frontiers | Frontiers in Environmental Science

TYPE Opinion
PUBLISHED 12 July 2022
DOI 10.3389/fenvs.2022.953111

OPEN ACCESS

EDITED BY
Bruno Sergi,
Harvard University, United States

REVIEWED BY
Elchin Suleymanov,
Baku Enginering University, Azerbaijan

*CORRESPONDENCE
Yuriy A. Krupnov,
yukrupnov@mail.ru

SPECIALTY SECTION
This article was submitted to Environmental Economics and Management, a section of the journal Frontiers in Environmental Science

RECEIVED 25 May 2022
ACCEPTED 27 June 2022
PUBLISHED 12 July 2022

CITATION
Kukushkina AV, Mursaliev AO, Krupnov YA and Alekseev AN (2022), Environmental competitiveness of the economy: Opportunities for its improvement with the help of AI. *Front. Environ. Sci.* 10:953111. doi: 10.3389/fenvs.2022.953111

Environmental competitiveness of the economy: Opportunities for its improvement with the help of AI

Anna V. Kukushkina[1], Araz O. Mursaliev[1], Yuriy A. Krupnov[2]* and Alexander N. Alekseev[3]

[1]Moscow State Institute of International Relations (University) of the Ministry of Foreign Affairs Russian Federation, Moscow, Russia, [2]Financial University under the Government of the Russian Federation, Moscow, Russia, [3]Plekhanov Russian University of Economics, Moscow, Russia

KEYWORDS

environmental competitiveness of the economy, artificial intelligence (AI), environmental economics and management, sustainable development goals (SDGs), environmental protection

Introduction

The ecological competitiveness of the economy is a new concept that emerged in the era of the Sustainable Development Goals under the influence of the United Nations (UN) global initiative. The ecological competitiveness of the economy is understood, on the one hand, as a set of conditions created to protect the environment (for example, the predominance of responsible production and consumption practices, the predominance of sustainable communities and territories), and on the other hand, the environmental results achieved (for example, the state of the climate, the level of biodiversity, the purity of water and air), as well as the correlation of these results with other economic systems (AlAbri et al., 2022; Del-Aguila-Arcentales et al., 2022; Martínez and Poveda, 2022).

Every year the environmental competitiveness of the economy increasingly determines the attractiveness of economic systems for:

- Living (which is especially important for aging societies, as it forms their potential to overcome demographic crises) (Wu, 2022);
- Work (attracting and retaining highly qualified personnel, including among migrant workers) (Sabbir and Taufique, 2022);
- Investment ("green" finance is gaining popularity around the world) (Awawdeh et al., 2022);
- International foreign economic cooperation (an example is the introduction of a carbon tax for exporters in the European Union) (Owusu Kwateng et al., 2022).

The problem lies in the uncertainty of the prospects for improving the environmental competitiveness of the economy in the era of artificial intelligence (AI). In this article, a scientific search for a solution to the problem is carried out. The hypothesis of this research is that artificial intelligence improves the environmental competitiveness of the

economy. The advanced hypothesis is based on evidence that artificial intelligence (AI) enables automated ("smart") environmental monitoring, promptly identifying and eradicating violations of environmental legislation, presented in works by Asha et al. (2022), Bakirman (2022), Sasaki et al. (2019).

With the accumulation of experience in "smart" monitoring, it is becoming a preventive measure. Fraga-Lamas et al. (2021), Wilson et al. (2022) also point out in their papers that artificial intelligence (AI) can be used for "smart" organization and management of circular production works, automated and highly-accurate sorting of production and consumption waste. As a result, environmental pollution is reduced.

Philip and Kavitha (2022), Yankovskaya et al. (2022) point out in their works that artificial intelligence (AI) allows developing "green" corporate management, providing intelligent support for managerial decision making. For example, through the selection of directions for business development associated with the lowest ecological costs.

As is noted in the work by Guchhait et al. (2021), artificial intelligence (AI) also supports the development of green finance by automatically sorting and selecting the most ecologically responsible investment opportunities. Further, "smart" environmental tax optimization is possible through an automated search for ways to reduce the environmental tax burden of business, which is particularly topical in the context of the introduction of carbon tax.

The article is aimed at determining the prospects and advantages of improving the environmental competitiveness of the economy with the use of artificial intelligence. The article also contains applied economic policy implications.

The potential of artificial intelligence in improving the environmental competitiveness of the economy

Environmental competitiveness is a special component of the competitiveness of the economic and social system, associated with peculiarities of the management of natural resources (Del-Aguila-Arcentales et al., 2022). It shall be understood to mean the ability of the economic system to use natural resources in the most efficient (sustainable, prudent and environmentally friendly) way, avoiding their depletion with a view to creating the most favourable ecosystem for human life, as well as preserving the heritage for future generations (AlAbri et al., 2022; Wang M. et al., 2022).

The Global Sustainable Competitiveness Index: SolAbility (2022) occupies a central place among the indicators of environmental competitiveness of the economy. Therefore, the research in this article is based on this indicator. It provides full and detailed information of the essence of the ecological competitiveness of the economy, highlighting the following components in its structure and calculating separately:

- Natural capital: Favorable natural environment in the economic system (Congjuan et al., 2022);
- Resource Intensity: Resource efficiency of the economy (Wang N. et al., 2022);
- Social capital: Social cohesion in environmental issues (Popkova et al., 2021);
- Intellectual capital: The level of environmental education and the availability of "green" innovations (Popkova et al., 2018);
- Governance: The level of development of "green" infrastructure and the state regulators' commitment to environmental priorities (Mahmoodi and Dahmardeh, 2022).

In the works of Adamova et al. (2021), Asha et al. (2022), Li et al. (2021), Ligozat et al. (2022), Sasaki et al. (2019), it is noted that artificial intelligence (AI) has the greatest potential in increasing the environmental competitiveness of the economy in terms of resource efficiency of the economy (through monitoring of resource consumption and automation of resource conservation), intellectual capital (through the generation of "green" innovations) and government regulation (through increasing transparency, accountability and manageability of environmental economics and management).

Dong and Meng (2021), Rana et al. (2021) point out in their works that artificial intelligence (AI) significantly contributes to improving the overall competitiveness of the economy and, in particular, to improving digital competitiveness. Nevertheless, the contribution to the ecological competitiveness of the economy has not been studied much, so it remains unclear what research gap is being filled in this article.

AI's contribution to ensuring the ecological competitiveness of the economy: An overview of international best practices

This article uses the Global Sustainable Competitiveness Index (SolAbility, 2022), based on five equisignificant indicators of environmental competitiveness, as an empirical research base:

Natural Capital: A specified natural habitat, including the availability of resources and the degree of their depletion;
Social Capital: Health, security, freedom, equality, and life satisfaction that contribute to social advance;
Resource Efficiency: Efficiency of utilization of limited attainable resources;

TABLE 1 The level of artificial intelligence (AI) development and environmental competitiveness of the top 15 economies in the SolAbility rating (2022) in 2021.

	Country	Indicators of environmental competitiveness, points 1–100					Use of big data and analytics, places 1–64
		Natural capital	Resource intensity	Social capital	Intel-lectual capital	Gover-nance	
Empirical data	Sweden	60.2	58.0	62.4	67.9	57.6	10
	Finland	59.8	50.6	62.3	64.3	66.3	16
	Switzerland	55.4	61.8	59.8	62.7	62.2	23
	Denmark	53.2	56.4	60.4	66.8	64.0	13
	Norway	62.5	48.9	63.5	64.4	59.9	9
	Iceland	65.2	43.0	64.1	62.5	64.1	20
	Irish	51.4	57.7	55.8	51.2	71.7	30
	France	54.2	57.3	55.4	58.7	58.3	52
	Austria	49.1	50.3	60.7	58.7	64.0	27
	Germany	46.2	52.3	56.1	63.2	65.0	53
	Estonia	48.1	43.8	60.4	54.9	73.2	34
	Japan	40.6	47.7	58.2	65.3	64.7	63
	Croatia	61.4	47.0	54.5	49.1	63.6	61
	New Zealand	60.2	47.2	56.0	46.9	64.4	33
	Portugal	49.5	48.6	59.4	55.5	60.9	58
Regression statistics of dependence on the use of big data and analytics	Constant	61.06	53.74	63.22	64.27	63.65	—
	Regression coefficient	−0.20	−0.07	−0.12	−0.14	0.01	—
	Significance of F	0.037*	0.386	0.0002**	0.122	0.869	—
	Correlation	0.5404	0.2412	0.7275	0.4173	0.0465	—

Significance level (α): * 0.05; **0.01. Source: Composed by the authors based on materials of IMD Business School (2022), SolAbility (2022).

Intellectual Capital: The ability to create wealth and jobs through innovations and value creation by economic sectors in open (free, global) markets.

Governance Performance: The framework for sustainable development and social well-being, achieved through the equitable distribution of resources, infrastructure, regulation of markets and employment.

To test the hypothesis put forward in the article, the influence of use of big data and analytics [as an artificial intelligence (AI) indicator] is determined according to the assessment of IMD Business School (2022) on the indicators of environmental competitiveness according to the assessment of SolAbility (2022). The study is conducted using the regression analysis method in 2021 on the example of the top 15 countries with the highest environmental competitiveness of the economy (leaders of the SolAbility rating of the same name, 2022). Empirical data and analysis results are presented in Table 1.

The results obtained in Table 1 showed that, firstly, there is a reliable pattern of growth of natural capital and social capital as artificial intelligence (AI) spreads. Thus, the improvement of the position of the sample countries in the IMD rating (2022) according to the use of big data and analytics indicator contributes to the increase of natural capital by 0.20 points (correlation 54.04%, the pattern is reliable at the significance level of 0.05) and the growth of social capital by 0.12 points (correlation 72.75%, the pattern is reliable at the significance level of 0.01). Based on the established regression patterns, it was revealed that at the maximum level of artificial intelligence (AI) development (1st place), an increase in natural capital by 11.75% and social capital by 6.48% is achieved.

Secondly, the spread of artificial intelligence (AI) does not contribute to improving the sustainability of governance, as evidenced by unreliable regression and weak correlation. Thirdly, despite the absence of a sufficiently reliable regression dependence, the close relationship of the remaining indicators with artificial intelligence (AI) is evidenced by a pronounced correlation: with resource intensity (24.12%) and with intellectual capital (41.73%). Consequently, these indicators of the environmental competitiveness of the economy can be improved through the use of AI, but these advantages are not guaranteed (they do not occur in all countries and not in all cases).

The obtained results validate the advanced hypothesis and prove that artificial intelligence opens up new opportunities for improving the environmental competitiveness of the economy.

Artificial intelligence allows slowing down/preventing the depletion of natural resources (to preserve natural capital), and supporting social advance through health, security, freedom, equality, and life satisfaction (development of social capital).

Prospects for improving the environmental competitiveness of the economy using AI: Economic policy implications

In this article, it is suggested to focus on those components of this competitiveness that are most closely related to the development of artificial intelligence (AI) in order to maximize the actual contribution of artificial intelligence (AI) in practice, aimed at improving the environmental competitiveness of the economy. The following main (priority) measures are proposed:

- To develop natural capital, it is recommended to use the so-called "AI imagination" to discover new ways of regenerative nature-based management. In this regard, it is necessary to inform artificial intelligence (using a digital code) of the advantages of various practices of ecological economics and management, teach and program it to search for the most optimal combination of business practices that can improve the environmental situation;
- To strengthen social capital, it is proposed to create an even greater number of more "smart" chatbots (both private and public) in order to increase the awareness of communities about current environmental problems and the opportunities available to them to solve these problems through responsible production and consumption practices.

The following additional measures are proposed:

- To increase resource intensity and increase intellectual capital, it is advisable to expand the use of artificial intelligence (AI) in R&D conducted by both research institutes (for the economy as a whole) and individual business structures (for their own needs). This will make it possible to create both universal and unique applied solutions to improve the resource efficiency of environmental economics and management.

The proposed recommendations will allow integrating artificial intelligence (AI) into environmental economics and management practices and thereby increase their scale and their efficiency.

Discussion

The article contributes to the development of the Theory of environmental economics and management by clarifying the role and importance of artificial intelligence (AI) in ensuring the ecological competitiveness of the economy. The increment of scientific knowledge in the article is provided due to the justification that, unlike the assumptions made in the works of Adamova et al. (2021), Asha et al. (2022), Li et al. (2021), Ligozat et al. (2022), Sasaki et al. (2019), the potential artificial intelligence (AI) in improving the environmental competitiveness of the economy is most pronounced in the field of natural and social capital development, and not in relation to the resource efficiency of the economy, intellectual capital and government regulation, as previously assumed in these publications.

As a result of the study, it was possible to prove that artificial intelligence (AI) makes a reliable and stable contribution to the development of natural capital (improving environmental conditions in the economic system and supporting the implementation of SDGs 13-15) and social capital (increasing social cohesion in environmental protection and supporting SDG 11). At the same time, it is observed less pronounced and insufficiently reliable for the global economy as a whole, but perhaps reliable enough in individual countries, AI' contribution to increasing resource Intensity (improving the resource efficiency of the economy and supporting the implementation of SDG 12) and the development of intellectual capital (increasing the level of environmental education and the availability of "green" innovations and supporting the achievement of SDG 4). Nevertheless, on a global economic scale, no significant AI' contribution to governance has been identified (increasing the level of development of "green" infrastructure and the commitment of state regulatory authorities to environmental priorities, that is, in support of achieving SDG 9).

Conclusion

So, the hypothesis put forward in the article has been proved: artificial intelligence determines success in slowing down/preventing the depletion of natural resources by 54.04%, and determines social advance by 72.75%. It opens up broad prospects for improving the environmental competitiveness of the economy in the artificial intelligence (AI) era. The theoretical significance of the results obtained in this study lies in the reasoned position that, despite the overall positive contribution to improving the environmental competitiveness of the economy, artificial intelligence (AI) has a significantly different potential in the development of individual components of this competitiveness. This makes it possible to use artificial intelligence (AI) more flexibly and effectively in improving environmental economics and management. The article has also revealed AI' contribution to improving the environmental competitiveness of the economy in the context of the components of this competitiveness, as well as in the light of the implementation of the Sustainable Development Goals (SDGs).

The empirical value of the article consists in revealing the prospects for improving the environmental competitiveness of

the economy in the artificial intelligence (AI) era. In particular, it has been proved that natural capital can be increased by 11.75%, and social capital—by 6.48%. The outlined prospects and the proposed economic policy implications for improving the environmental competitiveness of the economy with the use of artificial intelligence (AI) make it possible to improve the practice of state and corporate management of the environmental economics, focusing the use of artificial intelligence (AI) in the most promising areas.

In conclusion, it is necessary to pay attention to the limitations of the results obtained in the article due to the fact that no significant AI' contribution to the development of resource intensity, intellectual capital and governance has been identified. The fact that positive and sufficiently reliable connections have not been revealed in this study does not necessary mean that they are actually absent. In future studies, the sample should be expanded to include, in particular, developing countries. In addition, it is advisable to conduct case studies that will help to identify hidden connections between artificial intelligence (AI) and the environmental competitiveness of the economy.

Author contributions

All authors contributed to manuscript writing revision, read, and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Adamova, M. A., Kardanova, M. L., Yakusheva, A. V., Dyakonova, M. A., and Mankieva, A. V. (2021). Artificial intelligence in politics global leadership and the risks of competitive struggle. *Adv. Res. Russ. Bus. Manag.* 2021, 409–417.

AlAbri, S., Taghizadeh, S. K., Khan, G. M., and Rahman, S. A. (2022). Exploratory innovation, exploitative innovation and operational performance: Influence of informal social relations in environmental competitiveness. *Qual. Quant.* 56 (3), 1223–1244. doi:10.1007/s11135-021-01173-z

Asha, P., Natrayan, L., Geetha, B. T., Beulah, J. R., Sumathy, R., Varalakshmi, G., et al. (2022). IoT enabled environmental toxicology for air pollution monitoring using AI techniques. *Environ. Res.* 205, 112574. doi:10.1016/j.envres.2021.112574

Awawdeh, A. E., Ananzeh, M., El-khateeb, A. I., and Aljumah, A. (2022). Role of green financing and corporate social responsibility (CSR) in technological innovation and corporate environmental performance: A COVID-19 perspective. *Cfri* 12 (2), 297–316. doi:10.1108/CFRI-03-2021-0048

Bakirman, T. (2022). AI-based environmental monitoring with UAV systems. *Photogrammetric Eng. Remote Sens.* 88 (2), 102.

Congjuan, L., Abulimiti, M., Jinglong, F., and Haifeng, W. (2022). Ecologic service, economic benefits, and sustainability of the man-made ecosystem in the taklamakan desert. *Front. Environ. Sci.* 10, 813932. doi:10.3389/fenvs.2022.813932

Del-Aguila-Arcentales, S., Alvarez-Risco, A., Jaramillo-Arévalo, M., De-La-cruz-diaz, M., and Anderson-Seminario, M. d. l. M. (2022). Influence of social, environmental and economic sustainable development Goals (SDGs) over continuation of entrepreneurship and competitiveness. *JOItmC* 8 (2), 73. doi:10.3390/joitmc8020073

Dong, T., and Meng, L. (2021). Assessment of international competitiveness of AI industry based on positive and negative ideal points weighting method. *Mob. Inf. Syst.* 2021, 1–9. doi:10.1155/2021/9119262

Fraga-Lamas, P., Lopes, S. I., and Fernández-Caramés, T. M. (2021). Green iot and edge AI as key technological enablers for a sustainable digital transition towards a smart circular economy: An industry 5.0 use case. *Sensors* 21 (17), 5745. doi:10.3390/s21175745

Guchhait, R., Sarkar, M., and Sarkar, B. (2021). How much green investments are efficient for a smart production system? *IFIP Adv. Inf. Commun. Technol.* 632 IFIP, 450–459. doi:10.1007/978-3-030-85906-0_50

IMD Business School (2022).. World Competitiveness Ranking 2021. URL: https://www.imd.org/centers/world-competitiveness-center/rankings/world-competitiveness/ (data accessed 05 16, 2022).

Li, V. O. K., Lam, J. C. K., and Cui, J. (2021). AI for social good: AI and big data approaches for environmental decision-making. *Environ. Sci. Policy* 125, 241–246. doi:10.1016/j.envsci.2021.09.001

Ligozat, A.-L., Lefevre, J., Bugeau, A., and Combaz, J. (2022). Unraveling the hidden environmental impacts of AI solutions for environment life cycle assessment of AI solutions. *Sustainability* 14 (9), 5172. doi:10.3390/su14095172

Mahmoodi, M., and Dahmardeh, N. (2022). Environmental kuznets curve hypothesis with considering ecological footprint and governance quality: Evidence from emerging countries. *Front. Environ. Sci.* 10, 849676. doi:10.3389/fenvs.2022.849676

Martínez, C. I. P., and Poveda, A. C. (2022). The effects of environmental performance on competitiveness and innovation: A stochastic Frontier approach for Colombia. *Environ. Syst. Decis.* 42 (1), 51–62. doi:10.1007/s10669-021-09828-w

Owusu Kwateng, K., Tetteh, F. K., Atchulo, H. B., and Opoku-Mensah, S. (2022). Effect of corporate environmental strategies on firms' competitiveness, the mediating role of supply chain collaboration. *Jgr.* doi:10.1108/JGR-02-2021-0026

Philip, J. M., and Kavitha, N. S. (2022). Smart waste management system using optimised routing for environmental protection. *J. Environ. Prot. Ecol.* 23 (3), 1020–1030.

Popkova, E., Bogoviz, A. V., and Sergi, B. S. (2021). Towards digital society management and 'capitalism 4.0' in contemporary Russia. *Humanit Soc. Sci. Commun.* 8 (1), 77. doi:10.1057/s41599-021-00743-8

Popkova, E., Gornostaeva, Z., and Tregulova, N. (2018). Role of innovations in provision of competitiveness and innovational development of economy and overcoming of "underdevelopment whirlpools" in Russia and countries of Eastern Europe. *Jeee* 10 (3), 511–523. doi:10.1108/JEEE-12-2017-0100

Rana, N. P., Chatterjee, S., Dwivedi, Y. K., and Akter, S. (2021). Understanding dark side of artificial intelligence (AI) integrated business analytics: Assessing firm's operational inefficiency and competitiveness. *Eur. J. Inf. Syst.* 31, 364–387. doi:10.1080/0960085X.2021.1955628

Sabbir, M. M., and Taufique, K. M. R. (2022). Sustainable employee green behavior in the workplace: Integrating cognitive and non-cognitive factors in corporate environmental policy. *Bus. Strat. Env.* 31 (1), 110–128. doi:10.1002/bse.2877

Sasaki, S., Kiyoki, Y., Sarkar-Swaisgood, M., Shaw, R., and Veesommai, C. (2019). 5D world map system for disaster-resilience monitoring from global to local: Environmental artificial intelligence (AI) system for leading SDG 9 and 11. *Front. Artif. Intell. Appl.* 321, 306–323. doi:10.3233/FAIA200022

SolAbility (2022). *The global sustainable competitiveness Index*. URL: https://solability.com/the-global-sustainable-competitiveness-index/downloads (data accessed 05 16, 2022).

Wang, M., Li, Y., and Liao, G. (2022a). Spatial spillover and interaction between high-tech industrial agglomeration and urban ecological efficiency. *Front. Environ. Sci.* 10, 829851. doi:10.3389/fenvs.2022.829851

Wang, N., Zhang, S. J., and Wang, W. (2022b). Impact of environmental innovation strategy on green competitiveness: Evidence from China. *Ijerph* 19 (10), 5879. doi:10.3390/ijerph19105879

Wilson, M., Paschen, J., and Pitt, L. (2022). The circular economy meets artificial intelligence (AI): Understanding the opportunities of AI for reverse logistics. *Meq* 33 (1), 9–25. doi:10.1108/MEQ-10-2020-0222

Wu, G. (2022). Research on the spatial impact of green finance on the ecological development of Chinese economy. *Front. Environ. Sci.* 10, 887896. doi:10.3389/fenvs.2022.887896

Yankovskaya, V. V., Bogoviz, A. V., Lobova, S. V., Trembach, K. I., and Buravova, A. A. (2022). Framework strategy for developing regenerative environmental management based on smart agriculture. *Smart Innovation, Syst. Technol.* 264, 281–286. doi:10.1007/978-981-16-7633-8_31