Green Competitiveness Forecasting as an Instrument for Sustainable Business Transformation

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Abstract

Modern conditions for transforming the business environment in the context of implementing sustainable development goals, decarbonising the economy, and ensuring climate neutrality determine the need to implement effective measures at the level of individual enterprises. External challenges determine the urgency of strengthening enterprises' green competitive advantages and forming an integral level of green competitiveness. The paper offers a methodological basis for the long-term forecasting of enterprises' green competitiveness levels. The key object of the research is a set of companies representing the machine building, agriculture, and food industries, as strategic branches of Ukraine's economy. The period of 2020–2028 was chosen as the interval for foresight. The application of autoregressive integrated ARIMA modelling by means of the non-linear least squares method made it possible to determine transformation vectors, marketing determinants, and target orientations for increasing the integral level of green competitiveness. The assessment of the results showed that the leading enterprises in the optimistic scenario are PJSC "SVF Agrotron" (agro-industrial complex), where the predictive value of green competitiveness is 0.84; PJSC "Wimm-Bill-Dunn Ukraine" (food industry), for which the predictive value is 0.73; and PJSC "Motor Sich" (mechanical engineering), for which the predictive value of green competitiveness is 0.74. The results of the evaluation revealed the leading enterprises according to the optimistic scenario for the

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agro-industrial complex, food industry, and mechanical engineering. The research substantiates the claim that the priorities of the strategy for increasing the level of green competitiveness and the relevant determinants of its implementation should be determined considering the transformation scenarios of its level.

Key words
sustainable development, green competitiveness, forecasting, transformation.

Introduction

The approved Sustainable Development Goals 2030 underscore the critical need for companies to transform their management technologies based on green economy principles. As competition intensifies across sectors, developing green competitive advantages becomes essential for enterprises aiming to boost their overall green competitiveness (Brych et al., 2021; Chen et al., 2023; Gavkalova et al., 2022a). The convergence and complementary effects generated during the formation of these green competitive advantages play pivotal roles in ensuring the sustainable development of enterprises. They enable expansion in competitive positions in both domestic and global markets, enhancing investment attractiveness and capitalisation (Hussain et al., 2021; Kwilinski et al., 2024; Szczepańska-Woszczyna et al., 2022). Moreover, the management of green competitiveness should extend beyond merely analysing past and current indicators. A deep understanding of the competitive environment, including its distinct features and the systems and processes within it, is crucial. This comprehensive awareness aids companies in making informed strategic decisions that foster sustainable competitive advantages (Kwilinski, 2023; Letunovska et al., 2022; Vaníčková et al., 2020). Forecasting within the business environment is particularly valuable as it allows for the simulation of various scenarios, helping evaluate decisions and changes aimed at strengthening green competitive advantages. The effective forecasting of green competitiveness is instrumental in identifying priority areas for market analysis, planning the development of new green products and services, and making strategic decisions about ecological renovations (Dacko-Pikiewicz, 2019; Hakhverdyan et al., 2022; Kwilinski et al., 2023a; Korobets et al., 2020). It also supports the formation of a green brand and the greening of overall company activities. Such forecasting serves as a foundation for strategic decision-making, ensuring that companies not only adapt to but also anticipate changes in market demands and environmental regulations, thereby securing a competitive edge in the increasingly green-focused global market (Vysochyna et al., 2022; Yermachenko et al., 2023).

This study aims to forecast the green competitiveness of Ukrainian enterprises within the machine-building, agriculture, and food industries, which are strategic sectors of Ukraine's economy. The paper addresses a gap in the theoretical landscape of green competitiveness theory with a developed approach that employs the ARIMA model for forecasting green competitiveness.

The paper has the following structure: the literature review section delves into existing research, exploring definitions, components, and previous models of green competitiveness, particularly focusing on forecasting models used in sustainability. This section also identifies gaps in the current literature that this paper aims to address. The methodology section describes the research design and approach, detailing the data sources, analytical tools, and software used for forecasting green competitiveness; the research results section presents the findings, utilising various statistical displays such as tables and graphs to clarify the data; the discussion section explores how the results are interpreted in light of the reviewed literature, exploring how they connect with established theories and what implications they hold for businesses focusing on sustainability; and the conclusions section summarises the key findings and their theoretical and practical implications, while recommendations for businesses and suggestions for future research areas are also provided, acknowledging the study's limitations.

1. Literature review

The analysis of publications indicates that scientists use many approaches and methods for modelling sustainable development processes, depending on various research tasks. The relevance of forecasting is confirmed by its sustainable implementation in the business practices of developed countries (Munim et al., 2022; Oh et al., 2023; Drożdż, 2019). Forecasting is one of the most essential approaches in regulating the economy, understanding development prospects, and making informed decisions in the USA. The review of scholars' latest scientific papers devoted to evaluating and forecasting indicators of sustainable development and the functioning of the circular economy made it possible to distinguish the following key areas of research activity: forecasting the impact of digital technologies on the formation of the sustainable energy industry, assessing the impact of the smart grids and artificial intelligence using for the decarbonisation of the economy, and forecasting the dynamics of CO2 emissions and the implementation of alternative energy technologies and approaches (Khalatur et al., 2022; Kolosok et al., 2022, Kwilinski et al., 2024).

The authors (Bagherian et al., 2024; Makieła et al., 2023), using the DEMATEL approach and the MICMAC methodology, investigate the potential impact of digital technologies on the energy sustainability of the European energy sector. Within the framework of the study, the future transformations of the energy market are analysed and the influence of smart production technologies on ensuring the energy sustainability of countries is predicted. Forecasting the demand and supply of electricity, J. -H. Syu et al., (2024) and Tkachenko et al. (2019) outline that greenhouse gas emissions are a problem for humanity, especially from the point of view of electricity consumption. To solve the problem, they propose developing a smart grid and implementing an artificial intelligence-based electricity management concept that includes forecasting, anomaly detection, management, and market equalisation. Hoxha et al., (2023) and Gavkalova et al., (2022b) analyse the functioning of the transport industry in the context of energy consumption. Using the ensemble stacking machine learning method, the authors forecast the demand for energy resources in Turkey's transport industry. Hoxha et al., (2023) emphasises the importance of predicting fuel demand as a basis for ensuring the sustainable development of urban transport. Cui et al. (2023) highlights that long-term forecasting of the dynamics of carbon emissions is important for managing the national macro-economy and reducing environmental pollution. Implementing the SARIMA methodology allows clustering countries according to CO2 emission. Utkucan Şahin & Chen (2023) emphasise that forecasting greenhouse gas emissions plays an essential role in planning the development of the energy industry. Utkucan Şahin & Chen (2023) propose to apply the optimised fractional nonlinear grey Bernoulli model to study the impact of Covid-19 on CO2 emissions from fossil fuels in the USA. Utkucan Şahin & Chen (2023) concluded that COVID-19 caused CO2 emissions from coal, natural gas, oil and total CO2 to decrease by 2%, 2%, 16% and 12% respectively in 2020. Rossi & Candio (2023) concluded the importance of informing stakeholders about the company's activities and plans for implementing sustainable development goals. Rossi & Candio (2023) note that the indicator of the environmental component has a positive effect on the forecast error, regardless of other controls, including social and managerial components. Guo et al. (2023) note that forecasting CO2 emissions in regions is quite essential. Using the STIRPAT model, the authors predicted the trajectories of carbon emissions until 2060 in China's power, steel, cement, transport, coal, and chemical industries. The authors emphasise that the forecasting results form the basis for developing regional strategies for ensuring carbon neutrality. At the same time, the studies (Hossin et al., 2023; Oshodi, 2022; Williams, 2022; Ziabina et al., 2022) form integrated political strategies analyses the perspectives of China and the world's access to energy, evaluates energy intensity, the prospects for the development of renewable energy, the volume of greenhouse gas emissions, and private sector investments in the energy sector to achieve the goals of sustainable development. Hossin et al. (2023) highlight that China is making significant progress in achieving the goals of the Paris Agreement, particularly in terms of access to clean solutions in households, private sector investment in energy, renewable energy production and energy efficiency. According to European Union directives, the scientists (Mitrică, 2023; Vysochyna et al., 2022b; Chygryn et al., 2022) notes that developing alternative energy sources in the transport sector is critical due to significant air pollution. The author predicts the economic feasibility of investing in specific sub-sectors of the transport sector to reduce CO2 emissions and atmospheric pollution. At the same time, authors (Ang et al., 2023; Kiselicki et al., 2022; Kwilinski et al., 2023b; Szczepańska-Woszczyna et al., 2023) point out that environmental, social and governance aspects play a significant role in implementing sustainable development globally. Many transnational corporations use various types of ratings, formed by specialised rating agencies, to assess the system of activity risks (Zhanibek et al., 2022; Ziabina et al., 2020; Wróblewski et al., 2021). However, the corresponding rating process is expensive and time-consuming. Therefore, the authors emphasise the relevance of forecasting for researching dynamic relationships between companies and analysing financial and dynamic network information. Thus, the formation of strategies for ecologically oriented development of enterprises and strengthening their green competitive advantages necessitates the construction of scenarios for transforming green competitiveness. Despite the powerful scientific experience of using forecasting to solve the problems of sustainable development, there is no scientific toolkit for forecasting the indicator of green competitiveness. This research fills the scientific gap regarding forming business sector transformation scenarios by forecasting green competitiveness based on autoregressive integrated moving averages (the Box-Jenkins model).

2. Methodology

Based on previous research (Yang et al., 2021) that advocates the significance of developing companies' green competitiveness as a dominant of sustainable development principles implementation, the present paper attempts to create scenarios for companies' green competitiveness (CGC) transformation. The basis of the developed approach is the ARIMA autoregressive integrated modelling toolkit by the nonlinear least squares method. The ARIMA model (autoregressive integrated moving average or the Box-Jenkins model) is a more modern and convenient time series modelling technology that combines time series and elements of regression modelling in its structure. The specified modelling method is more relevant for forecasting socio-economic indicators in the long term (the time lag is one year) and evaluating the forecast values of green competitiveness. The ARIMA methodology models trends, cycles, seasonality, and other determinants that affect the determined indicator. It uses a three-stage approach involving the following iterations (Box et al., 1994): model identification, checking the time series for stationarity, estimation of modelling parameters, diagnostic verification of obtained simulation results, and construction of relevant scenarios. To eliminate heteroskedasticity (it is not allowed to evaluate the obtained parameters of the model and carry out the forecasting procedure), the initial series of values of the green competitiveness of enterprises is checked for stationarity. Determining the stationarity of several values of green competitiveness allows, at the first stage of forecasting, to present the general view of the appropriate ARIMA model for forecasting the green competitive advantages of enterprises:

$$d(\mathrm{CGC})_t = \alpha + \beta_1 d(\mathrm{CGC})_{t-1} + \cdots + \beta_p d(\mathrm{CGC})_{t-i} + \delta_t + n_1\delta_{t-1} + \cdots + n_\partial \delta_{t-\partial} \qquad (1)$$

where α – model constant; $\beta_{1,} \dots, \beta_p, n_{1,} \dots, n_q$ – model parameters; $\delta_t \dots \delta_{t-i}$ – white noise model; i – the order of the autoregressive part of the model; ∂ – moving average model order; d (CGC)t – the first difference in the CGC in the t-th period; Prob – probability; R-squared – determination coefficient.

At the next stage, the parameters p and q in the ARIMA model are determined using the Akaike information criterion (AIC) (Portet, 2020):

$$AIC = \ln(\hat{\sigma}^2) + \frac{2(p+q+1)}{n} \quad (2)$$

where $\hat{\sigma}^2$ – expected variance; p – order of autoregressive part of the model; q – moving average model order; n – number of observations.

The object of investigation is Ukrainian companies (PJSC "Motor Sich", PJSC "Wimm-Bill-Dunn Ukraine", PJSC "SVF Agroton") within the machine-building, agriculture, and food industries. The timeframe for analysis is 2001–2019 years. The data for analysis was obtained from the open financial and non-financial reports of the selected companies, internal analytical data. Indicators of green competitiveness, as raw data for forecasting, were calculated in a previous study (Yang et al., 2021). The study applies EViews10 for calculation. The interval for foresight was chosen as 2020–2028 (after 2028, the model is inadequate).

3. Research results

To eliminate heteroskedasticity, enterprises' initial series of green competitiveness values was checked for stationarity by using Akaike criterion. Table 1 presents the empirical results of evaluating the ARIMA model with the minimum value of the Akaike criterion.

Table 1. Empirical results of ARIMA estimation of the model with the minimum value of the Akaike criterion

Companies	Coefficient	Prob	R-squared
PJSC "Motor Sich"			
α	0.0321	0.002	0.46
$d(\text{CGC})_{t-1}$	-0.4086	0.059	
PJSC "Wimm-Bill-Dunn Ukraine"			
α	0.0221	0.007	0.48
$d(\text{CGC})_{t-1}$	-0.4776	0.051	
PJSC "SVF Agroton"			
α	0.0075	0.044	0.46
$d(\text{CGC})_{t-6}$	0.3701	0.028	

Source: calculated by authors

The results of the calculations showed that during forecasting for the long-term period (2020–2028) under a realistic scenario, the highest level of green competitiveness will be: PrJSC "SVF Agrotron" (agro-industrial complex – 0.84); in PJSC "Wimm-Bill-Dann Ukraine" (food industry – 0.73); in PJSC "Motor Sich" (mechanical engineering – 0.74). According to an optimistic scenario, with long-term forecasting, the level of green competitiveness can even reach its maximum value of 1. Their leading positions in the respective industries explain high forecast levels of green competitiveness for the analyzed enterprises. In particular, Agroton is the largest diversified vertically integrated agricultural producer in Eastern Ukraine. The main activity of the "Agroton" group of companies is cultivating, processing, storing, and selling crops such as sunflower and wheat. In addition, the "Agroton" group of companies is engaged in animal husbandry and food production. The company uses an environmentally friendly method of processing No-till, which involves a complete rejection of conventional ploughing. The essence of the technology is that the soil is covered with a layer of mulch, and natural processes enrich it, allowing it to recover naturally. This forms a flat surface, protects the soil from air and water erosion and weeds and creates valuable microflora. PJSC "Wimm-Bill-Dann Ukraine" is also a leader in terms of its products' quality and environmental friendliness. The company implemented a quality and safety management system based on the international standard ISO 9001: 2008 requirements and received a certificate for ISO 22000: 2005. The food safety management system was also certified to comply with the international standard ISO 22000:2005 requirements. Everything ensures high product quality and environmental safety of the production itself.

Figures 1-3 present the foresight results for machine-building, food industry enterprises, and the agricultural sector. The forecasting results are given for three enterprise leaders in these industries. According to a realistic scenario, calculations prove that the forecast value of the integral level of green competitiveness for PJSC "Motor Sich" was 0.74. The pessimistic and optimistic trends in enterprises' green competitiveness dynamics indicate a large gap between them.

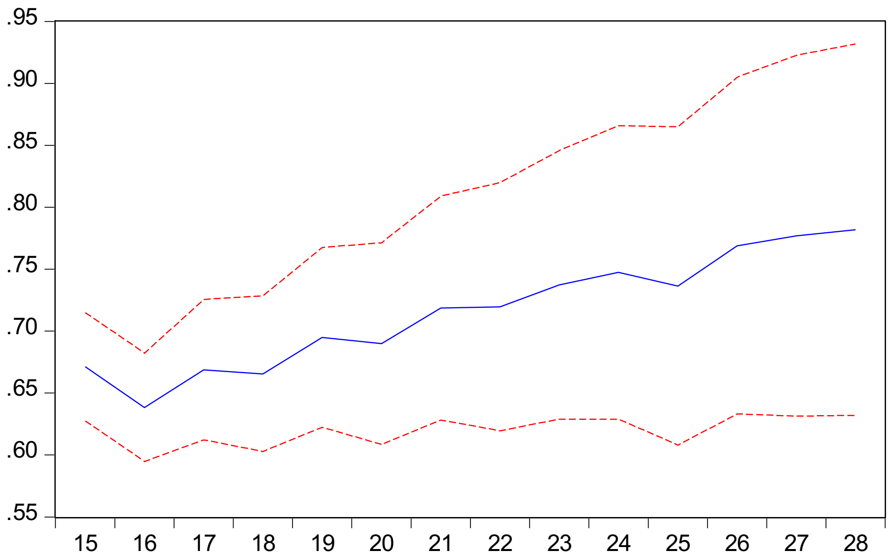

Figure 1. Graphical interpretation of the forecast dynamics of changes in the integral level of green competitiveness of PJSC "Motor Sich."
Source: created by authors

However, even the integral level of green competitiveness under the pessimistic scenario exceeds the level of 0,55, which indicates that its value falls into the interval above the average, and the forecast value under the optimistic scenario will reach almost the maximum level of 0,95. Figure 2 presents the foresight results for the food industry enterprise PJSC "Wimm-Bill-Dann Ukraine" for 2020-2028. The results of the calculations prove that under a realistic scenario for the PJSC "Wimm-Bill-Dann Ukraine" enterprise, the forecast value of the integral level of green competitiveness was 0.73. In turn, implementing the pessimistic scenario will ensure an integral level of green competitiveness of at least 0,50.

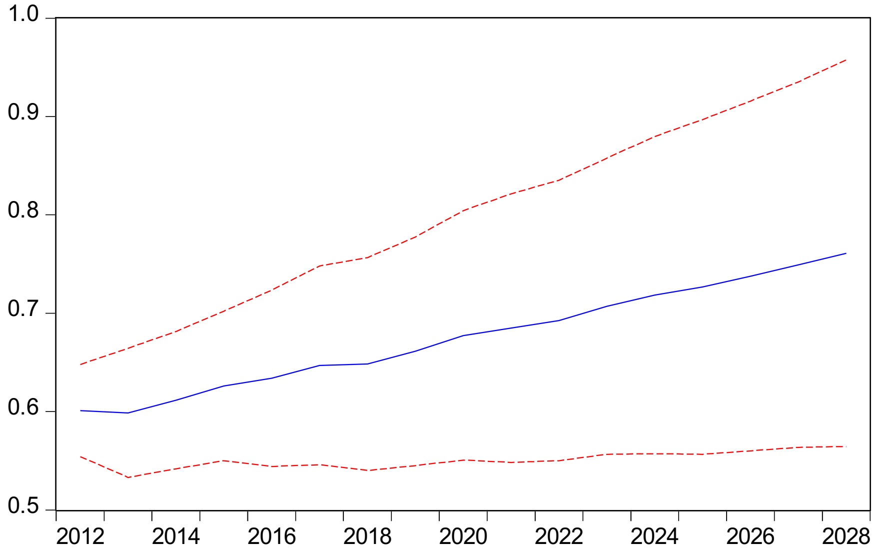

Figure 2. Graphical interpretation of the forecast dynamics of changes in the integral level of green competitiveness of Wimm-Bill-Dann Ukraine PJSC
Source: created by authors

At the same time, under the optimistic scenario for PJSC Wimm-Bill-Dann Ukraine, the maximum value of the integral level of green competitiveness will approach 1. Figure 3 presents the foresight results for the agro-industrial complex enterprise PJSC "SVF Agroton" for 2020-2028.

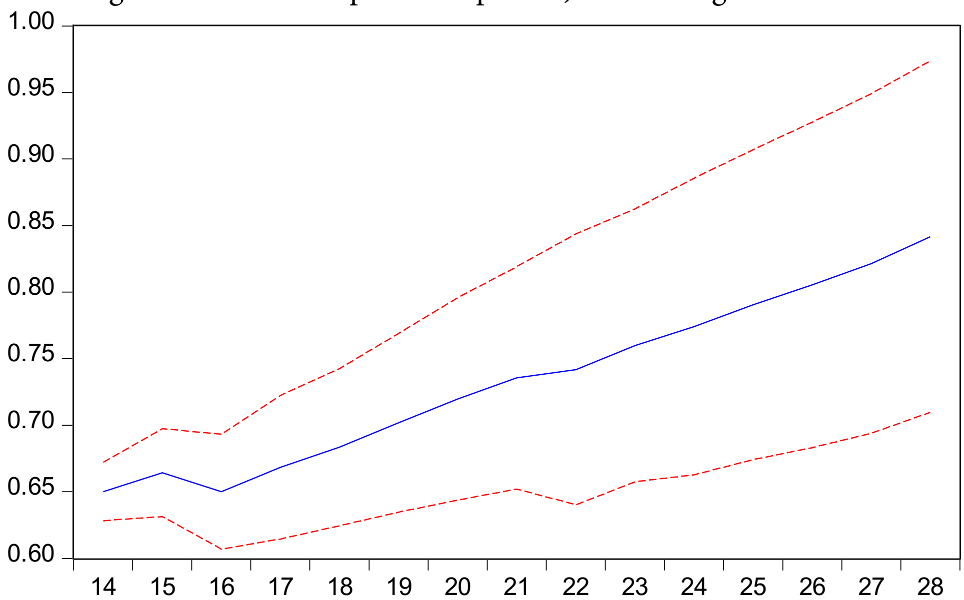

Figure 3. Graphical interpretation of the forecast dynamics of changes in the integral level of green competitiveness of PJSC "SVF Agroton".
Source: created by authors

The calculations show that, under a realistic scenario, the forecast value of the integral level of green competitiveness for PJSC "SVF Agroton" was 0.84. This enterprise is a leader in terms of green competitiveness. At the same time, under the pessimistic scenario, the level of green competitiveness in 2028 will reach 0.68. Implementing the optimistic scenario will provide the maximum predictive value of green competitiveness at 0.98.

4. Discussion

The long-term forecasting of the transformation of the level of green competitiveness was carried out using the ARIMA autoregressive integrated modelling toolkit by the nonlinear least squares method. The calculations made it possible to single out the leading enterprises according to the level of green competitiveness within the framework of an optimistic scenario, the implementation of which will ensure the maximum integrated level of green competitive advantages of enterprises. The result obtained in the paper doesn't contradict the relevant research in the forecasting of social and economic indicators in connection with environmental determinants. Thus, the paper (Liang et al., 2024) uses a combined forecasting model by integrating autoregressive integrated moving averages and reference vector regression models for forecasting carbon emissions at the city level. The authors conclude that the proposed approach ensures high efficiency of the forecasting process. To ensure the decarbonization of the economy, the authors (Verma et al., 2023) emphasize the importance of forecasting atmospheric pollution by PM2.5 emissions in densely populated areas of cities. Using a combination of CATALYST, ARIMA and LSTM models gave the authors high performance in forecasting particulate matter pollution 2.5. However, researchers from China (Zou et al., 2024) use the ARIMA method to forecast research trends in energy transformation and formalize relevant clusters of scientific publications. Scientists (Li & Zhang, 2023) emphasize that using statistical autoregressive integrated moving averages for forecasting the level of carbon dioxide emissions makes it possible to form strategic guidelines for climate change prevention. In particular, understanding the trajectory of CO2 emission changes will justify several environmental policy measures to reduce environmental pollution. In turn, the authors (Srivastava & Jha, 2023; Kwilinski, 2019) apply the methods of forecasting the generation rate of solid household waste, considering indicators of socio-economic development of the regions, to substantiate the prospective directions of waste management policy in India. The application of ARIMA and GM models for forecasting the scale of public consumption and the potential of ecosystems allowed the authors (Liu et al., 2023) to formalize the ecological footprint and assess the sustainability of ecosystems for planning the development needs of regions.

Building green competitive advantages will increase the competitiveness of industries and supply chains, contributing to climate-efficient solutions and promoting green technologies (Tambovceva et al., 2017; Sannikova et al., 2023; Kwilinski et al., 2023c; Rajiani et al., 2020). The development of climate-neutral industries and the formation of their green competitive advantages should be ensured by several systemic strategic measures: implementation of reforms, regulatory acts and initiatives related to climate change and efficient use of resources, stimulation of green investments, and development of energy saving; introduction of environmental standards and green labelling, transformation of the market in the direction of the development of efficient equipment, green technologies and ecological construction; development of financing mechanisms, encouragement of green investments at the enterprise level, use of leasing, creation of energy service companies, etc.

Conclusions

Long-term forecasting of the transformation of enterprises' green competitiveness level involves using the ARIMA autoregressive integrated modelling toolkit by the nonlinear method of least squares. The evaluation results showed that the leading enterprises in the optimistic scenario are PJSC "SVF Agrotron" (agro-industrial complex) – 0.84; PJSC "Wimm-Bill-Dunn Ukraine" (food industry) – 0.73; PJSC "Motor Sich" (mechanical engineering) – 0.74. Implementation of the optimistic scenario will ensure the maximum integrated level of green competitive advantages for enterprises. It is substantiated that the priorities of the strategy for increasing the green competitiveness level and the relevant determinants of its implementation should be determined considering the transformation scenarios of its level. This determined the need to improve the scientific and methodological basis for long-term forecasting of the green competitiveness level. Ensuring the green competitive positions of modern enterprises involves the creation of ecologically oriented strategies for functioning in a competitive environment and ensuring the improvement of production efficiency at the expense of economic, environmental, marketing, social and corporate components of green competitiveness.

To further enhance the green competitiveness of Ukrainian companies, it is imperative for policymakers to foster a supportive regulatory and financial environment that strongly incentivizes sustainable practices. Governmental policies that offer tax incentives, subsidies, or grants specifically designed for investments in green technologies and sustainable practices are essential. Additionally, the establishment of clear sustainability standards and guidelines would assist industries in making a smooth transition toward greener operations. Training programs are also vital and should be developed to equip workers with the skills necessary for implementing and maintaining green technologies effectively. Moreover, collaborations between the government, research institutions, and private sectors are crucial for driving innovation and development in sustainable technologies. By creating innovation hubs or clusters focused on green technologies, there would be an enabled environment for knowledge sharing and co-development of new solutions that are tailored to the specific needs of Ukraine's strategic industries such as machine building, agriculture, and food production. These hubs could serve as incubators for sustainable ideas and practices, providing a platform for start-ups and established companies to innovate and scale up green technologies.

Additionally, enhancing public awareness and consumer education about the benefits of sustainable practices can further drive the market demand for green products, thus encouraging companies to adopt greener methods. The government could support this through public campaigns, educational programs, and incentives for consumers who choose environmentally friendly products. These comprehensive policy measures and collaborative efforts would not only bolster the green competitiveness of Ukrainian enterprises but also significantly contribute to the broader national goal of sustainable economic development. They would help create a robust ecosystem where economic growth and environmental sustainability go hand in hand, ensuring long-term prosperity and ecological balance.

Despite the valuable findings this study has a few limitations which could be overcome in the further investigations. Thus, future research could enhance our understanding of green competitiveness by integrating more flexible predictive models that employ machine learning to better handle nonlinear relationships and interactions among multiple variables. Broadening the study to include a wider variety of industries and comparing green competitiveness across different economic contexts would also be insightful, helping to determine the generalizability of the findings and identify sector-specific challenges and opportunities. Further investigations could examine the specific impacts of various government policies on green competitiveness, analysing which incentives and support mechanisms are most effective in different contexts. Longitudinal studies would be particularly valuable, tracking changes in green competitiveness over time in response to technological and policy shifts, offering a dynamic perspective on sustainable business practices. Additionally, qualitative research exploring the perceptions and experiences of business leaders and policymakers could provide deeper insights into the motivational factors and challenges influencing the adoption of green technologies and practices.

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Reference

1. Ang, G., Guo, Z., Lim, E.-P. (2023). On Predicting ESG Ratings Using Dynamic Company Networks. *ACM Transactions on Management Information Systems*, *14*(3), Article 27. https://doi.org/10.1145/3607874
2. Bagherian, A., Gershon, M., Kumar, S., Mishra, M. K. (2024). Analyzing the relationship between digitalization and energy sustainability: A comprehensive ISM-MICMAC and DEMATEL approach. *Expert Systems with Applications*, *236*, Article 121193. https://doi.org/10.1016/j.eswa.2023.121193
3. Box, G.E.P., Jenkins, G.M., Reinsel, G.C. Time Series Analysis Forecasting and Control, 3rd ed. Englewood Cliffs, NJ: Prentice-Hall, 1994.
4. Brych, V., Zatonatska, T., Dluhopolskyi, O., Borysiak, O., Vakun, O. (2021). Estimating the Efficiency of the Green Energy Services' Marketing Management Based on Segmentation. *Marketing and Management of Innovations*, *3*, 188-198. https://doi.org/10.21272/mmi.2021.3-16.
5. Chen, Y., Lyulyov, O., Pimonenko, T., & Kwilinski, A. (2023). Green development of the country: Role of macroeconomic stability. *Energy & Environment*, *0*. https://doi.org/10.1177/0958305X231151679.
6. Chygryn, O., Kuzior, A., Olefirenko, O., & Uzik, J (2022). Green Brand as a New Pattern of Energy-Efficient Consumption *Marketing and Management of Innovations*, 3, 78-87. https://doi.org/10.21272/mmi.2022.3-07.
7. Cui, T., Shi, Y., Lv, B., Ding, R., Li, X. (2023). Federated learning with SARIMA-based clustering for carbon emission prediction. *Journal of Cleaner Production*, *426*, Article 139069. https://doi.org/10.1016/j.jclepro.2023.139069.
8. Dacko-Pikiewicz, Z. (2019). The Selected Aspects of Strategic Management in the City Divided by the Border in the Context of the Development of the Cross-Border Market of Cultural Services. *Polish Journal of Management Studies, 19*(1), 130-144. https://doi.org/10.17512/pjms.2019.19.1.10.
9. Drożdż, W. (2019). The Development of Electromobility in Poland. *Virtual Economics*, *2*(2), 61–69. https://doi.org/10.34021/ve.2019.02.02(4).
10. Gavkalova, N., Akimova, L., Zilinska, A., Avedyan, L., Akimov, O., & Kyrychenko, Y. (2022a). Efficiency in the context of ensuring sustainable territorial development. *Financial and credit activity problems of theory and practice*, *4*(45), 234-243.
11. Gavkalova, N., Lola, Y., Prokopovych, S., Akimov, O., Smalskys, V., & Akimova, L. (2022b). Innovative Development of Renewable Energy During the Crisis Period and Its Impact on the Environment. *Virtual Economics*, *5*(1), 65–77. https://doi.org/10.34021/ve.2022.05.01(4).
12. Guo, Y.; Hou, Z.; Fang, Y.; Wang, Q.; Huang, L.; Luo, J.; Shi, T.; Sun, W. (2023). Forecasting and Scenario Analysis of Carbon Emissions in Key Industries: A Case Study in Henan Province, China. *Energies*, *16*, Article 7103. https://doi.org/10.3390/ en16207103
13. Hakhverdyan, D., & Shahinyan, M. (2022). Competitiveness, innovation and productivity of the country. *Marketing and Management of Innovations*, *1*, 108-123. https://doi.org/10.21272/mmi.2022.1-08.
14. Hossin, M.A.; Xiong, S.; Alemzero, D.; Abudu, H. (2023). Analyzing the Progress of China and the World in Achieving Sustainable Development Goals 7 and 13. *Sustainability,* 15, Article 14115. https://doi.org/10.3390/ su151914115
15. Hoxha, J., Çodur, M.Y., Mustafaraj, E., Kanj, H., Masri, A.E. (2023). Prediction of transportation energy demand in Türkiye using stacking ensemble models: Methodology and comparative analysis. *Applied Energy*, *350*, Article 121765. https://doi.org/10.1016/j.apenergy.2023.121765.

16. Hussain, H.I., Haseeb, M., Kamarudin, F., Dacko-Pikiewicz, Z., & Szczepańska-Woszczyna, K. (2021). The role of globalization, economic growth and natural resources on the ecological footprint in Thailand: Evidence from nonlinear causal estimations. *Processes*, *9*, Article 1103. https://doi.org/10.3390/pr9071103.
17. Syu, J. H., Lin, J. C. W., & Srivastava, G. (2024). AI-Based Electricity Grid Management for Sustainability, Reliability, and Security. *IEEE Consumer Electronics Magazine, 13(*1), 91-96. https://doi: 10.1109/MCE.2023.3264884.
18. Khalatur, S., & Dubovych, O. (2022). Financial Engineering of Green Finance as an Element of Environmental Innovation Management. *Marketing and Management of Innovations, 1*, 232-246. https://doi.org/10.21272/mmi.2022.1-17.
19. Kiselicki, M., Kirovska, Z., Josimovski, S., & Anastasovski, M. (2022). E-Commerce as a Revenue Generator for Small and Medium Companies in Developing Countries. *Economics and Culture*, *19*(2), 47-56.
20. Kolosok, S., Saher, L., Kovalenko, Y., & Delibasic, M. (2022). Renewable Energy and Energy Innovations: Examining Relationships Using Markov Switching Regression Model. *Marketing and Management of Innovations, 2*, 151-160. https://doi.org/10.21272/mmi.2022.2-14.
21. Korobets, O., Chygryn, O., Saienko, M., & Liulova, L. (2020). Development Evolution of the Environmental Risk Management Theory: A Meta-Analysis. *Virtual Economics*, *3*(4), 169–187. https://doi.org/10.34021/ve.2020.03.04(9).
22. Kwilinski, A. (2019). Implementation of Blockchain Technology in Accounting Sphere. *Academy of Accounting and Financial Studies Journal*, *23*, 1-6.
23. Kwilinski, A. (2023). The Relationship between Sustainable Development and Digital Transformation: Bibliometric Analysis. *Virtual Economics, 6*, 56–69. https://doi.org/10.34021/ve.2023.06.03(4).
24. Kwilinski, A. (2024). Understanding the Nonlinear Effect of Digital Technology Development on CO2 Reduction. *Sustainable Development*, 1-15. https://doi.org/10.1002/sd.2964.
25. Kwilinski, A., Lyulyov, O., & Pimonenko, T. (2023a). Spillover Effects of Green Finance on Attaining Sustainable Development: Spatial Durbin Model. *Computation*, *11*, Article 199. https://doi.org/10.3390/computation11100199.
26. Kwilinski, A., Lyulyov, O., & Pimonenko, T. (2023b). The Role of Country's Green Brand and Digitalization in Enhancing Environmental, Social, and Governance Performance. *Economics and Environment*, *87*(4), Article 613. https://doi.org/10.34659/eis.2023.87.4.613.
27. Kwilinski, A., Lyulyov, O., & Pimonenko, T. (2023c). Unlocking Sustainable Value through Digital Transformation: An Examination of ESG Performance. *Information*, *14*, Article 444. https://doi.org/10.3390/info14080444.
28. Kwilinski, A., Lyulyov, O., & Pimonenko, T. (2024). Reducing Transport Sector CO2 Emissions Patterns: Environmental Technologies and Renewable Energy. *Journal of Open Innovation: Technology, Market, and Complexity*, *10*(1), Article 100217. https://doi.org/10.1016/j.joitmc.2024.100217.
29. Letunovska, N., Abazov, R., & Chen, Y. (2022). Framing a Regional Spatial Development Perspective: The Relation between Health and Regional Performance. *Virtual Economics*, *5*, 87-99. https://doi.org/10.34021/ve.2022.05.04(5).
30. Li, X., & Zhang, X. (2023). A comparative study of statistical and machine learning models on carbon dioxide emissions prediction of China. *Environ Sci Pollut Res, 30*, 117485–117502. https://doi.org/10.1007/s11356-023-30428-5
31. Liang Ye, L., Du, P., Wang, S. (2024). Industrial carbon emission forecasting considering external factors based on linear and machine learning models. *Journal of Cleaner Production*, 434, Article 140010. https://doi.org/10.1016/j.jclepro.2023.140010.
32. Liu, H.; Lin, X.; Wei, J.; Hu, L. (2023). Assessing Environmental Sustainability Based on the Three-Dimensional Emergy Ecological Footprint (3D EEF) Model: A Case Study of Gansu Province, China. *Sustainability,* 15, Article 8007. https://doi.org/10.3390/su15108007

33. Makieła, Z.J., Kinelski, G., Stęchły, J., Raczek, M., Wrana, K., & Michałek, J. (2022). Tools for Network Smart City Management—The Case Study of Potential Possibility of Managing Energy and Associated Emissions in Metropolitan Areas. *Energies,* 15(7), Article 2316. https://doi.org/10.3390/en15072316.
34. Mitrică, E. (2023). Economic analysis of the initial investment for intermediary introduction of compressed natural gas in Romania. *Energy for Sustainable Development*, 76, Article 101270. https://doi.org/10.1016/j.esd.2023.101270.
35. Mucha-Kuś, K., Kinelski, G., Makieła, Z., Stuss, M.M., Raczek, M., Wrana, K., & Borysiak, O. (2023). Cooperation Among Industry And Cities As A Tool For Sustainable Management Of Metropolises. *Polish Journal of Management Studies,* 28(1), 218-239. https://doi.org/10.17512/pjms.2023.28.1.13.
36. Munim, Z. H. Duru, O., Ng, A. K.Y. (2022). Transhipment port's competitiveness forecasting using analytic network process modelling, *Transport Policy*, 124, 70-82. https://doi.org/10.1016/j.tranpol.2021.07.015
37. Oh, H., Lee, J.Y., Jeong, E., Kim, J.Y. (2023). Simulated effects of carbon pricing on industrial sector energy use. *Japan and the World Economy*, 68, Article 101222. https://doi.org/10.1016/j.japwor.2023.101222.
38. Oshodi, A. F. (2022). Backward integration policy and manufacturing firms value added in Nigeria. *Economics and Culture*, *19*(1), 5-16.
39. Portet, S. (2020). A primer on model selection using the Akaike Information Criterion. *Infectious Disease Modelling*, 5, 111–128.
40. Rajiani, I., & Kot, S. (2020). Javanese Indonesia: Human Resource Management Issues in a Uniquely Collectivist Culture. *Cultural Management: Science and Education*, *4*(2), 9-21. https://doi.org/10.30819/cmse.4-2.01.
41. Rossi, P., Candio, P. (2023). The independent and moderating role of choice of non-financial reporting format on forecast accuracy and ESG disclosure. *Journal of Environmental Management*, *345*, Article 118891. https://doi.org/10.1016/j.jenvman.2023.118891.
42. Sannikova, A., Vevere, V., & Titko, J. (2023). Competences necessary for a social entrepreneur: a case study of Latvia. *Business: Theory and Practice*, *24*(2), 604-612.
43. Senaratne, M., Zimbroff, A., & Stevens, J. T. (2021). An instrument to assess Blue Economy entrepreneurship ecosystems: a case study from the Seychelles. *Journal of the Indian Ocean Region*, *17*(2), 205–223. https://doi.org/10.1080/19480881.2021.1969516.
44. Srivastava, A., Jha, P. (2023). A multi-model forecasting approach for solid waste generation by integrating demographic and socioeconomic factors: a case study of Prayagraj, India. *Environmental Monitoring and Assessment*, 195, Article 768. https://doi.org/10.1007/s10661-023-11338-y
45. Szczepańska-Woszczyna, K., & Muras, W. (2023). Shareholders and the Long-Term Ability of a Company to Value Creation: The Case of the It Sector. *Polish Journal of Management Studies, 28*(2), 323-348. https://doi.org/10.17512/pjms.2023.28.2.19.
46. Szczepańska-Woszczyna, K., Gedvilaitė, D., Nazarko, J., Stasiukynas, A., Rubina, A. (2022). Assessment of Economic Convergence among Countries in the European Union. *Technological and Economic Development of Economy, 28*, 1572-1588. https://doi.org/10.3846/tede.2022.17518.
47. Tambovceva, T., Titko, J., & Alksne, A. (2017). Corporate social responsibility perceived by Latvian Enterprises. In *Proceedings of the 30th International Business Information Management Association Conference, IBIMA* (pp. 1557-1568).
48. Tkachenko, V., Klymchuk, M., & Ivakhnenko, I. (2019). Scientific prediction of the balanced energy saving development strategy of the construction projects. *Virtual Economics*, *2*(2), 70–84. https://doi.org/10.34021/ve.2019.02.02(5).

49. Utkucan Şahin, U., Chen, Y. (2023). Assessing the current and future effects of Covid-19 on energy related-CO2 emissions in the United States using seasonal fractional grey model. *Energy Strategy Reviews*, 50, Article 101234.https://doi.org/10.1016/j.esr.2023.101234.
50. Vaníčková, R., & Szczepańska-Woszczyna, K. (2020). Innovation of Business and Marketing Plan of Growth Strategy and Competitive Advantage in Exhibition Industry. *Polish Journal of Management Studies, 21*(2), 425-445. https://doi.org/10.17512/pjms.2020.21.2.30.
51. Verma, A., Ranga, V. & Vishwakarma, D.K. (2023). A novel approach for forecasting PM2.5 pollution in Delhi using CATALYST. *Environmental Monitoring and Assessment*, *195*, Article 1457. https://doi.org/10.1007/s10661-023-12020-z
52. Vysochyna, A., Molotok, I., Babenko, V., Merezhko, V., Holynska, O., & Rud, I. (2022a). Impact of municipal financial resilience on sustainable economic development: Case of Ukraine. *Rev. Econ. Financ*, *20*, 662-668.
53. Vysochyna, A., Samusevych, Y., & Reshetniak, Y. (2022b, June). Public Sector Leadership as a Core Prerequisite for National Security Resistance to COVID-19. In *PRIZK International Conference-Novel Insights in the Leadership in Business and Economics After the COVID-19 Pandemic* (pp. 53-66). Cham: Springer Nature Switzerland.
54. Williams, Z. (2022). The Materiality Challenge of ESG Ratings. *Economics and Culture*, *19*(2), 97-108.
55. Wróblewski, Ł., & Lis, M. (2021). Marketing Mix of Cultural Institutions on the Cross-Border Market of a City Divided by a Border – An Analysis and Evaluation. *Polish Journal of Management Studies, 23*(2), 555-572. https://doi.org/10.17512/pjms.2021.23.2.33.
56. Yang, C., Kwilinski, A., Chygryn, O., Lyulyov, O., Pimonenko, T. (2021). The green competitiveness of enterprises: Justifying the quality criteria of digital marketing communication channels. *Sustainability, 13*, Article 13679. https://doi.org/10.3390/su132413679
57. Yermachenko, V., Bondarenko, D., Akimova, L., Karpa, M., Akimov, O., & Kalashnyk, N. (2023). Theory and Practice of Public Management of Smart Infrastructure in the Conditions of the Digital Society'Development: Socio-economic Aspects. *Economic Affairs*, *68*(01), 617-633.
58. Zhanibek, A., Abazov, R., & Khazbulatov, A. (2022). Digital Transformation of a Country's Image: The Case of the Astana International Finance Centre in Kazakhstan. *Virtual Economics*, *5*, 71-94. https://doi.org/10.34021/ve.2022.05.02(4).
59. Ziabina, Y., & Navickas, V (2022). Innovations in Energy Efficiency Management: Role of Public Governance. *Marketing and Management of Innovations, 4,* 218-227. https://doi.org/10.21272/mmi.2022.4-20.
60. Ziabina, Y., & Pimonenko, T. (2020). The Green Deal Policy for Renewable Energy: A Bibliometric Analysis. *Virtual Economics*, *3*(4), 147–168. https://doi.org/10.34021/ve.2020.03.04(8).
61. Zou, T., Guo, P., Li, F., Wu, Q. (2024). Research topic identification and trend prediction of China's energy policy: A combined LDA-ARIMA approach. *Renewable Energy*, *220*, Article 119619. https://doi.org/10.1016/j.renene.2023.119619.