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Fight against climate change and sustainable development based on ecological economy and management in the AI era

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Introduction

Fundamental changes are taking place in the modern economy and business under the influence of two global trends. The first trend is associated with the development of the digital economy based on smart technologies under the influence of the Fourth Industrial Revolution. Automation happens in all industries and encompasses all types of business processes. In the era of artificial intelligence (AI), the countries of the world set themselves the strategic task to strengthen digital competitiveness and gain unique competitive advantages in the global markets of high-tech products (Popkova, 2022; Popkova and Sergi, 2022). For this purpose, innovations are actively being introduced into the economy and business, as well as telecommunications infrastructure is being developed (Ruffolo, 2022). The significance of the described trend is emphasized by SDG 9.

The second trend is environmental protection (Calero Preciado et al., 2022). This protection is becoming ubiquitous, which clearly demonstrates the introduction of green innovations at all stages of the value chain: from the transition to renewable energy sources to biodegradable packaging and recycling (Mentzel et al., 2022). Among the wide range of environmental initiatives implemented in the economy and business, the fight against climate change occupies an important place (Dirmeyer et al., 2022). This trend is reflected in the formulation of SDG 13.

The above trends are reflected in the development of ecological economy and management in the AI era. We understand ecological economy and management as a sphere of the economy in which economic processes and business practices are conducted with strict observation of environmental principles, norms and standards and strive toward contributing to environmental protection and the fight against climate change (Badry et al., 2022; Bakkaloglu et al., 2022; Chen et al., 2022; Mohd Fuzi et al., 2022). The AI era is a new stage in the development of the global economy, which started due to the Fourth Industrial Revolution and is characterized by the formation of Industry 4.0,

information society and the digital economy (Luitse and Denkena, 2021; Som, 2021; Li et al., 2022; Ruffolo, 2022; Wilson et al., 2022).

It is noteworthy that the peak of both described global trends falls on the period from 2020 to 2030, called the "Decade of Action". In the existing literature, these trends are mostly considered separately, and the subject area at the crossroads of these trends—ecological economics and management in the AI era—is a gap in the literature, since it is poorly studied. On the one hand, this makes it possible to reliably describe the theories of ecological economics and smart economics, respectively, as well as to study in detail and in-depth the existing practice within the boundaries of each trend.

On the other hand, an isolated consideration causes uncertainty about the consequences of the overlap of these trends on each other, which takes place in practice. Theoretical models compiled separately within the boundaries of each trend do not allow making reliable forecasts of economic practice, since they are limited by a narrow set of factors of the corresponding trend. The problem is that this reduces the efficiency of economic and business management, as well as hinders sustainable development.

This article seeks to solve the problem posed by filling the identified gap in the literature. The purpose of the article is to study the contribution of ecological economy and management in the AI era to the fight against climate change for sustainable development. To achieve this goal, the article sets two research tasks. The first task is to model the contribution of ecological economy and management in the AI era to the fight against climate change for sustainable development. The second task is to identify and measure the synergetic effect of the systemic development of ecological economy and management in the AI era to combat climate change from the perspective of sustainable development.

Literature review

This article is based on three concepts elaborated in detail and well-established in the scientific literature. The first is the concept of ecological economics and business management (Hassan et al., 2022; Xie and Jamaani, 2022). The second is the concept of a digital economy based on smart technologies in the AI era (Atabekova et al., 2022; Gyamfi et al., 2022). The third is climate change and the fight against climate change (Bechtel et al., 2022; Popkova and Shi, 2022; Skeirytė et al., 2022; Victor-Gallardo et al., 2022). These concepts have been studied in detail, and this indicates a high degree of elaboration of the research problem and the reliability of its theoretical basis. However, there is a scarcity of scientific research at the Intersections of these concepts, which is a gap in the literature. In this regard, the following two research questions (RQ) arise.

RQ_1: What impact does the development of the digital economy and business based on smart technologies in the AI era have on the ecological economy and management? The available literature indicates the high risks of negative consequences of the development of the digital economy and business based on smart technologies in the era of AI for the environment. Among these negative consequences are increased energy intensity of automated business (Fu et al., 2022; Kakraliya et al., 2022; Matsunaga et al., 2022), increased environmental costs of high-tech economic growth (Kong, 2021; Sun et al., 2021), as well as the limitation of the use of "clean energy" (Garriz and Domingo, 2022; Xiong et al., 2022).

Taking into account the publications of Bermeo-Ayerbe et al. (2022), Chehri et al. (2022), Farzaneh et al. (2021), Wang et al. (2021), which note the positive contribution of smart technologies to the development of the ecological economy and business, for example, Smart Grid, climate-smart agriculture, automated recycling, this article puts forward the H_1 hypothesis that the development of the digital economy and business based on smart technologies in the AI era can have a positive impact on ecological economy and management under certain conditions. The article is devoted to the verification of the proposed hypothesis and the identification of the conditions under which the hypothesis is confirmed.

RQ_2: How to manage the development of the digital economy and business based on smart technologies in the AI era to maximize their contribution to the fight against climate change in support of sustainable development? The existing literature offers separate recommendations for managing subjects of both the digital economy and business based on smart technologies in the AI era. In their papers, Fendrich et al. (2022), Xie and Jamaani (2022) consider that from the standpoint of the state, it is necessary to develop an e-government system in the direction of tightening environmental control (smart environmental taxation, automated quality and environmental certification).

In their works, Rachinsky-Spivakov (2022), Zikargae et al. (2022) express the opinion that from the standpoint of consumers and the general public, electronic participation of the population in environmental protection issues should be expanded and the information society should be developed in the direction of public environmental control. In their research, Kazancoglu et al. (2021), Mishra et al. (2022) propose to develop environmentally responsible high-tech industries from a business perspective. Taking into account the positive contribution of all these subjects separately, this article puts forward the H_2 hypothesis that in order to maximize their contribution to the fight against climate change in support of sustainable development, it is preferable to systematically manage the development of the digital economy and business based on smart technologies in the AI era.

Methodology

To obtain the most accurate and reliable results, the study relies on the mathematical apparatus. The solution of the first task, which consists in modelling the contribution of ecological economics and management in the AI era to the fight against climate change for sustainable development, is carried out using the method of correlation analysis. The choice of the correlation analysis method and its preference for the regression analysis method, which acts as its alternative, is related to the fact that the purpose of the article is to study the complex relationships of indicators, since the trends in the development of the ecological economy and the digital economy have an equal impact on each other (dependent and factor variables cannot be distinguished).

The information and empirical base of the study is statistical data for 2022 published by WIPO (2022). The indicators of the economy and management in the AI era are: 1) Government's online service; 2) E-participation; 3) High-tech manufacturing. The indicators of ecological economy and management are: 1) GDP/unit of energy use; 2) Environmental performance; 3) ISO 14001 environmental certificates/bn PPP$ GDP. The values of all indicators are expressed in points to ensure their comparability. The average correlation between groups of indicators is also determined.

The study sample includes 15 of the best countries in the world with a formed digital economy, which are active participants in the Fourth Industrial Revolution and have demonstrated the best results in combating climate change in 2022 in terms of implementing SDG 13 according to the UN (2022). The criterion for selecting countries was also the availability of the full volume of statistical data (without gaps) on the indicators selected for the study in WIPO (2022) materials. The sample structure is dominated by five East and South Asia countries (33.33%) and five OECD countries (33.33%). The sample also includes two LAC countries (13.33%), one Sub-Saharan Africa country (6.67%), one MENA country (6.67%) and 1 E. Europe and C. Asia country (6.67%).

The solution of the second task related to the identification and measurement of the synergetic effect of the systemic development of ecological economy and management in the AI era to combat climate change from the standpoint of sustainable development is carried out using the regression analysis method. The regression dependence of Goal 13 Score (according to UN, 2022) in 2022 on the totality of the six indicators of the ecological economy and digital economy listed above from UN (2022) materials is determined. The correlation coefficients of Goal 13 Score with the selected six indicators are individually compared with the multiple correlation coefficient in the regression model. Based on the obtained regression equation, a forecast is made for the system management of all six indicators to combat climate change.

Results

Modelling the contribution of ecological economy and management in the AI era to the fight against climate change for sustainable development

As part of the first task, the correlation analysis method was used to model the contribution of ecological economy and management in the AI era to the fight against climate change for sustainable development. The sample of the study, as well as the results of its processing using the selected method are shown in Table 1.

The results of modelling from Table 1 identified the significant contribution of environmental economics and management in the AI era to the fight against climate change for sustainable development. Among the indicators of economy and management in the AI era, high-tech manufacturing demonstrated the closest relationship with the indicators of ecological economy and management: 20.51%, reflecting the key contribution of business. The contribution of the state is also significant (the correlation of government's online service with indicators of ecological economy and management was 18.24%) and the contribution of society (the correlation of e-participation with indicators of ecological economy and management was 13.33%).

Indicators of environmental economics and management, in turn, have also demonstrated a close relationship with indicators of economy and management in the AI era. The correlation for GDP/unit of energy use averaged 11.92%, for environmental performance—5.90%, for ISO 14001 environmental certificates/bn PPP$ GDP—34.26%. Nevertheless, the average correlation of the considered six indicators with SDG 13 score turned out to be negative and amounted to −16.39%. This indicates an insufficient use of the potential of ecological economics and management in the era of artificial intelligence in terms of increasing the contribution to the fight against climate change in the interests of sustainable development.

The results obtained allow concluding that ecological economy and management in the AI era take new forms of e-government, information society and high-tech business. Ecological economy and management contribute to the fight against climate change for sustainable development. This is manifested in the reduction of the economy's energy intensity, increase in ecological efficiency of economic growth and development of ecological certification and quality of products. This contribution is expressed in the fight against climate change and is achieved through a combination of the institutes of the AI era and ecological economy and management.

TABLE 1 Ecological economy, management in the AI era and the results of the fight against climate change in 2022, scores 1–100.

Country	Regions in the UN classification (2022)	Indicators of economy and management in the AI era			Ecological economy and management indicators			Goal 13 score
		Government's online service	E-participation	High-tech manufacturing, %	GDP/unit of energy use	Environmental performance	ISO 14001 environmental certificates/bn PPP$ GDP	
		x_1	x_2	x_3	x_4	x_5	x_6	y
India	East and South Asia	85.3	85.7	45.8	25.5	18.9	5.7	96.2
Brazil	LAC	87.1	75.0	49.4	26.7	43.6	5.8	93.3
Peru	LAC	75.3	76.2	15.5	43.4	39.8	11.7	92.7
Vietnam	East and South Asia	65.3	70.2	39.0	19.6	20.1	11.2	92.6
Indonesia	East and South Asia	68.2	75.0	39.0	36.9	28.2	4.5	92.1
Colombia	OECD	76.5	86.9	25.4	47.5	42.4	24.8	88.7
Turkey	OECD	85.9	89.3	41.3	45.8	26.3	7.3	85.9
China	East and South Asia	90.6	96.4	64.4	15.5	28.4	42.9	85.5
South Africa	Sub-Saharan Africa	74.7	75.0	26.8	10.0	37.2	7.6	81.7
Iran (the Islamic Republic of Iran)	MENA	58.8	46.4	50.6	7.0	34.5	2.8	78.9
Chile	OECD	85.3	85.7	30.8	28.8	46.7	13.4	78.3
Italy	OECD	82.9	82.1	52.2	43.5	57.7	44.9	76.3
Malaysia	East and South Asia	85.3	85.7	60.3	25.5	35.0	16.8	73.7
Hungary	OECD	74.7	67.9	79.7	30.1	55.1	54.8	72.4
Russian Federation	E. Europe and C. Asia	81.8	86.9	29.4	9.4	37.5	1.3	70.8
Correlation coefficients, %	Government's online service	100.00	-	-	-	-	-	−6.63
	E-participation	84.18	100.00	-	-	-	-	4.50
	High-tech manufacturing, %	15.84	−10.55	100.00	-	-	-	−34.33
	GDP/unit of energy use	20.31	31.82	−16.38	100.00	-	-	28.82
	Environmental performance	11.67	−9.94	15.97	26.43	100.00	-	−55.71
	ISO 14001 certificates/	22.73	18.11	61.94	25.32	55.23	100.00	−34.97
	Arithmetic mean	18.24[a]	13.33[a]	20.51[a]	11.92[b]	5.90[b]	34.26[b]	−16.39

[a]With indicators of ecological economy and management.

[b]With indicators of economy and management in the AI, era.

Source: compiled and calculated by the authors based on the materials of UN (2022), WIPO (2022).

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The synergetic effect of the systemic development of ecological economy and management in the AI era to combat climate change from the perspective of sustainable development

As part of the second task of the study, the regression analysis method was used to identify and measure the synergetic effect of the systemic development of ecological economy and management in the AI era to combat climate change from the standpoint of sustainable development. The regression dependence of Goal 13 Score in 2022 on six indicators of the ecological economy and digital economy from Table 1 was determined, which allowed us to obtain the following equation of multiple linear regression:

$$y = 116,75 + 1,04^{*}x_1 - 0,98^{*}x_2 - 0,41^{*}x_3 + 0,32^{*}x_4 - 0,91^{*}x_5 + 0,35^{*}x_6 \quad (1)$$

To check the reliability of the regression Eq. 1, we will conduct the F-test. The significance of F was 0.0521, therefore, the equation corresponds to $\alpha = 0.10$. For 15 observations and six factor variables ($k_1 = 6$; $k_2 = 15\text{-}6\text{-}1 = 8$), the tabular F = 2.67. The observed F = 3.5215—it exceeded the tabular and, therefore, the F-test was passed.

It is also advisable to conduct a Student's t-test. At 14 degrees of freedom, the tabular t = 1.345. The observed t exceeded the tabular modulo for all variables and amounted to 6.8115 for the constant, 2.0410 for x_1, −2.2981 for x_2, −2.0893 for x_3,2,3649 for x_4, −3.5882 for x_5 and 1.6068 for x_6. Therefore, the *t*-test is also passed. Together, both tests confirmed the validity and reliability of Eq. 1 at a significance level of 0.10.

The multiple correlation coefficient in the regression model was 85.17% (R^2 = 75.54), significantly exceeding the correlation coefficients of Goal 13 Score with the selected six indicators separately (shown in Table 1 and are (modulo) from 4.50% to 55.71%, and on average, as indicated above, they are -16.39%. Based on the obtained regression Eq. 1, a forecast of the system management of all six indicators for combating climate change is made.

According to the forecast, with an increase of 15% government's online service (from 78.51 points in 2022 to 90.29 points), as well as with an increase of 15%, respectively, GDP/unit of energy use (from 27.68 points to 33.22 points) and ISO 14001 environmental certificates/bn PPP$ GDP (from 17.03 score up to 20.44 points) Goal 13 score will increase to the maximum possible 100% (+18.06% compared to 83.95 points in 2022).

The received results allow for a conclusion that the systemic development of ecological economy and management in the AI era ensures the synergetic effect for fighting climate change from the position of sustainable development. Isolated measures of the development of ecological economy and management in the AI era give a limited contribution to the fight against climate change. Thus, the development of e-government by one point leads to an increase in the result of the implementation of SDG 13 by 1.04 points. A decrease in the energy intensity of GDP by 1% leads to an increase in the results of the implementation of SDG 13 by 0.32 points. An increase in the activity of ecological certification of the quality of products by 1% leads to an increase in the result of the implementation of SDG 13 by 0.35 points.

The full-scale fight against climate change within separate directions requires their unattainable scale. Thus, to reach 100 points on SDG 13, it is necessary to raise government's online service up to 94 points or increase GDP/unit of energy use up to 80 points, or raise ISO 14001 environmental certificates/bn PPP$ GDP up to 65 points—which cannot be achieved in the mid-term. Collectively, these measures allow—in the case of a slight increase in their scale—achieving full-scale results in the fight against climate change.

Discussion

The article contributes to the literature by strengthening the systemic links between the concept of ecological economics and business management and the concept of the digital economy based on smart technologies in the AI era, as well as by filling the gap in knowledge at the intersection of these concepts. In contrast to the position of such scientists as Fu et al. (2022), Garris and Domingo (2022), Kakraliya et al. (2022), Kong (2021), Matsunaga et al. (2022), Sun et al. (2021), Xiong et al. (2022), the authors proved that the development of the digital economy and business based on smart technologies in the AI era can have a positive impact on the ecological economy and management, provided that all economic entities—the state, society and business—show high corporate environmental responsibility.

In contrast to the position of Fendrich et al. (2022), Kazancoglu et al. (2021), Mishra et al. (2022), Rachinsky-Spivakov (2022), Xie and Jamaani (2022), Zikargae et al. (2022), it has been proved that systematic management of the development of the digital economy and business based on smart technologies in the AI era is required to maximize their contribution to the fight against climate change in support of sustainable development. This will make it possible to obtain a synergistic effect in the form of achieving much better results of the implementation of SDG13 (correlation of 85.17%) compared to managing these factors separately (correlation modulo: from 4.50% to 55.71%, and on average 16.39%).

The scientific novelty and originality of the paper lie in its filling the gap at the intersection of ecological economy and business management, the concept of the digital economy and the concept of climate change and the fight against climate

change. Due to this, the paper, first, revealed the influence of the development of the digital economy and business based on smart technologies in the AI era on ecological economy and management, manifested in the increase in results on SDG 3. Second, the paper offered prospective measures for managing the development of the digital economy and business based on smart technologies in the AI era to maximize their contribution to the fight against climate change, in the support of sustainable development, which include the increase in government's online service, growth of GDP/unit of energy use and increase in ISO 14001 environmental certificates.

Conclusion

The article has formed a systematic view of environmental economics and management in the AI era, filled the identified gap in the literature and solved the problems posed. The article has answered both RQ and proved both hypotheses put forward. The development of the digital economy and business based on smart technologies in the era of AI can have a positive impact on the ecological economy and management, provided that the corporate environmental responsibility of market participants is high (the H_1 hypothesis has been proved).

Systematic management of the development of the digital economy and business based on smart technologies in the AI era, providing a synergistic effect in the form of maximizing their contribution to the fight against climate change in support of sustainable development is preferable (the H_2 hypothesis has been proved). The theoretical significance of the results obtained in the article is related to the clarification of cause-and-effect relationships in the development of ecological economy and management in the AI era. The practical significance of the authors' conclusions and recommendations lies in the fact that they will improve the efficiency of economic management and business in the "Decade of Action" and support the sustainable development of the AI economy.

In conclusion, it is necessary to mention the limitation of this research: the results obtained are generalized, and they would be reliable for the world economy on the whole, while the specifics of isolated economic systems are beyond the limits of this research. It is generally known that the digital economy and ecological management have vivid and significant specifics in different countries. To deal with this limitation in future studies, it is necessary to focus on the specifics of ecological economy and management in the AI era and the development of practical recommendations for the fight against climate change which would take into account the national specifics.

Author contributions

AS, TL, and IM. contributed to conception and design of the study. AK organized the database. TL performed the statistical analysis. AS wrote the first draft of the manuscript. AS, TL, IM, and AK wrote sections of the manuscript. All authors contributed to manuscript 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

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