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Economic and legal approaches to the humanization of FinTech in the economy of artificial intelligence through the integration of blockchain into ESG Finance

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The purpose of the article is to study the current experience and prospects of the humanization of FinTech in the economy of artificial intelligence. The research methodology is based on the use of the method of structural equation modeling (SEM). The study analyzes statistics for 2021–2022 (annual indicators). The sample included 118 countries. As a result, the modern international experience of FinTech humanization in the economy of artificial intelligence has been studied and the causal relationships of FinTech humanization in the economy of artificial intelligence through the integration of blockchain into ESG finance have been identified. The article proposes an economic and legal approach to the humanization of FinTech in the economy of artificial intelligence by integrating blockchain into ESG finance to ascertain the economic and political implications. The article contributes to the literature by clarifying the scientific provisions of the concept of the humanization of the economy. The theoretical significance of the obtained results is that the developed model (SEM) and the detailed regression equations have formed a comprehensive understanding of the patterns of humanization of FinTech. The resulting econometric model can be used to predict prospects for the development of blockchain-based ESG finance, as well as high-precision planning of state economic policy. The practical significance of the authors' conclusions and recommendations is that they have formed a clear idea of modern barriers ("market failures" and "institutional traps") and prospects (improvement of the institutional environment through the application of an economic and legal approach) to the humanization of FinTech in the economy of artificial intelligence through the integration of blockchain into ESG finance.

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Introduction

Finance permeates the entire economy, playing an important infrastructural role in it. The decisions on financing determine which investment projects will be developed and implemented in practice. It is advisable to consider the consequences of these decisions in terms of risks. These risks are associated with so-called errors of the first kind, due to which socially significant projects do not receive the necessary investment support and lack funding. This leads to the fact that they can be implemented at a slow pace, have a small scale or be postponed for the indefinite future. (Keynejad et al., 2021).

Examples of socially significant projects include the installation of more advanced treatment facilities at industrial enterprises, the transfer of industrial facilities outside cities to dedicated and specially equipped industrial zones, the launch of circular production, the development of transport and logistics networks, as well as improving the industrial safety in a workplace (Popkova and Sergi, 2021).

Risks also imply errors of the second kind, due to which projects that carry a potential danger to society can receive funding and be implemented (Yue, 2022). Examples about this could be the construction of new industrial facilities in close proximity to residential buildings in cities, an increase in the scale of activities of irresponsible employers, etc.

The reasons for these risks lie in the imperfection of the practice of making investment decisions. Most financial resources are concentrated in the hands of shareholders, investors and specialized financial organizations—subjects of making key investment decisions. When the latter are guided primarily by economic criteria, these risks increase. The economic criteria include the payback period, return on investment, the effectiveness of the investment project in comparison with alternative ones (NPV).

The adoption of the Sustainable Development Goals (SDGs) served as an impetus for the widespread application of not only economic, but also social and environmental criteria for making investment decisions. Non-economic criteria include consequences for employees, consumers, society and the environment. Taking into account non-economic criteria in guiding investment decisions contributes to the humanization of finance. But the "Decade of Action" is unique and notable not only for the popularization of non-economic criteria, but also for the automation of investment decision-making processes.

The Fourth Industrial Revolution led to the formation of Industry 4.0, in which high-tech finance is actively developing: FinTech. Modern FinTech practice includes numerous examples of intellectual support for investment decision-making, including scoring in banks, AI-based brokerage applications, digital investment platforms, smart assistants and chatbots of financial organizations, as well as smart technologies used to provide financial security (Popkova et al., 2021).

The above causes the high relevance of the analysis of modern experience and determining the prospects for the humanization of FinTech in the economy of artificial intelligence, which is the purpose of this article. The originality of the research lies in the development of a new economic and legal approach to the humanization of FinTech in the economy of artificial intelligence through the integration of blockchain into ESG finance.

This paper's contribution to the literature is the clarification of the cause-and-effect relationships of the humanization of FinTech based on ESG finance. Owing to this, the paper fills the gaps at the intersection of high-tech and sustainable development of finance in the AI economy. The practical significance of the paper is due to the developed authors' approach allowing for the systemic improvement of not only regulatory-legal and institutional support but also organization and management of the process of FinTech humanization. For this, a promising measure of state and corporate management of FinTech—integration of blockchain into ESG finance—is proposed. The goal is achieved through the solution of the following four research tasks:

1. Analysis of the influence of state regulation factors on the development of ESG finance;
2. Assessment of the impact of the widespread use of blockchain technologies in society on the development of ESG finance;
3. Identification of the influence of government regulation factors on blockchain finance;
4. Identification of the benefits of ESG finance for sustainable development (17 UN SDGs).

Literature review

The central category of this research is FinTech, which is treated as high-tech finance—electronic payments with the use of the leading automation tools (Ai et al., 2023; Awais et al., 2023; Campanella et al., 2023; Irimia-Diéguez et al., 2023; Li et al., 2023; Tut, 2023).

The article is based on the scientific provisions of the concept of the humanization of the economy. According to this concept, the humanization of FinTech means the development of sustainable (ESG) finance that simultaneously meets two conditions: (1) do not cause negative consequences for society (S-component) and the environment (E-component) (Li et al., 2022); (2) provide benefits for society (S-component) and the environment (E-component) (Long and Blok, 2021). It should be emphasized that economic efficiency is taken into account using the G-component (Popkova et al., 2022).

And although non-commercial investment projects, in particular, obviously unprofitable ones, may relate to FinTech, in most cases, humanistic FinTech projects assume at least a payback, and ideally a return on investment. In this article, attention is focused on break-even projects, since only they fully comply with ESG principles (Patel et al., 2022). The international experience of the humanization of FinTech is described in the works by Hudaefi et al. (2023), Joia and Proença (2022), Lisha et al. (2023), Molla and Biru (2023), Nugraha et al. (2022), Wang et al. (2022) and Wang et al. (2023).

In the economy of artificial intelligence, the prospects for the development of FinTech are associated with the further expansion of the use of distributed ledger technology (blockchain), which has already become quite widespread today. Natanelov et al. (2022) in their paper describe the advantages of concluding smart contracts based on blockchain technology for supply chain financing, and also gives an example of mapping the innovative potential in beef supply chains in Australia and China.

In their paper, Zheng et al. (2022) consider an example of the use of blockchain technology for the exchange of corporate credit information in supply chain financing. Guo et al. (2022) give an example of a lean structure based on blockchain and the Internet of Things to ensure transparency of information in supply chain financing. Dang et al. (2022) point to the advantages of risk assessment and forecasting of small and medium-sized enterprises in supply chain financing using blockchain technology and a deep learning model.

As a result of the literature review, a high degree of elaboration of the fundamental issues of this study has been revealed, as well as a high level of formation of the categorical apparatus. Nevertheless, the uncertainty of the causal relationships of the humanization of FinTech in the economy of artificial intelligence remains. This is a gap in the literature that this article aims to fill.

To this end, the authors pose the following four research questions (RQ).

RQ_1: How (on the basis of what determining factors) does the humanization of finance take place (development within the framework of ESG principles)? In their works Gillan et al. (2021), Weston and Nnadi (2021) propose a socio-economic approach to the humanization of finance based on corporate social responsibility. Based on the works of Ben Fatma and Chouaibi (2021), Jamali et al. (2020), which note the importance of the institutional environment for the development of corporate social responsibility, this article puts forward the hypothesis H_1 that public institutions (factors of state regulation) largely determine the development of ESG finance.

RQ_2: How (on the basis of what determining factors) does ESG finance develop in the FinTech in the framework of the economy of artificial intelligence? In their works, Chang et al. (2022), Kim and Li (2021) suggest that the development of ESG finance is a natural market process that occurs spontaneously due to automation in the economy of artificial intelligence.

Based on the research materials of Chang et al. (2021), Zeidan (2022), which indicate the complexity, as well as the contradictory nature of market trends in the field of financial automation, this article puts forward the H_2 hypothesis that the spread of blockchain technologies in society makes a limited (moderate) contribution to the development of ESG finance. This means that the favorable influence of market factors, which consist in the formation of the economy of artificial intelligence and the spread of advanced technologies, is not sufficient for the development of FinTech.

RQ_3: What influence do public institutions (factors of state regulation) have on blockchain finance as one of the key components of modern FinTech? In their publications Ibrahim and Truby (2021), Takanashi (2020), Truby et al. (2022) indicate that strong public institutions and the favorable influence of government regulation factors (rule of law, economic freedom, high quality of government regulation, political and business stability, high level of development of the e-government system, as well as high efficiency of government regulation) have a positive (stimulating) impact on blockchain finance.

Based on the works of Peláez-Repiso et al. (2021), Tokarieva et al. (2021), who cite as a scientific argument an insufficiently strong regulatory framework for blockchain financing (for example, government restrictions on the use of cryptocurrencies), this article puts forward the hypothesis H_3 that state institutions (factors of state regulation) can have a negative impact on blockchain finance: to retard their development even in a highly developed institutional environment.

RQ_4: What advantages (regarding the SDGs implementation) does the humanization of finance (ESG-based development) provide? The existing literature reveals the advantages of ESG finance for individual SDGs. For example, in the work of Wu (2022) the advantages of the green blockchain for the sustainable development of green reverse logistics based on blockchain are noted, which supports the practical implementation of SDG 12. In their work, Chin et al. (2022) proposed using blockchain technology for green innovations in ecosystem-based business models as a dynamic capability of values appropriation in support of the practical implementation of SDG14-15.

In their publication, Lasla et al. (2022) presented GreenPoW, an energy-efficient blockchain Proof-of-Work consensus algorithm, to support the practical implementation of SDG 7. In their work, Bai et al. (2021) gave an example of blockchain-based trust management for agriculture (crop production) and proposed a game-theoretic approach to support the practical implementation of SDG 2. Jiang and Zheng (2021) presented a coupling mechanism of green building industry innovation ecosystem based on blockchain Smart City in support of the practical implementation SDG 11.

Based on the works of Aravindaraj and Rajan Chinna (2022), Backes and Traverso (2022), which substantiate the systemic relationship of the 174 UN SDGs, this article puts forward the H_4 hypothesis that the development of ESG finance provides complex implications for sustainable development, spreading to all 17 UN SDGs at once.

In order to fill the identified gap in the literature, search for answers to the research question posed and test the hypotheses put forward, this article examines in detail the causal relationships of the humanization of FinTech in the economy of artificial intelligence through the integration of blockchain into ESG finance.

Methods

The research methodology is based on the use of economic and mathematical apparatus to obtain the most accurate and reliable results. Given the complexity of the cause-and-effect relationships of FinTech humanization in the economy of artificial intelligence, the structural equation modeling (SEM) method was chosen for their study, which allows taking into account both direct and inverse relationships of indicators, as well as the most complete representation of multiple relationships of various groups of indicators. The SEM method is widely used, in particular, for studying FinTech and sustainable finance. The mentioned advantages of the SEM methods are described by Adediran and Ali (2021), Yan et al. (2022), and Zhu et al. (2019).

The study is based on statistics for 2021–2022 (annual indicators). The sample includes 118 countries of the world, for which all the necessary statistics are available (i.e., there are no gaps in the data). Firstly, the indicator of the use of blockchain finance in 2021: percentage of crypto owners of the population (%) from Triple A materials (2022) is designated as bcn. Secondly, the indicator of the humanization of the economy in 2021: ESG Index from the materials of Risk Indices (2022) is designated as ESG. Thirdly, the indicators of the development of public institutions (factors of state regulation) in 2021:

Rule of law (Government's online service): WIPO indicator (2022), designated as gr_1;
Index of economic freedom: The Heritage Foundation (2022), designated as gr_2;
The quality of state regulation (Regulatory quality): the WIPO indicator (2022), designated as gr_3;
Political and operational stability: the WIPO indicator (2022), designated as gr_4;
Effectiveness of state regulation (Government effectiveness): the WIPO indicator (2022), designated as gr_5;
The level of development of the electronic government system (Government's online service): the WIPO indicator (2022), designated as gr_6.

The values of the listed factors of state regulation are taken in points from 0 to 100 from the materials of the dataset "Humanization of economic growth in the global economy: Big Data and Digital Modeling—2022" (Institute of Scientific Communications, 2022). Fourth, the performance indicators for the 17 UN SDGs (Goals scores) for 2022 from the UN materials (2022) are designated as SDG 1–17, respectively. The empirical base of the study is given in the Microsoft Excel table attached to this article. The economic and geographical structure of the sample (according to the UN classification, 2022) is shown in Fig. 1.

As can be seen from Fig. 1, OECD countries predominate in the sample (37 countries, 31%). The share of Africa countries is 18% (21 countries), E. Europe & C. Asia: 15% (18 countries), East

& South Asia: 14% (16 countries), LAC: 12% (14 countries), MENA: 10% (12 countries). The representation of countries from all economic and geographical groups of the world indicates the validity of the sample. Each of the four research tasks is solved separately in a given order using the methods of correlation and regression analysis. The concept of the study is given in Table 1.

The reliability of regression models is checked using the *F*-test. To form a complete picture, the obtained results of regression and correlation analysis are combined into a general model of structural equations (SEM), which also takes into account errors.

Results

Analysis of the influence of government regulation factors on the development of ESG finance. As part of the first task of the study, the $ESG = F(gr_{1\text{-}6})$ function was created based on the available sample to determine the influence of government regulation factors on the development of ESG finance using the regression analysis method. This made it possible to obtain a model of multiple (six-factor) linear regression (1), the reliability of which is checked in Table 2.

$$ESG = 65.5809 - 0.0140{*}gr_1 + 0.3558{*}gr_2 - 0.4268{*}gr_3 - \\ -0.2214{*}gr_4 - 0.1651{*}gr_5 + 0.0189{*}gr_6 \quad (1)$$

The resulting model (1) indicates that ESG finance is developing under the influence of an increase in the level of economic freedom and the progress of the e-government system.

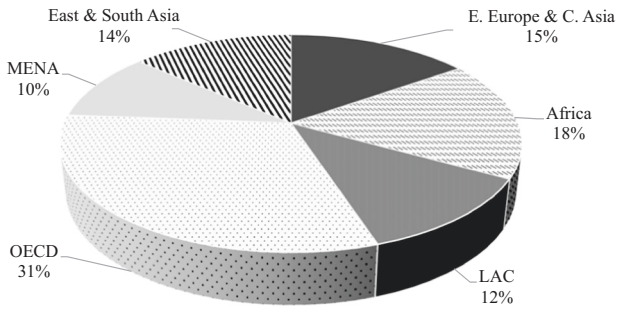

Fig. 1 Economic and geographical structure of the sample. Share of the categories of countries, according to the UN (2022), in the structure of the sample that was created for this research.

However, the increase: (1) guarantees of the rule of law; (2) the quality of government regulation; (3) political and business stability, and (4) the effectiveness of government regulation hinders the development of ESG finance.

As shown in Table 2, model (1) corresponds to the highest level of significance $\alpha = 0.01$. At a given significance level, the critical *F*-value is 2.99. The observed *F* exceeds the critical one ($68.08 > 2.99$), therefore, the *F*-test is passed, and the model is reliable. This confirmed the H_1 hypothesis and proved that government regulatory factors largely determine the development of ESG finance, although the influence of these factors is not always positive, and may be constraining.

Assessment of the contribution of the spread of blockchain technologies in society to the development of ESG finance. As part of the second task of the study, the $ESG = F(bcn)$ function was created based on the available sample to determine the contribution of the spread of blockchain technologies in society to the development of ESG finance using the regression analysis method. This made it possible to obtain a model of simple (one-factor) linear regression (2), the reliability of which is checked in

Table 2 Details of regression analysis in the model $ESG = F(gr_{1\text{-}6})$.

Regression statistics	Multiple *R*	0.8867
	R-square	0.7863
	Adjusted *R*-square	0.7748
	Standard error	6.2480
	Observations	118.0000
Analysis of variance	Significance *F*	$6.4{*}10^{-35}$
	Significance level	0.01
	Critical *F*-value[a]	2.99
	Observed *F*	68.0800
t-statistics	Constant	8.2371
	Rule of law	−0.1562
	Index of Economic Freedom	2.3202
	Quality of state regulation	−4.0746
	Political and operational stability	−2.2559
	The level of development of the e-government system	−3.4818
	Effectiveness of state regulation	0.1501

[a]At $n = 118$; $m = 6$; $k_1 = m = 6$; $k_2 = n - m - 1 = 118 - 6 - 1 = 112$.
Source: calculated and compiled by the authors.

Table 1 Research concept.

Research question (RQ)	Research hypothesis (H)	The task of the study	The mathematical expression of the component of the research model
RQ_1: What factors are driving the development of ESG finance?	H_1: factors of state regulation largely determine the development of ESG finance.	Analysis of the influence of government regulation factors on the development of ESG finance	$ESG = F(gr_{1\text{-}6})$
RQ_2: What factors are driving the development of ESG finance in FinTech?	H_2: The spread of blockchain technologies in society makes a moderate contribution to the development of ESG finance.	Assessment of the contribution of the spread of blockchain technologies in society to the development of ESG finance	$ESG = F(bcn)$
RQ_3: What impact do government regulatory factors have on blockchain finance?	H_3: government regulatory factors can have a negative impact on blockchain finance.	Identification of the influence of government regulation factors on blockchain finance	$bcn = F(gr_{1\text{-}6})$
RQ_4: What benefits for SDGs do ESG finance provide?	H_4: ESG finance provides comprehensive implications for all 17 UN SDGs.	Identifying the benefits of ESG finance for sustainable development (17 UN SDGs)	$SDG_{1\text{-}17} = F(ESG)$

Source: developed by the authors.

Table 3 Details of regression analysis in the model ESG = *F*(bcn).

Regression statistics	Multiple *R*	0.1702
	R-square	0.0290
	Adjusted *R*-square	0.0201
	Standard error	13.0290
	Observations	118
Analysis of variance	Significance *F*	0.06532
	Significance level	0.1
	Critical *F*-value[a]	3.24
	Observed *F*	3.4622
t-statistics	Constant	21.1083
	Percentage of crypto owners of the population	1.8607

[a]At $n = 118$; $m = 1$; $k_1 = m = 1$; $k_2 = n - m - 1 = 118 - 1 - 1 = 116$.
Source: calculated and compiled by the authors.

Table 4 Details of regression analysis in the model bcn = $F(gr_{1\text{-}6})$.

Regression statistics	Multiple *R*	0.2718
	R-square	0.0739
	Adjusted *R*-square	0.0238
	Standard error	2.8947
	Observations	118
Analysis of variance	Significance of *F*	0.1931
	Significance level	0.20
t-statistics	Constant	1.2364
	Rule of law	−0.5995
	Index of Economic Freedom	−0.6915
	Quality of state regulation	−0.4484
	Political and operational stability	−0.6310
	The level of development of the e-government system	2.0034
	Effectiveness of state regulation	0.9330

Source: calculated and compiled by the authors.

Table 3.

$$\mathrm{ESG} = 36.0120 + 0.7650^{*}\mathrm{bcn} \quad (2)$$

The resulting model (2) indicates that when the percentage of crypto owners of the population increases by 1%, the ENG Index increases by 0.7650 points.

As shown in Table 2, model (2) corresponds to the significance level $\alpha = 0.1$. At a given significance level, the critical *F*-value is 3.24. The observed *F* exceeds the critical one ($3.46 > 3.24$), therefore, the *F*-test is passed, and the model is reliable. This confirmed the H_2 hypothesis and proved that the spread of blockchain technologies in society contributes to the development of ESG finance, although this contribution is still moderate at the current intermediate stage of the Fourth Industrial Revolution (most likely, this contribution will increase in the coming years).

Identification of the influence of government regulation factors on blockchain finance. As part of the third task of the study, the function $\mathrm{bcn} = F(\mathrm{gr}_{1\text{-}6})$ was created to determine the influence of government regulation factors on blockchain finance using the regression analysis method based on the available sample. This made it possible to obtain a model of multiple (six-factor) linear regression (3), the reliability of which is checked in Table 4.

$$\mathrm{bcn} = 4.4215 - 0.0249^{*}\mathrm{gr}_1 - 0.0491^{*}\mathrm{gr}_2 - 0.0218^{*}\mathrm{gr}_3 - \\ -0.0287^{*}\mathrm{gr}_4 + 0.0440^{*}\mathrm{gr}_5 + 0.0544^{*}\mathrm{gr}_6 \quad (3)$$

The resulting model (3) indicates that the development of blockchain finance depends on improving the efficiency of government regulation and the progress of the e-government system. However, the increase in: (1) guarantees of the rule of law; (2) the level of economic freedom; (3) the quality of government regulation; (4) political and business stability hinders the development of blockchain finance.

As demonstrated in Table 2, model (2) corresponds to the significance level $\alpha = 0.2$, at which the *F*-test cannot be performed. This indicates a reduced and limited reliability of the model (3). This confirmed the H_3 hypothesis and proved that government regulatory factors can have not only a positive, but also zero and even negative impact on blockchain finance.

Identifying the benefits of ESG finance for sustainable development (17 UN SDGs). As part of the fourth task of the study, $\mathrm{SDG}_{1\text{-}9} = F(\mathrm{ESG})$ functions were created using the regression analysis method based on the available sample to identify the benefits of ESG finance for sustainable development (17 UN SDGs). Regression coefficients and other parameters of regression models, as well as verification of their reliability, are shown in Tables 5 and 6.

According to Tables 5 and 6, most of the obtained regression models correspond to the highest level of significance $\alpha = 0.1$ and have successfully passed the *F*-test (except for the $\mathrm{SDG}_{14} = F(\mathrm{ESG})$ function), that is, they are reliable. However, most regression coefficients have a negative sign. This confirmed the H_4 hypothesis and proved that ESG finance has a complex impact on all 17 UN SDGs, but this impact is negative in most cases (except SDG 12 and SDG 13).

Discussion

To form a systematic view that most fully and reliably reflects the cause-and-effect relationships of the humanization of FinTech in the economy of artificial intelligence through the integration of blockchain into ESG finance, all the results obtained are presented in the form of a general SEM model (Fig. 2).

The SEM model in Fig. 2 demonstrated a stable systemic relationship of FinTech humanization in the economy of artificial intelligence through the integration of blockchain into ESG finance. The theoretical significance of the created SEM model is that is comprehensively reflects the influence of a wide range of legal and economic factors on the humanization of FinTech. This allowed overcoming the fragmentary character of the existing views (reflected in the literature) on the influence of separate factors on the considered process.

The model also has large prospects of practical application. The usefulness for practice is as follows: based on the compiled SEM model, the subjects of state and corporate management of FinTech humanization will be able to select the most effective managerial measures with the highest precision. This will allow raising the effectiveness of state policy and corporate management of FinTech, thus accelerating its humanization. The model summarized the obtained quantitative results. Their qualitative interpretation in comparison with the existing literature is given in Table 7.

The article contributes to the literature by clarifying the scientific provisions of the concept of the humanization of the economy. Unlike Gillan et al. (2021), Weston and Nnadi (2021), it has been proved that the development of ESG finance does not occur directly due to corporate social responsibility, but it is

Table 5 Details of regression analysis in the model $SDG_{1-9} = F(ESG)$.

-	-	Goal 1 Score	Goal 2 Score	Goal 3 Score	Goal 4 Score	Goal 5 Score	Goal 6 Score	Goal 7 Score	Goal 8 Score	Goal 9 Score
Regression statistics	Multiple R	0.6415	0.3655	0.8828	0.7012	0.6451	0.8236	0.7101	0.7851	0.8205
	R-square	0.4115	0.1336	0.7793	0.4916	0.4161	0.6783	0.5042	0.6165	0.6732
	Adjusted *R*-square	0.4064	0.1261	0.7774	0.4872	0.4111	0.6755	0.4999	0.6131	0.6704
	Standard error	25.9878	7.2820	8.1009	12.2021	11.1257	7.9823	16.3537	6.0122	15.1516
	Observations	118	118	118	118	118	118	118	118	118
Analysis of variance	Significance of *F*	$5*10^{-15}$	$4.7*10^{-0.5}$	$7.4*10^{-40}$	$9.5*10^{-19}$	$3.2*10^{-15}$	$2.4*10^{-30}$	$2.2*10^{-19}$	$6.8*10^{-26}$	$6.1*10^{-30}$
	Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.04
	Critical *F*-value[a]	6.84	6.84	6.84	6.84	6.84	6.84	6.84	6.84	6.84
	Observed *F*	81.1124	17.8869	409.5047	112.1739	82.6736	244.5346	117.9583	186.4406	238.9374
Coefficients	Constant	139.7080	70.9699	119.6442	121.8044	93.3532	105.0243	126.5231	93.5427	114.9966
	ESG Index	−1.6436	−0.2163	−1.1512	−0.9075	−0.7104	−0.8765	−1.2473	−0.5765	−1.6447
t-statistics	Constant	18.9247	34.3086	51.9917	35.1403	29.5378	46.3171	27.2353	54.7711	26.7180
	ESG Index	−9.0062	−4.2293	−20.2362	−10.5912	−9.0925	−15.6376	−10.8609	−13.6543	−15.4576

[a]At $n = 118$; $m = 1$; $k_1 = m = 1$; $k_2 = n - m - 1 = 118 - 1 - 1 = 116$.
Source: calculated and compiled by the authors.

Table 6 Details of regression analysis in the model $SDG_{10-17} = F(ESG)$.

-	-	Goal 10 Score	Goal 11 Score	Goal 12 Score	Goal 13 Score	Goal 14 Score	Goal 15 Score	Goal 16 Score	Goal 17 Score
Regression statistics	Multiple *R*	0.4937	0.7861	0.7933	0.6390	0.1326	0.3747	0.8493	0.4839
	R-square	0.2437	0.6180	0.6293	0.4083	0.0176	0.1404	0.7213	0.2341
	Adjusted *R*-square	0.2372	0.6147	0.6261	0.4032	0.0091	0.1330	0.7189	0.2275
	Standard error	26.6076	10.1215	10.8718	15.9262	28.5945	12.9876	6.7081	10.3918
	Observations	118	118	118	118	118	118	118	118
Analysis of variance	Significance of *F*	$1.3*10^{-0.8}$	$5.4*10^{-26}$	$9.3*10^{-27}$	$6.9*10^{-15}$	0.15242	$2.9*10^{-0.5}$	$5.7*10^{-34}$	$2.8*10^{-0.8}$
	Significance level	0.01	0.01	0.01	0.01	-	0.01	0.01	0.01
	Critical *F*-value[a]	6.84	6.84	6.84	6.84	-	6.84	6.84	6.84
	Observed *F*	37.3788	187.6530	196.9241	80.0600	2.0751	18.9480	300.2759	35.4610
Coefficients	Constant	97.2030	112.6106	32.6634	39.9848	59.2372	81.2462	101.9146	76.8619
	ESG Index	−1.1423	−0.9736	1.0713	1.0007	−0.2893	−0.3970	−0.8163	−0.4346
t-statistics	Constant	12.8603	39.1662	10.5764	8.8381	7.2927	22.0218	53.4827	26.0374
	ESG Index	−6.1138	−13.6986	14.0330	8.9476	−1.4405	−4.3529	−17.3285	−5.9549

[a]At $n = 118$; $m = 1$; $k_1 = m = 1$; $k_2 = n - m - 1 = 118 - 1 - 1 = 116$.
Source: calculated and compiled by the authors.

largely (correlation: 88.67%) mediated by factors of state regulation. The stability of public institutions directly contributes to the development of ESG finance, and certain government regulatory measures stimulate corporate social responsibility, thereby indirectly supporting the development of ESG finance. Although at present, in general, the institutional environment and the influence of factors of state regulation largely inhibit the development of ESG finance and therefore needs to be improved.

Unlike Chang et al. (2022), Kim and Li (2021), it has been proved that the spread of blockchain technologies in society makes a limited (moderate correlation of 17.02%) contribution to the development of ESG finance. This means that the favorable influence of market factors, which consist in the formation of the economy of artificial intelligence and the spread of advanced technologies, is not sufficient for the development of FinTech.

Contrary to the position expressed by such authors as Ibrahim and Truby (2021), Takanashi (2020), Truby et al. (2022), it has been proved that public institutions (factors of state regulation) can have a negative impact on blockchain finance: to retard their development even in a highly developed institutional environment. Thus, the increase in: guarantees of the rule of law, the level of economic freedom, the quality of government regulation and political and operational stability, instead of the expected support, hinders the development of blockchain finance. At the same time, the cumulative impact of state regulation factors is estimated at 27.18%. This requires a serious adjustment of the institutional environment and the approach to state regulation of blockchain finance.

In contrast to Bai et al. (2021), Chin et al. (2022), Jiang and Zheng (2021), Lasla et al. (2022), Wu (2022), it has been proved that the development of ESG finance provides complex implications for sustainable development, spreading to all 17 UN SDGs at once. The impact of ESG finance on the results of the 17 UN SDGs is strong in most cases (the correlation is close to 90%), but negative, except for SDG 12 and SDG 13 with a positive link and SDG 14 with a zero link.

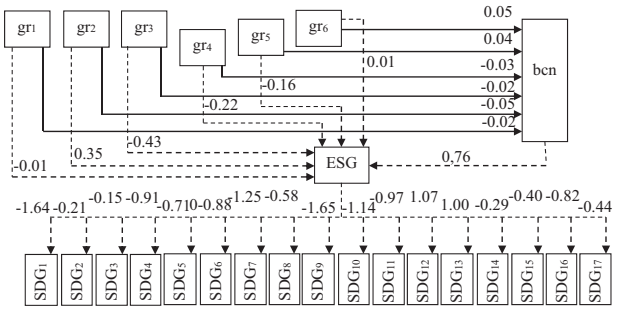

Fig. 2 SEM model of humanization of FinTech in the AI economy. The SEM model, which provides a systematic representation of the cause-and-effect relationships of FinTech humanization in the artificial intelligence economy through the integration of blockchain into ESG. finance.

Conclusion

The conducted research made it possible to analyze the modern international experience of FinTech humanization in the economy of artificial intelligence and to identify the systemic nature of the causal relationships of FinTech humanization in the economy of artificial intelligence through the integration of blockchain into ESG finance. The main conclusions in accordance with the four tasks of the study are as follows:

1. The development of ESG finance to a large extent (correlation: 88.67%) is mediated by factors of state regulation. But at present, in general, the institutional environment and the influence of factors of state regulation largely inhibit the development of ESG finance and therefore needs to be improved.;
2. The spread of blockchain technologies in society makes a limited (moderate correlation of 17.02%) contribution to the development of ESG finance. This means that the favorable influence of market factors, which consist in the formation of the economy of artificial intelligence and the spread of advanced technologies, is not sufficient for the development of FinTech. To overcome the identified "market failure", it is necessary to form and maintain a favorable institutional environment;
3. Public institutions (factors of state regulation) can have a negative impact on blockchain finance: to retard their development even in a highly developed institutional environment. The cumulative impact of state regulation factors is estimated at 27.18%. It is established that the increase in: guarantees of the rule of law, the level of economic freedom, the quality of government regulation and political and operational stability, instead of the expected support, hinders the development of blockchain finance, which creates "institutional traps" that need to be overcome.
4. The development of ESG finance provides comprehensive implications for sustainable development, spreading to all 17 UN SDGs at once. The impact of ESG finance on the results of the 17 UN SDGs is strong in most cases (the correlation is close to 90%), but negative, except for SDG 12

Table 7 Contribution of the article to the literature.

Research question (RQ)	Existing literature		The new results obtained in the article
	Scientific provisions	Sources	
RQ_1: What factors are driving the development of ESG finance?	Mainly due to corporate social responsibility factors	Gillan et al. (2021), Weston and Nnadi, M. (2021)	Also largely due to factors of state regulation
RQ_2: What factors are driving the development of ESG finance in FinTech?	Due to market factors: natural, spontaneous market process	Chang et al. (2022), Kim and Li (2021)	A "market failure" that needs to be overcome through government regulation
RQ_3: What impact do government regulatory factors have on blockchain finance?	Exceptionally positive influence	Ibrahim and Truby (2021), Takanashi (2020), Truby et al. (2022)	Controversial: both positive and negative influences
RQ_4: What benefits for SDGs do ESG finance provide?	Advantages for individual SDGs	Bai et al. (2021), Chin et al. (2022), Jiang and Zheng (2021), Lasla et al. (2022), Wu (2022)	Complex and contradictory impact on all 17 UN SDGs

Source: developed and compiled by the authors.

and SDG 13 with a positive link and SDG 14 with a zero link.

Thus, the article answered all the research questions posed and confirmed all the hypotheses put forward. As an economic policy implication, an economic and legal approach to the humanization of FinTech in the economy of artificial intelligence through the integration of blockchain into ESG finance is proposed. The recommended approach is largely based on government regulation and is reduced to improving the institutional support for the humanization of FinTech.

The theoretical significance of the obtained results is that the developed model (SEM) and the detailed regression equations have formed a comprehensive understanding of the patterns of humanization of FinTech. The resulting econometric model can be used to predict prospects for the development of blockchain-based ESG finance, as well as high-precision planning of state economic policy.

The practical significance of the authors' conclusions and recommendations is that they have formed a clear idea of modern barriers ("market failures" and "institutional traps") and prospects (improvement of the institutional environment through the application of an economic and legal approach) to the humanization of FinTech in the economy of artificial intelligence through the integration of blockchain into ESG finance.

The social significance of the authors' conclusions and recommendations is their support for the practical implementation of 17 UN SDGs through the humanization of FinTech in the AI economy. The proposed novel applied solution on the integration of blockchain into ESG finance will allow raising transparency, predictability, manageability and effectiveness of FinTech, as well as making it widely accessible in the AI economy.

At the end of this study, it should be noted that it is limited to general, universal conclusions and recommendations for the world economic system, which need further in-depth rethinking and detailing. In particular, the identified negative implications of ESG finance for the SDGs deserve increased attention in future studies, since the ESG principles are designed to directly support the SDGs.

The lack of a positive effect indicates contradictions in the institutional environment and, possibly, a formal approach to the implementation of ESG principles in FinTech. This requires serious attention and clarification. In addition, in further scientific research, it is advisable to pay attention to national peculiarities and develop detailed recommendations for the practical implementation of the economic and legal approach to the humanization of FinTech in the economy of artificial intelligence by integrating blockchain into ESG finance, and if necessary, take into account the characteristics of the selected economic and geographical regions of the world.

Data availability

All the data used in the article are taken from the following open sources: 1. Institute of Scientific Communications (2022). Dataset "Humanization of economic growth in the global economy: Big Data and digital modeling—2022". URL: https://datasets-isc.ru/data2/905-data-set-gumanizatsiya-ekonmicheskogo-rosta-v-globalnom-khozyajstve-bolshie-dannye-i-tsifrovoe-modelirovanie-2020 (data accessed: 18.10.2022). 2. Risk Indexes (2022). ESG Index 2021: Ranking and Scores. URL: https://risk-indexes.com/esg-index/ (data accessed: 17.10.2022). 3. The Heritage Foundation (2022). Country Rankings of Economic Freedom 2021. URL: https://www.heritage.org/index/ (data accessed: 18.10.2022). 4. Triple A (2022). Cryptocurrency across the world. URL: https://triple-a.io/crypto-ownership-data/ (data accessed: 17.10.2022). 5. UN (2022). The Sustainable Development Goals Report 2022. URL: https://unstats.un.org/sdgs/report/2022/ (data accessed: 18.10.2022). 6. WIPO (2022). Global Innovation Index 2021 Economy profiles The following tables provide detailed profiles for 132 economies. URL: https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2022-section6-en-gii-2022-economy-profiles-global-innovation-index-2022-15th-edition.pdf (data accessed: 18.10.2022).

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References

Adediran AO, Ali HM (2021) A hierarchical hidden variable model of effective housing finance in Nigeria through SEM smart-PLS. Adv Intell Syst Comput 1375 AIST:769–779. https://doi.org/10.1007/978-3-030-73050-5_75

Ai R, Zheng Y, Yüksel S, Dinçer H (2023) Investigating the components of FinTech ecosystem for distributed energy investments with an integrated quantum spherical decision support system. Financ Innov 9(1):27. https://doi.org/10.1186/s40854-022-00442-6

Aravindaraj K, Rajan Chinna P (2022) A systematic literature review of integration of industry 4.0 and warehouse management to achieve sustainable development goals (SDGs). Clean Logist Supply Chain 5:100072. https://doi.org/10.1016/j.clscn.2022.100072

Awais M, Afzal A, Firdousi S, Hasnaoui A (2023) Is FinTech the new path to sustainable resource utilisation and economic development. Resour Policy 81:103309. https://doi.org/10.1016/j.resourpol.2023.103309

Backes JG, Traverso M (2022) Life cycle sustainability assessment as a metrics towards SDGs agenda 2030. Curr Opin Green Sustain Chem 38:100683. https://doi.org/10.1016/j.cogsc.2022.100683

Bai Y, Fan K, Zhang K, Li H, Yang Y (2021) Blockchain-based trust management for agricultural green supply: a game theoretic approach. J Clean Prod 310:127407. https://doi.org/10.1016/j.jclepro.2021.127407

Ben Fatma H, Chouaibi J (2021) Corporate governance and CSR disclosure: evidence from European financial institutions. Int J Discl Gov 18(4):346–361. https://doi.org/10.1057/s41310-021-00117-1

Campanella F, Serino L, Battisti E, Giakoumelou A, Karasamani I (2023) FinTech in the financial system: Towards a capital-intensive and high competence human capital reality? J Bus Res 155:113376. https://doi.org/10.1016/j.jbusres.2022.113376

Chang K, Cheng X, Wang Y, Liu Q, Hu J (2021) The impacts of ESG performance and digital finance on corporate financing efficiency in China. Appl Econ Lett. https://doi.org/10.1080/13504851.2021.1996527

Chang X, Fu K, Jin Y, Liem PF (2022) Sustainable Finance: ESG/CSR, Firm Value, and Investment Returns. Asia Pac J Financ Stud 51(3):325–371. https://doi.org/10.1111/ajfs.12379

Chin T, Shi Y, Singh SK, Agbanyo GK, Ferraris A (2022) Leveraging blockchain technology for green innovation in ecosystem-based business models: a dynamic capability of values appropriation. Technol Forecast Soc Chang 183:121908. https://doi.org/10.1016/j.techfore.2022.121908

Dang C, Wang F, Yang Z, Zhang H, Qian Y (2022) Evaluating and forecasting the risks of small to medium-sized enterprises in the supply chain finance market using blockchain technology and deep learning model. Oper Manag Res. https://doi.org/10.1007/s12063-021-00252-6

Gillan SL, Koch A, Starks LT (2021) Firms and social responsibility: A review of ESG and CSR research in corporate finance. J Corp Financ 66:101889. https://doi.org/10.1016/j.jcorpfin.2021.101889

Guo L, Chen J, Li S, Li Y, Lu J (2022) A blockchain and IoT-based lightweight framework for enabling information transparency in supply chain finance. Digit Commun Netw 8(4):576–587. https://doi.org/10.1016/j.dcan.2022.03.020

Hudaefi FA, Hassan MK, Abduh M (2023) Exploring the development of Islamic FinTech ecosystem in Indonesia: a text analytics. Qual Res Financ Markets. https://doi.org/10.1108/QRFM-04-2022-0058

Ibrahim IA, Truby J (2021) Governance in the era of Blockchain technology in Qatar: a roadmap and a manual for Trade Finance. J Bank Regul https://doi.org/10.1057/s41261-021-00165-1

Institute of Scientific Communications (2022) Dataset "Humanization of economic growth in the global economy: Big Data and Digital Modeling – 2022". https://datasets-isc.ru/data2/905-data-set-gumanizatsiya-ekonmicheskogo-rosta-v-globalnom-khozyajstve-bolshie-dannye-i-tsifrovoe-modelirovanie-2020 (data accessed: 18 Oct 2022)

Irimia-Diéguez A, Velicia-Martín F, Aguayo-Camacho M (2023) Predicting FinTech innovation adoption: the mediator role of social norms and attitudes. Financ Innov 9(1):36. https://doi.org/10.1186/s40854-022-00434-6

Jamali D, Jain T, Samara G, Zoghbi E (2020) How institutions affect CSR practices in the Middle East and North Africa: a critical review. J World Bus 55(5):101127. https://doi.org/10.1016/j.jwb.2020.101127
Jiang Y, Zheng W (2021) Coupling mechanism of green building industry innovation ecosystem based on blockchain smart city. J Clean Prod 307:126766. https://doi.org/10.1016/j.jclepro.2021.126766
Joia LA, Proença R (2022) The social representation of FinTech from the perspective of traditional financial sector professionals: evidence from Brazil. Financ Innov 8(1):93. https://doi.org/10.1186/s40854-022-00409-7
Keynejad RC, Yapa HM, Ganguli P (2021) Achieving the sustainable development goals: investing in early career interdisciplinarity. Humaniti Soc Sci Commun 8(1):153. https://doi.org/10.1057/s41599-021-00834-6
Kim S, Li Z (2021) Understanding the impact of esg practices in corporate finance. Sustainability (Switzerland) 13(7):3746
Lasla N, Al-Sahan L, Abdallah M, Younis M (2022) Green-PoW: an energy-efficient blockchain Proof-of-Work consensus algorithm. Comput Netw 214:109118. https://doi.org/10.1016/j.comnet.2022.109118
Li E, Mao MQ, Zhang HF, Zheng H (2023) Banks' investments in FinTech ventures. J Bank Financ 149:106754. https://doi.org/10.1016/j.jbankfin.2022.106754
Li Z, Feng L, Pan Z, Sohail HM (2022) ESG performance and stock prices: evidence from the COVID-19 outbreak in China. Humanit Soc Sci Commun 9(1):242. https://doi.org/10.1057/s41599-022-01259-5
Lisha L, Mousa S, Arnone G, Huerta-Soto R, Shiming Z (2023) Natural resources, green innovation, FinTech, and sustainability: a fresh insight from BRICS. Resour Policy 80:103119. https://doi.org/10.1016/j.resourpol.2022.103119
Long TB, Blok V (2021) Niche level investment challenges for European Green Deal financing in Europe: lessons from and for the agri-food climate transition. Humanit Soc Sci Commun 8(1):269. https://doi.org/10.1057/s41599-021-00945-0
Molla A, Biru A (2023) The evolution of the FinTech entrepreneurial ecosystem in Africa: An exploratory study and model for future development. Technol Forecast Soc Chang 186:122123. https://doi.org/10.1016/j.techfore.2022.122123
Natanelov V, Cao S, Foth M, Dulleck U (2022) Blockchain smart contracts for supply chain finance: Mapping the innovation potential in Australia-China beef supply chains. J Ind Inf Integr 30:100389. https://doi.org/10.1016/j.jii.2022.100389
Nugraha DP, Setiawan B, Nathan RJ, Fekete-Farkas M (2022) FinTech adoption drivers for innovation for SMEs in Indonesia. J Open Innov Technol Mark Complex 8(4):208. https://doi.org/10.3390/joitmc8040208
Patel R, Migliavacca M, Oriani ME (2022) Blockchain in banking and finance: a bibliometric review. Res Inte Bus Financ 62:101718. https://doi.org/10.1016/j.ribaf.2022.101718
Peláez-Repiso A, Sánchez-Núñez P, García Calvente Y (2021) Tax regulation on blockchain and cryptocurrency: the implications for open innovation. J Open Innov Technol Mark Complex 7(1):98. https://doi.org/10.3390/JOITMC7010098
Popkova E, Bogoviz AV, Sergi BS (2021) Towards digital society management and 'capitalism 4.0' in contemporary Russia. Humanit Soc Sci Commun 8(1):77. https://doi.org/10.1057/s41599-021-00743-8
Popkova EG, Bogoviz AV, Lobova SV, Sozinova AA, Sergi BS (2022) Changing entrepreneurial attitudes for mitigating the global pandemic's social drama. Humanit Soc Sci Commun 9(1):141. https://doi.org/10.1057/s41599-022-01151-2
Popkova EG, Sergi BS (2021) Dataset modelling of the financial risk management of social entrepreneurship in emerging economies. Risks 9(12):211. https://doi.org/10.3390/risks9120211
Risk Indexes (2022) ESG Index 2021: ranking and scores. URL: https://risk-indexes.com/esg-index/ (data accessed: 17 Oct 2022)
Takanashi Y (2020) Future of finance: from g20 to practical implementation of multi-stakeholder governance on blockchain based finance. Lecture notes in computer science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 12063 LNCS:242–253. https://doi.org/10.1007/978-3-030-54455-3_18
The Heritage Foundation (2022) Country rankings of economic freedom 2021. URL: https://www.heritage.org/index/ (data accessed: 18 Oct 2022)
Tokarieva K, Vnukova N, Aleksiyev V (2021) Legal aspects of blockchain technology regulation in the financial sphere. CEUR Workshop Proc 3200:250–254
Triple A (2022) Cryptocurrency across the world. https://triple-a.io/crypto-ownership-data/ (data accessed: 17 Oct 2022)
Truby J, Dahdal A, Caudevilla O (2022) Global blockchain-based trade finance solutions: analysis of governance models and impact on local laws in six jurisdictions. Glob J Comp Law 11(2):167–196. https://doi.org/10.1163/2211906X-11020001
Tut D (2023) FinTech and the COVID-19 pandemic: evidence from electronic payment systems. Emerg Mark Rev 54:100999. https://doi.org/10.1016/j.ememar.2023.100999
UN (2022) The Sustainable Development Goals Report 2022. https://unstats.un.org/sdgs/report/2022/ (data accessed: 18 Oct 2022)
Wang D, Peng K, Tang K, Wu Y (2022) Does FinTech development enhance corporate ESG performance? Evidence from an emerging market. Sustainability (Switzerland) 14(24):16597. https://doi.org/10.3390/su142416597
Wang Y, Hu J, Chen J (2023) Does FinTech facilitate cross-border M&As? Evidence from Chinese A-share listed firms. Int Rev Financ Anal 85:102435. https://doi.org/10.1016/j.irfa.2022.102435
Weston P, Nnadi M (2021) Evaluation of strategic and financial variables of corporate sustainability and ESG policies on corporate finance performance. J Sustain Financ Invest https://doi.org/10.1080/20430795.2021.1883984
WIPO (2022) Global Innovation Index 2021 Economy profiles The following tables provide detailed profiles for 132 economies. URL: https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2022-section6-en-gii-2022-economy-profiles-global-innovation-index-2022-15th-edition.pdf (data accessed: 18 Oct 2022)
Wu J (2022) Sustainable development of green reverse logistics based on blockchain. Energy Rep 8:11547–11553. https://doi.org/10.1016/j.egyr.2022.08.219
Yan C, Siddik AB, Yong L, Zheng G-W, Rahman MN (2022) A two-staged SEM-artificial neural network approach to analyze the impact of FinTech adoption on the sustainability performance of banking firms: The mediating effect of green finance and innovation. Systems 10(5):148. https://doi.org/10.3390/systems10050148
Yue W (2022) Foreign direct investment and the innovation performance of local enterprises. Humanit Soc Sci Commun 9(1):252. https://doi.org/10.1057/s41599-022-01274-6
Zeidan R (2022) Why don't asset managers accelerate ESG investing? A sentiment analysis based on 13,000 messages from finance professionals. Bus Strategy Environ https://doi.org/10.1002/bse.3062
Zheng K, Zheng LJ, Gauthier J, Behl A, Zhang JZ (2022) Blockchain technology for enterprise credit information sharing in supply chain finance. J Innov Knowl 7(4):100256. https://doi.org/10.1016/j.jik.2022.100256
Zhu X, Wei Y, Lai Y, Zhong S, Dai C (2019) Empirical analysis of the driving factors of China's 'Land finance' mechanism using soft budget constraint theory and the PLS-SEM model. Sustainability (Switzerland) 11(3):742. https://doi.org/10.3390/su11030742

Competing interests
The authors declare no competing interests.

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This article does not contain any studies with human participants performed by any of the authors

Informed consent
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