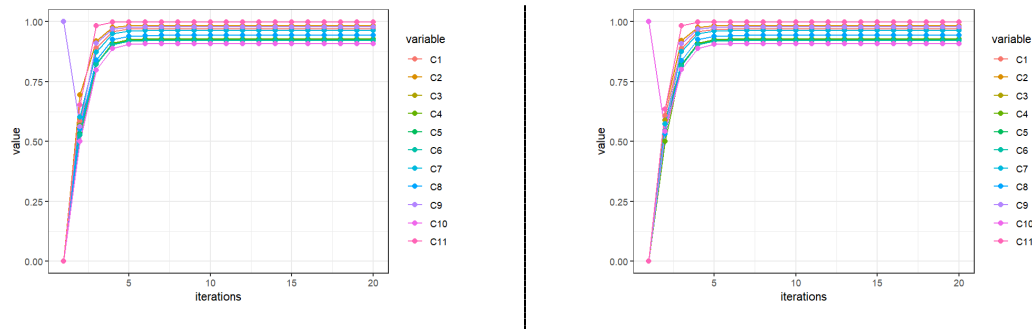


Figure 2. FCM-Based Simulations/Scenario Analysis

Source: Authors' calculations

This analysis provided insights into potential outcomes of different policy actions, helping to identify the most effective strategies for enhancing ESG Sustainability. The results indicate that growth and improvement in core factors materially impact the financial sector's ESG Sustainability, with changes in each factor positively influencing others.

Conclusions

This research contributes to the growing literature on sustainable finance by introducing the novel concept of ESG Sustainability and presenting a structured approach to identify and model its key determinants. Using expert knowledge through Fuzzy Cognitive Maps; the study identified ten fundamental factors that determine the financial sector's ESG sustainability in Georgia. The main findings highlight the significance of the local regulatory framework and the role of international financial institutions, both of which emerged as key drivers of sustainable finance. Additionally, awareness, education, and expertise in sustainable finance, international regulations and demand from private sector turned out to have substantial influence.

The scenario analysis conducted as part of this research demonstrates the potential impact of targeted policy actions on enhancing ESG sustainability. By simulating different scenarios, the research provides a valuable tool for decision-makers to evaluate the effects of interventions. The findings emphasise that a coordinated approach involving both local regulatory measures and international engagement is likely to be most effective in advancing ESG sustainability within the financial sector.

While this study provides valuable insights, there is scope for future research to further refine and expand its findings. Increasing the number of experts for each target group could enhance the robustness and generalizability of the results. Additionally, adding new target groups, such as academia, could provide additional perspectives and enrich the analysis. Expanding the study to cover other countries, particularly those in emerging markets, would help determine whether the results observed in Georgia are consistent across different contexts or whether unique country-specific factors emerge.

Moreover, while this study relied primarily on expert knowledge due to the limited availability of quantitative data, future research could integrate data where available to complement and validate the expert-driven FCM models. Combining qualitative insights with quantitative indicators would provide a more comprehensive understanding of ESG sustainability dynamics.

Overall, the insights gained from this study extend beyond Georgia, offering a framework that can be applied to assess ESG sustainability in other emerging markets. By emphasising the integration of expert knowledge in the limited environment, this research underscores the importance of adaptive, context-specific methodologies in advancing research on sustainable finance. The FCM approach utilised here has proven to be a valuable means of analysing complex interdependencies within the financial system, thus providing a robust basis for informed policy and strategic decision-making in sustainable finance. By addressing the opportunities

for future research, this study lays the groundwork for continued exploration and advancement of ESG sustainability in the financial sector.

References

- Basel Committee on Banking Supervision (BCBS). (2021). *Climate-related risk drivers and their transmission channels*. Retrieved from: www.bis.org/bcbs/publ/d517.pdf
- Bolton, P., Despres, M., Da Silva, L. A. P., Samama, F., & Svartzman, R. (2020). *The Green Swan: Central banking and financial stability in the age of climate change*. BIS Books. Retrieved from: <https://www.bis.org/publ/othp31.pdf>
- Carney, M. (2015). *Breaking the tragedy of the horizon: Climate change and financial stability* [Speech]. Lloyd's of London. Retrieved from: <https://www.bankofengland.co.uk/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability>
- Cull, R., Gill, I., Pedraza, A., Ruiz-Ortega, C., & Zeni, F. (2024). Mobilising private capital for the Sustainable Development Goals (No. 10838). The World Bank. Retrieved from: <https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099515007022422343/idu1c22e2ec41eee514d2d19dfb115b648d7fa6f>
- Dikopoulou, Z., Papageorgiou, E., Jetter, A., & Bochtis, D. (2018). Open source tool in R language to estimate the inference of the Fuzzy Cognitive Map in environmental decision making. 9th International Congress on Environmental Modelling and Software - Ft. Collins, Colorado, USA - June 2018. Retrieved from: <https://scholarsarchive.byu.edu/cgi/viewcontent.cgi?article=4289&context=iemssconference>
- Dunbar, K., Sarkis, J., & Treku, D.N. (2024). FinTech for environmental sustainability: Promises and pitfalls. *One Earth*, 7(1), 23-30. <http://doi.org/10.1016/j.oneear.2023.12.012>
- Edwards, G. I., & Kok, K. (2021). Building a Fuzzy Cognitive Map from stakeholder knowledge: An Episodic, asynchronous approach. *Current Research in Environmental Sustainability*, 3, 100053. <http://doi.org/10.1016/j.crsust.2021.100053>
- EU Commission. (2018). *Action Plan: Financing Sustainable Growth*. Retrieved from: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0097>
- G20 Sustainable Finance Study Group. (2018). *Sustainable Finance Synthesis Report*. Retrieved from: https://unepinquiry.org/wp-content/uploads/2018/11/G20_Sustainable_Finance_Synthesis_Report_2018.pdf
- International Capital Market Association (ICMA). (2020). *Sustainable Finance High-Level Definitions*. Retrieved from: <https://www.icmagroup.org/assets/documents/Regulatory/Green-Bonds/Sustainable-Finance-High-Level-Definitions-May-2020-051020.pdf>
- Intergovernmental Panel on Climate Change (IPCC). (2018). *Global Warming of 1.5°C: Summary for policymakers*. Retrieved from: <https://www.ipcc.ch/sr15/chapter/spm/>
- Jetter, A. J., & Kok, K. (2014). Fuzzy cognitive maps for futures studies—a methodological assessment of concepts and methods. *Futures*, 61, 45-57. <http://doi.org/10.1016/j.futures.2014.05.002>
- Kakulia, N. (2017). *The Characteristics of Transformation of Institutional Changes and Georgia*. World academy of science, engineering and technology, conference proceedings. Berlin, Germany. <https://www.gotriple.eu/documents/ftzenodo%3Aoi%3Azenodo.org%3A1130235>
- Khamisu, M.S., Paluri, R.A., & Sonwaney, V. (2024). Stakeholders' perspectives on critical success factors for environmental social and governance (ESG) implementation. *Journal of Environmental Management*, 365, 121583. <http://doi.org/10.1016/j.jenvman.2024.121583>
- Kosko, B. (1986). Fuzzy cognitive maps. *International Journal of Man-Machine Studies*, 1, 65-75. [http://doi.org/10.1016/S0020-7373\(86\)80040-2](http://doi.org/10.1016/S0020-7373(86)80040-2)
- Lui, T.K., & Zainulidin, M.H. (2024). From boardroom to sustainability reporting: stakeholder-RBV insights into ESG disclosures among Malaysian banks. *Bottom Line* <http://doi.org/10.1108/BL-04-2024-0046>
- Monasterolo, I. (2020). Climate change and the financial system. *Annual Review of Resource Economics*, 12(1), 299-320. <https://doi.org/10.1146/annurev-resource-110119-031134>

National Bank of Georgia. (2023). *ESG Guidelines through double materiality perspective*. Retrieved from: www.nbg.gov.ge/en/page/esg-guidelines

Network for Greening the Financial System (NGFS). (2019a). *A call for action: Climate change as a source of financial risk*. Retrieved from: https://www.ngfs.net/sites/default/files/medias/documents/ngfs_first_comprehensive_report_-_17042019_0.pdf

Network for Greening the Financial System (NGFS). (2019b). *Macroeconomic and financial stability: Implications of climate change*. Retrieved from: https://www.ngfs.net/sites/default/files/medias/documents/ngfs-report-technical-supplement_final_v2.pdf

Organisation for Economic Co-operation and Development (OECD). (2024a). *OECD review on aligning finance with climate goals*. Retrieved from: https://www.oecd.org/en/publications/oecd-review-on-aligning-finance-with-climate-goals_b9b7ce49-en.html

Organisation for Economic Co-operation and Development (OECD). (2024b). *Towards assessing the alignment of finance with climate resilience goals*. Retrieved from: <https://www.oecd.org/en/publications/towards-assessing-the-alignment-of-finance-with-climate-resilience-goals9446d65e-en.html>

Organisation for Economic Co-operation and Development (OECD). (2024c). *The new collective quantified goal on climate finance*. Retrieved from: https://www.oecd-ilibrary.org/environment/the-new-collective-quantified-goal-on-climate-finance_7b28309b-en

Olazabal, M., Chiabai, A., Foudi, S., & Neumann, M. B. (2018). Emergence of new knowledge for climate change adaptation. *Environmental Science & Policy*, 83, 46-53. <http://doi.org/10.1016/j.envsci.2018.01.017>

Özesmi, U., & Özesmi, S. L. (2004). Ecological models based on people's knowledge: a multi-step fuzzy cognitive mapping approach. *Ecological Modelling*, 176, 43-64. <http://doi.org/10.1016/j.ecolmodel.2003.10.027>

Papageorgiou, K., Singh, P. K., Papageorgiou, E., Chudasama, H., Bochtis, D., & Stamoulis, G. (2019). Fuzzy cognitive map-based sustainable socio-economic development planning for rural communities. *Sustainability*, 12(1), 305. <http://doi.org/10.3390/su12010305>

Somogyi, T., & Nagy, R. 2022. Some impacts of global warming on critical infrastructure protection - heat waves and the European financial sector. *Insights into Regional Development*, 4(4), 11-20. [https://doi.org/10.9770/ird.2022.4.4\(1\)](https://doi.org/10.9770/ird.2022.4.4(1))

Turhan, G.T., Tokal, P., & Sart, G (2023). The Role of Financial Sector Development and Educational Attainment in the Achievement of Economic Sustainability: Evidence from BRICS Economies. *Sustainability*, 15(6), Article Number 5527 <http://doi.org/10.3390/su15065527>

Tvalodze, S. (2023). Transmission Channels of Sustainability-related Financial Risks; VIII International Scientific Conference "Challenges of Globalization in Economics and Business", Tbilisi State University, 3 November, 2023. <https://tsu.ge/assets/media/files/7/Globalizacia%20ekonomikisa%20da%20biznesshi%20-%208.pdf>

Tvalodze, S., Nikuradze, E. (2023). Biodiversity-related Financial Risks – Why it matters and how can we measure them? Case study of Georgia, National Bank of Georgia (NBG) WP 02/2023. Retrieved from: <https://nbg.gov.ge/fm/wp/nbg-wp-2023-02.pdf?v=vcy6j>

United Nations (UN). (2024). *The 2024 Financing for Sustainable Development Report (FSDR 2024)*. Retrieved from: <https://desapublications.un.org/publications/financing-sustainable-development-report-2024>

Yuan, X.H., Murshed, M., & Khan, S. (2023). Does the depth of the Financial Markets matter for establishing Green Growth? Assessing Financial sector's potency in decoupling Economic Growth and Environmental Pollution. *Evaluation Review*, 47(6), 1135-1167. <https://doi.org/10.1177/0193841X221145777>

Voinov, A., & Gaddis, E.B. (2017). Values in Participatory Modeling: Theory and Practice. In: Gray, S., Paolisso, M., Jordan, R., Gray, S. (eds) *Environmental Modeling with Stakeholders*. Springer, Cham. https://doi.org/10.1007/978-3-319-25053-3_3

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