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Composite Index of the World Economy Technological Core Development: Methodological Framework

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ABSTRACT

The aim of the study is to develop and test approaches to constructing a composite index of the world economy's technological core development, represented by the United States of America (USA), the European Union (EU), and China. The research applies general scientific, economic, and econometric methods. **The methodological framework** is based on principal component analysis, which enables the integration of key indicators of global hypercompetition and the strategic autonomy of national economies. The index incorporates parameters reflecting the state and dynamics of the economy, infrastructure, and technological development. **The results** assess the degree of self-sufficiency of technological cores in terms of access to critical resources and their dependence on certain goods and export markets. Empirical testing of the composite index demonstrates that in the 21st century, China has significantly narrowed the gap with the EU and the USA, most notably in advanced technologies and access to strategic resources. The EU and the USA hold roughly comparable positions as technological cores; however, since the 2008–2009 global financial crisis, the EU's global competitiveness has been declining, reflected in its growing dependence on imports of knowledge-intensive information and communication technologies and research and development services. **Conclusion**. The proposed composite index clarifies theoretical approaches to the formation of a polycentric world economy, highlights the strengthened positions of new economic and technological centres, and provides a practical tool for assessing the maturity of technological cores.

Keywords: technological core; composite index; European Union; USA; China; global competitiveness; strategic autonomy

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ОРИГИНАЛЬНАЯ СТАТЬЯ

Композитный индекс сформированности технологических ядер мирового хозяйства: методика построения

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АННОТАЦИЯ

Целью исследования является разработка и апробация подходов к построению интегрального индекса сформированности технологических ядер мирового хозяйства. В качестве технологических ядер рассматриваются Соединенные Штаты Америки (США), Европейский союз (ЕС) и Китайская Народная Республика (КНР). В исследовании применяются общенаучные, экономические и экономико-математические методы. **Методологическая основа** построения индекса базируется на методе главных компонент, позволяющем

интегрировать ключевые параметры глобальной гиперконкуренции и стратегической автономии национальных экономик. В состав индекса включены показатели состояния и динамики развития экономики, инфраструктуры и технологического уровня. **Полученные результаты** позволяют оценить степень самодостаточности технологических ядер с точки зрения доступа к критическим ресурсам, а также их зависимость от отдельных товаров и рынков сбыта. Апробация интегрального индекса показала, что в XXI в. Китай существенно приблизился к ЕС и США, особенно в сфере развития передовых технологий и обеспечения доступа к критическим ресурсам. ЕС и США занимают сопоставимые позиции как технологические ядра мирового хозяйства, однако после кризиса 2008–2009 гг. глобальная конкурентоспособность ЕС снижается, что выражается в росте зависимости от импорта наукоемких услуг в секторах информационно-коммуникационных технологий и научно-исследовательских и опытно-конструкторских работ. **Выводы**. Разработанный интегральный индекс уточняет теоретические подходы к формированию полицентричного мирохозяйственного порядка, выявляет укрепление позиций новых центров экономической и технологической силы и служит практическим инструментом для оценки зрелости технологических ядер.
Ключевые слова: технологическое ядро; интегральный индекс; Евросоюз; США; Китай; глобальная конкурентоспособность; стратегическая автономия

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1. Introduction

Domestic and foreign researchers observe an emerging tendency towards strengthening global hypercompetition processes, which is manifested in the rivalry of countries and integration blocs for access to advanced technologies and sales markets [1]. The world's leading economies are striving to ensure accelerated development of knowledge-intensive sectors of national production that create high domestic added value [2]. Equally important is the task of ensuring an advanced competitive advantage for national economies in terms of integration into the most profitable segments of global value chains [3].

Concurrently, the world economy is witnessing a steadily increasing 'neo-capitalistic neo-protectionism' [4, 5]. Contrary to a 'classical' trade protectionism characterised by prohibitive tariffs and other customs formalities, the new one hinges on alternative restriction measures towards mobility of goods, services, and production factors [6]. 'Core' economies exhibit a great interest in fostering vitally significant sectors of the national economy, relying heavily on restrictive barriers to intercountry interindustry trade in services, as well as intellectual properties (hereinafter — IP) and foreign direct investments (hereinafter — FDI). In recent years, FDI screening, or testing for threats to national economic interests, has increasingly been used in relation to such critical sectors [7]. Modern forms of protectionism represent increasingly less transparent methods and mechanisms for restricting international economic cooperation. The frequency and amplitude of crisis shocks in the global economy have increased significantly, which has made it necessary to take measures in order to ensure the strategic autonomy of the resource sector and manufacturing industry [8]. Giunta et al. [9] suggest that ensuring the sustainable functioning of national economies today requires government agencies to implement a set of measures to support the regionalisation of production chains, localisation of the extraction and processing of critical raw materials, as well as diversification of foreign economic relations.

The transformation of the structure of the technological cores of the world economy is described in the concept of 'wandering internationalised reproductive cores' by E.G. Kochetov [10], by which the author understands mobile production centres of the world economy, carrying out their economic activities on a global scale and forming a geo-economic picture of the world.

The technological core of the global economy at the present stage is defined as a country or integration association capable of maintaining a competitive advantage in the economy and technology, as well as supporting strategic autonomy in relation to third major production and technological centres [11, 12]. Technological cores determine long-term technological trends in the development of the global economy and establish standards and principles for intercountry economic interaction [13]. Technological cores, therefore, receive the bulk of global income in the form of technological rent,

strengthening their dominance over developing economies [14].[1]

The scientific literature extensively studies the evolution of technological cores of the world economy from an evolutionary perspective. J. Arrighi convincingly demonstrated the movement of reproductive cores from Genoa and Holland to the modern United States of America (USA) and China. The evolution of long cycles of capital accumulation can be observed in the USA and China [15]. The "wandering" of reproductive nuclei is also characterised in the category of a spatio-temporal shift" by D. Harvey [16], driven primarily by activity of transnational enterprises [17]. Before the turn of the XXI century, the two key technological cores of the world were the United States and the European Union (EU). In recent decades, however, there has been a confident strengthening of China's position in the global economy [18].

Yet it is worth admitting that in the academic domain, there is no consensus regarding the evolution of technological cores and methodological approaches that determine the degree of their formation. As a scientific hypothesis, the authors of this article attempt to prove that the formation of a polycentric world order presupposes going beyond the dual system of global technological cores and the transition to a triple system of relations between the USA, the EU and China. This article develops theoretical approaches to constructing an integral index of the formation of technological cores of the modern world economy, which allows for their assessment and monitoring based on key parameters: global competitiveness and strategic autonomy.

2. Literature review

The current stage of formation and development of the technological cores of the world economy is unfolding in the context of increasing global geoeconomic fragmentation. One of its factors is recognised as the crisis of the globalisation model that existed before the global financial crisis of 2008–2009.[2] The United States and the European Union, as the technological cores of the global economy, have de facto ceased to view China only as an "assembly factory," as the People's Republic of China (PRC) has moved toward rapid expansion in the high-tech markets of Western countries [19]. Experts note the rapid convergence of the technological potential of China and the United States, especially after 2016 [20]. Growing instability in the global markets at the turn of the century is also claimed to be a significant factor in the recent fragmentation. A series of disruptions in transport and logistics chains, political and macroeconomic shocks in the global economy caused by the COVID-19 pandemic have predetermined the course towards strengthening the self-sufficiency of national economies, reducing dependence on external markets for production resources, capital and final sales [21].

The process of autonomisation (separation) of economic blocks in the global economic system, as an expression of its geoeconomic fragmentation, is reflected in the concept of "strategic autonomy" of technological cores [22]. In terms of implementing this concept, the practice of the European Union, which is actively applying measures at the supranational level to achieve technological and resource sovereignty, is particularly characteristic [23, 24]. It is underscored that the world economy's technological cores accumulate their intellectual, research, and financial potential [25]. According to Glazyev, the concentration of global production and innovation resources around technological forces third countries to pay "intellectual rent" and follow the economic strategies of technological cores. However, the disposition of technological cores in the world economic landscape is not static. Meanwhile, at the end of the 20th and the beginning of the 21st century, three key cores were identified in the literature — the European Union, the USA, and Japan; today, researchers define the EU, the USA, and China as technological cores. The latter has demonstrated unprecedented growth of the national economy in recent decades [26], which is particularly notable in the aftermath of the country's accession to the World Trade Organisation (WTO) in 2001, ensuring a large influx of FDI into the country's productive sectors [27].

Since the beginning of the 21st century, a number of quantitative indicators and indices have appeared in the research field, reflecting the development of processes of global hypercompetition, the formation of production and cooperation ties

[1] Organisation for Economic Co-operation and Development (OECD). The Geopolitics of Innovation. Paris: OECD Publishing; 2020. URL: https://www.oecd.org/innovation/geopolitics-of-innovation.pdf

[2] Rodrik D. Globalization's wrong turn. Foreign Affairs. 2019;98(4):26–33.

between countries in the process of globalisation of the world economy.

Examples include the World Economic Forum's Global Competitiveness Index, which assesses the level of development of a country's institutions, infrastructure, financial sector, and other areas of the economy and society. Hidalgo and Hausmann [28] have proposed the Economic Complexity Index, measuring the level of a country's technological development. One of the areas of scientific research in the field of strategic autonomy has become the development of complex methods for assessing the strategic significance of certain resources (technologies) [29]. It should be noted that existing indices do not fully reflect the processes and degree of formation of technological cores in the world economy in the context of geoeconomic fragmentation and increased protectionism.

In our opinion, there is a gap between the conceptual understanding of the logic for the development of technological cores in the modern world economic system and the need for a quantitative assessment of their formation using economic and mathematical methods [30]. Already elaborated indices do not fully allow for studying the nature of global hypercompetition amidst geoeconomic fragmentation and expanding protectionist policies. This determines the growing demand to develop theoretical and practical approaches to constructing integral indices of the degree of formation of technological cores in the modern global economy.

3. Methodology

3.1. Main stages of research

The transformation of the nature and development of the world economy's technological cores prescribes the need to upgrade existing methods of their assessment. The composite index method is one of the most preferable quantitative approaches, considering a wide range of economic and other aspects that are critical for technological cores.

In the present research, the authors attempt to develop a novel composite index that reflects the degree of sophistication of the main world economy's technological cores.

During the initial stage, a set of standards that the index must meet has been specified. First, the index needs to contain the main information that is present in the underlying indicators of global competitiveness and strategic autonomy. Second, the absolute values of the index have to be normalised so that they are comparable between different technological cores. Last but not least, it is required that the index be decomposable into subindices accounting for its specific structural components.

The second stage of research implied the selection of the most effective tools for the index compilation. The literature has a large body of composite indices that measure innovation activity, economic development, etc. They are broadly based on various multidimensional statistical techniques, including weighted linear aggregation, entropy weighting, scaling, factor analysis, and principal component analysis (PCA) [31]. The latter one is of particular analytical relevance since it enables representation of a set of initial parameters in the form of several artificial variables that provide the main 'information' of a sample [32]. In addition, it alleviates redundancy and multicollinearity and reveals the latent structure of observations. Practically, PCA is utilised in the creation of the Global Innovation Index (GII), Sustainable Development Index (SDI), Digital Economy and Society Index (DESI), as well as indices compiled by the United Nations (UN) and World Bank.

Hence, the PCA method has been chosen as a primary quantitative tool for the creation of the novel index. Specifically, the values of the index are comprised of the first principal component that, to a great extent, recreates the dynamics of underlying parameters.

In order to bring indicators having different units of measurement to a single scale, we apply the data normalisation procedure according to formula (1).

$$x_{i,j,norm} = \frac{x_{i,j} - \overline{x_j}}{\sigma_j}, \quad (1)$$

where $x_{i,j,norm}$ is the normalised value of an observation, i represents a specific observation (a country or an integration union in a given period of time), j is the initial variable, $\overline{x_j}$ represents the mean of j among all observations, σ_j and represents the standard deviation of j among all observations.

To comprehensively analyse the process of polycentric world order formation on the basis of three technological cores, a set of composite indices for each structural subblock is calculated (*Fig. 1*).

In the third stage of research, a set of basic parameters for each aggregated structural subblock of

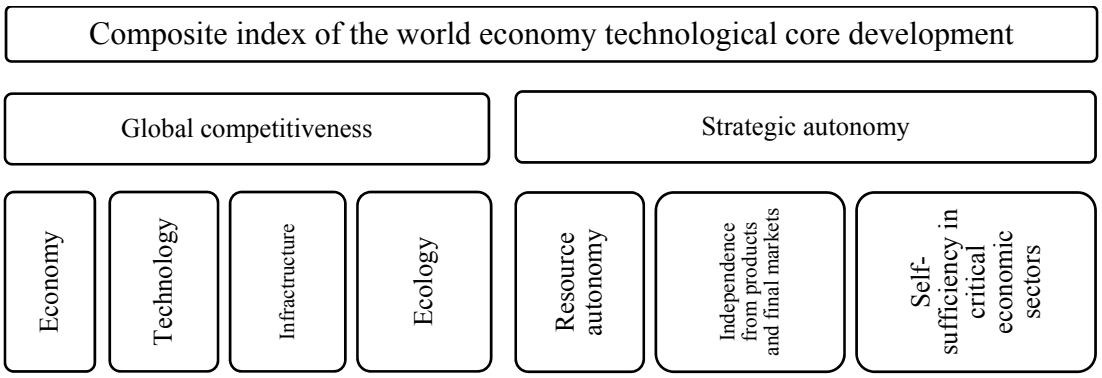

Fig. 1. **Structural subblocks of the Composite index of the world economy technological core development**

Source: Authors' elaboration.

the composite index (namely, global competitiveness and strategic autonomy) has been selected (*Table 1*). Importantly, all these indicators can be quantified and unambiguously interpreted.

Finally, during the fourth stage of research, the methodology presented above has been applied to the USA, the EU, and China for the period 2000–2023.

3.2. Baseline parameters of the "Global competitiveness" block

Today, the largest technological cores of the world economy find themselves involved in global hypercompetition for access to the key modern technologies, as well as to global final markets. Achieving success in such competition requires concerted actions to gain superior competitive advantages [33]. A commonly shared perspective is that broadly established economic development indicators (i.e., GDP, export volume, etc.) fail to uncover the whole nature of global hypercompetition.

The transition towards a new technological layout prioritises assessments of a country's innovation capacity and its investments into knowledge-intensive economic sectors. Maintaining critical infrastructure is crucial for ensuring technological leadership and sovereignty, which serves as a foundation for long-term international competitiveness. Finally, the nature of modern global hypercompetition dictates the necessity of responsible utilisation of natural resources and promotion of renewable sources of energy. To recap, in the present paper, the measurement of the positioning of world economy technological cores in global hypercompetition synthesises quantitative metrics representing certain aspects of economy, technology, infrastructure, and ecology.

Economy

The 'Economy' subblock comprises indicators of a country's position in the world economy and its macroeconomic performance. The share of world GDP is a critical measure of an economy's contribution to the global value added. The share in world exports accounts for a country's orientation to the global market, as well as its integration into inter-country economic relations. Thus, the share of world imports allows for assessing a country's potential as a final market for finished and intermediate products.

The share in world services exports or imports characterises a country's engagement in inter-country trade in intangibles as one of the most promising spheres of international economic cooperation [34]. In the present article, a share of the world's total inward and outward FDI stock is studied. The FDI stock represents a country's degree of control over priority sectors of other economies. Increasing values of the terms of trade index suggest that foreign trade becomes more profitable for a given country. By assessing gross fixed capital formation, one can judge the technological core's determination for the long-term investments in the production base.

To assess the overall macroeconomic performance of an economy and the efficiency of cooperation between certain economic sectors and agents, the authors estimate the rate of inflation and the level of unemployment. An advanced economy must demonstrate superior labour productivity that reflects how well the labour force performs different activities. Another indicator is the resource rent; the growth of the indicator suggests a decline in manufacturing and deterioration of the technological capacity of an economy [35]. Finally, the 'Economy' subblock includes the Human

Table 1

Parameters of global competitiveness and strategic autonomy of technological cores of the world economy

Subblock	Parameter	Unit of measurement	Source of data
Global competitiveness			
Economy	Share in world gross domestic product (GDP)	%	United Nations Conference on Trade and Development (UNCTAD)
	Share in world exports/imports of goods	%	UNCTAD
	Share in world exports/imports of services	%	World Bank
	Share in world total inward FDI stocks	%	UNCTAD
	Terms of trade	index	World Bank
	Economic complexity	index	Observatory of Economic Complexity
	Gross fixed capital formation	% of GDP	UNCTAD
	Rate of inflation (yearly est.)	index	UNCTAD
	Level of unemployment (average yearly est.)	%	World Bank
	Resource rent	% of GDP	World Bank
	Labour productivity	Per worker GDP, index, 2020 = 100	World Bank
	Human development index	index	United Nations Development Program (UNDP)
Technology	Research and development (R&D) expenditures	% of GDP	World Bank
	Share of high-end products in manufacturing exports	%	UNCTAD
	Share of Information and communication technologies (ICT) and computer services in services exports	%	UNCTAD
	Patents in 'green' and digital technologies	abs. number	Organization for Economic Cooperation and Development (OECD)
	Persons employed in R&D sector	per million of population	World Bank
	Publications in scientific journals	abs. number	World Bank
Infrastructure	ICT infrastructure advancement	index, from 0 to 100	UNCTAD
	Transport infrastructure advancement	index, from 0 to 100	UNCTAD
	Port container throughput	TEU	World Bank

Table 1 (continued)

Subblock	Parameter	Unit of measurement	Source of data
Ecology	CO2 emissions	Index, 2000 = 100	OECD
	Share of renewables in total energy consumption	%	OECD
	Energy intensity	tons per capita	OECD
Strategic autonomy			
Self-sufficiency in critical economic sectors	Share of domestic R&D in total R&D expenditures	%	OECD
	Share of domestic ICT in total ICT expenditures	%	OECD
Independence from products and final markets	Theil index for product structure of exports/imports	index	UNCTAD
	Theil index for geographical structure of exports/imports	index	UNCTAD
Resource autonomy	Arable land	% of total territory	World Bank
	Energy availability	index	UNCTAD
	Natural resources availability	index	UNCTAD

Source: Authors' elaboration: UNCTAD Data Hub. URL: https://unctadstat.unctad.org/EN/ (accessed on 10.03.2025); OECD Data Explorer. URL: https://www.oecd.org/en/data/datasets/oecd-DE.html (accessed on 11.03.2025); World Bank Open Data. URL: https://data.worldbank.org/ (accessed on 11.03.2025); The Observatory of Economic Complexity. URL: https://oec.world/en (accessed on 15.03.2025); United Nations Development Program. URL: https://www.undp.org/ (accessed on 20.03.2025).

Development Index as an aggregate metric of the effectiveness of an economy and institutions in terms of quality of life [36].

Technology

The 'Technology' subblock covers metrics of a country's orientation towards high-end industries [37]. The share of world R&D expenditures indicates an amount of national income directed to investments in growing higher technology sectors. Share of high-technology products in total exports measures a country's competitiveness in the international knowledge-intensive product markets [38]. The share of ICT and computer services in total service exports represents a country's position in the global value chains' segments of intangible production with the greatest value-added. Considering the growing importance of 'green' and digital technologies as drivers of the world economy, it appears critical to account for the patent performance of countries as their superior competitive edge.

Infrastructure

The 'Infrastructure' subblock comprises indicators characterising the advancement of infrastructure and maintenance [39]. Specifically, indices of ICT and transport infrastructure capacity proposed by UNCTAD[3] are assessed in the paper. The former index represents accessibility and integrity of communication systems and cybersecurity. The latter index estimates transport connectivity and coverage, as well as airport performance. To account for a country's ability to act

[3] United Nations Conference on Trade and Development. Productive Capacities Index: 2nd generation. Enhanced statistical and methodological approach with results. Geneva: UNCTAD; 2023. (UNCTAD/ALDC/2023/2). DOI: 10.18356/9789213587171

as a marine transport hub, in this paper, we study the port throughput indicator calculated as the volume of standardised twenty-foot containers handled in the port per unit of time.

Ecology

The 'Ecology' subblock is the final component of the 'Global competitiveness' block. First, we analyse CO_2 emissions as an index with the year 2000 as the base level. It appears that in the modern geoeconomics reality, large technological cores of the world economy ought to accommodate low energy-intensive and eco-friendly production technologies, as well as to curtail harmful impact on the biosphere by implementing targeted industrial policies. In addition, the paper assesses another indicator of the effectiveness of national ecological policies: the share of renewables in total energy consumption. Presumably, advanced economies outperform other countries in incentivising businesses and individuals to austere energy consumption so as to contain a negative ecological footprint.

3.3. Baseline parameters of the "Strategic autonomy" block

A distinctive feature of contemporary technological cores' formation is the promotion of strategic autonomy, which implies achieving high self-sufficiency of the national economy and mitigating the risks of foreign economic ties' disruptions. Strategic autonomy is the top priority for large technological cores amidst increasing turbulence in global commodity markets, as well as growing demand for energy sources. Apart from securing continuous access to energy, another central goal for the main global production centres is to maintain food security.

Today, the existing model of international trade and production manifests itself in the form of a dense network of inter-country collaboration, where breaking certain linkages risks evoking a series of cascade shocks impacting other countries and regions. The above problem motivates the necessity to diversify trade and economic ties and to lower dependence on specific markets. Attaining sustained development of a technological core is unfeasible without securing self-sufficiency in critical economic sectors (such as R&D and information and communication technologies (ICT)). Thus, reaching strategic autonomy hinges on multiple parameters. Here in the paper, to assess strategic autonomy, we apply a set of indicators presented below.

Resource autonomy

Resource autonomy is hereby defined as a country's possession of energy and natural resources critical to the sustained functioning of an industry. Hence, the 'Resource autonomy' subblock comprises the share of arable land with respect to an overall country's territory, as well as UNCTAD energy and natural resources availability indices that are designed to represent self-sufficiency in both positions. Particularly, the natural resources availability index measures the volume of domestic raw materials per unit of industrial value-added.

Independence from products and final markets

In the paper, dependency is understood as a situation when a country's exports (imports) are largely comprised of a relatively small number of goods (services) or when it is restricted to a certain number of geographical partners. To quantify such dependency, we apply the Theil concentration index, formula (2), which growing values indicate deepening dependency [40].

$$
\begin{gathered}
T = \frac{1}{n \times m} \sum_{k=1}^{n} \sum_{j=1}^{m} \left(\left(\frac{X_{jk}}{\mu} \right) \ln \left(\frac{X_{jk}}{\mu} \right) \right), \\
\mu = \frac{1}{n \times m} \sum_{k=1}^{n} \sum_{j=1}^{m} X_{jk}, \\
x_k = \sum_{j=1}^{m} X_{k,j} \times \left[\sum_{k=1}^{n} \sum_{j=1}^{m} X_{jk} \right]^{-1}, \\
x_{k,j} = X_{k,j} \times \left[\sum_{j=1}^{m} X_{k,j} \right]^{-1}, \\
T_p = \left(\sum_{k=1}^{n} x_k \times \ln x_k \right) + \ln n, \\
T_m = \left(\sum_{k=1}^{n} x_k \times \sum_{j=1}^{m} x_{k,j} \ln \left(x_{k,j} \times m \right) \right), \\
T = T_p + T_m,
\end{gathered}
\tag{2}
$$

where n is the total set of available (potential) products for exports (imports), m represents an

overall number of available (potential) geographical partners in exports (imports), $X_{k,j}$ is the value of exports (imports) of product *k* respectively to partner *j*, x_k stands for a share of product *k* in total exports (imports), $x_{k,j}$ is a share of partner *j* in exports (imports) of product *k*, м represents the average value of exports (imports) (for all products and geographical partners), T is the overall Theil concentration index, T_p is the product Their concentration index, T_m is the geographical partners (per a single product) Theil concentration index.

Self-sufficiency in critical economic sectors

This subblock estimates the share of domestic content of total R&D and ICT services consumed in the country. In our assumption, such a metric indicates the extent to which national companies are capable of satisfying the demand of technology-domestic intensive industries for funding new research and innovations, as well as ensuring smooth communication and coordination of interfirm transactions. Considering higher global risks related to cybersecurity and counterfeiting of intellectual properties, it is essential for leading technological cores of the world economy to curtail dependency on foreign suppliers of critical services.

3.4. Building the composite index

The proposed approaches to calculating the composite index are based on principal component analysis, which is a multidimensional statistical tool designed to move from a large number of initial features to a small number of new artificial variables reflecting the basic "information" about the initial features. In other words, the algorithm allows one to combine individual indicators into a single composite index. In this case, according to the methodology, the assignment of weights to individual components of the index is performed automatically. The most weight is given to indicators with the largest variation among the observations in the sample (i.e., those that carry the most "information"). Due to this, there is no need to assign weights based on expert opinion, which makes the composite indicator less subjective and allows for a more accurate description of the general trend. The composite indices themselves become normalised; the level of deviation from the average value, represented by zero, characterises differences between the level of development of technological cores.

The reduction of indicators with different units of measurement to a single scale, as mentioned earlier, is carried out by the method of data normalization, formula (1).

Thus, as a result of combining all the initial indices, a composite index of the world economy's technological core development is formed. The partial composite indexes for each block and subblock are calculated in a similar way (two indexes for blocks and seven indexes for subblocks in total). Due to this, it is possible to ensure a comparison of the cores for each of the constituent components of the composite index.

4. Results

4.1. Global competitiveness

Economy

The resulting index of the 'Economy' subblock is presented in *Fig. 2*. According to the estimated values, it is the European Union that maintains the greatest global competitiveness in the economy throughout the XXI century. Nonetheless, the position of China has notably improved over the last two decades, while the gap between China and the USA has become even less than that between the USA and the EU. Based on the methodology applied, one can infer that the most significant positive factors behind economic competitiveness are high economic complexity and active outward FDI activity of a technological core.

Analysing the economic complexity index, one can infer several main takeaways. *Table 2* suggests that among all three studied technological cores, the EU, with Germany as a leading economy, has the most complex structure of production and exports. In 2023, the index value for the EU amounted to 2.1, whereas for China and the USA it was 1.3 and 1.6, respectively. Despite steadily lagging behind the EU and the USA, China demonstrates superior growth of economic complexity: the index increased by more than 110% over 2000–2023. Another important indicator that China constantly outstrips the EU and the USA in is gross fixed capital formation (*Table 3*). China invests a large 41.3% of its GDP in fixed capital; the EU and the USA invest 22.2% and 21.4%, respectively. It is important to highlight that the EU and USA show no changes in the index throughout the studied period. On the

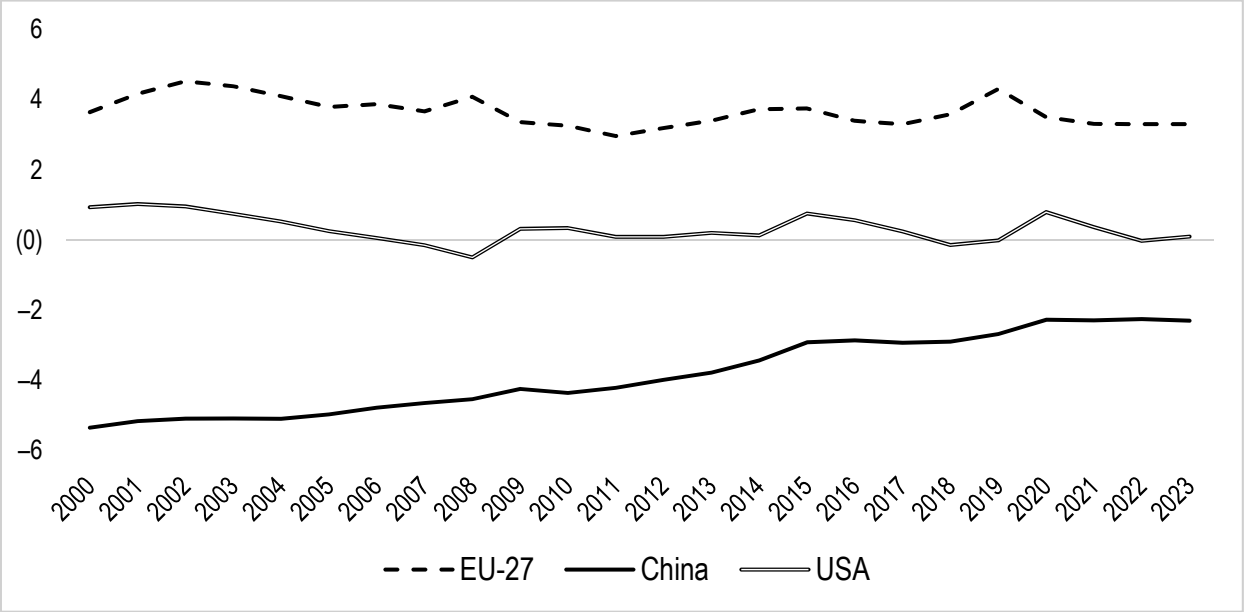

Fig. 2. **Composite index of the 'Economy' subblock of the 'Global competitiveness' block**

Source: authors' elaboration.

Table 2

Economic complexity index for the EU-27, China and the USA, 2000–2023

Technological core	2000	2005	2010	2015	2020	2023
EU-27	2.30	2.15	2.03	2.24	2.11	2.01
China	0.62	0.74	0.96	1.13	1.22	1.33
USA	1.81	1.68	1.70	1.78	1.69	1.64

Source: authors' elaboration on The Observatory of Economic Complexity database. URL: https://oec.world/en (retrieved on 15.03.2025).

contrary, gross fixed capital formation in China has increased by 8 p.p., which can be considered a substantial success that lays the pathway for future competitiveness of the Chinese economy.

To conclude, a trend towards equalisation of the three technological cores' positions in the world economy with respect to global economic competitiveness is observable. Since the beginning of the XXI century, China has manifested substantial progress in almost every aspect of the world's economic relations.

Technology

Specific features of contemporary polycentric world formation can be viewed in *Fig. 3.* To begin with, one should note that, contrary to the economy, the Chinese gap with the EU and the USA in the technological sphere is diminishing rather slowly. According to our estimations, it was only in 2021 that China managed to achieve the technological power that the EU demonstrated in 2004. The USA is a standalone leader among technological cores in terms of global technological competitiveness. However, the EU's gap with the USA is by no means critical. The study revealed that modern technological competitiveness hinges primarily on funding innovations, publishing activity, as well as hiring new researchers.

The values presented in *Table 4* suggest the USA is the leading technological core in funding innovations: the share of R&D expenditures in GDP was equal to 3.7% in 2023.

To compare, the EU spent only 2.3% of GDP on funding innovations in the same period. The dynamics of the indicator in China are admirable. In 2000, the share of R&D expenditures in GDP totalled a meagre 0.9%, but up to 2014 it reached 2.0%, and in 2023 its value exceeded 2.5%, thus

Table 3
Gross fixed capital formation, % of GDP, 2000–2023

Technological core	2000	2005	2010	2015	2020	2023
EU-27	22.83	21.98	20.65	20.17	22.03	22.19
China	33.43	39.43	43.93	42.09	42.49	41.34
USA	23.15	22.93	18.31	20.65	21.59	21.39

Source: authors' elaboration on the United Nations Development Programme database. URL: https://www.undp.org/ (retrieved on 20.03.2025).

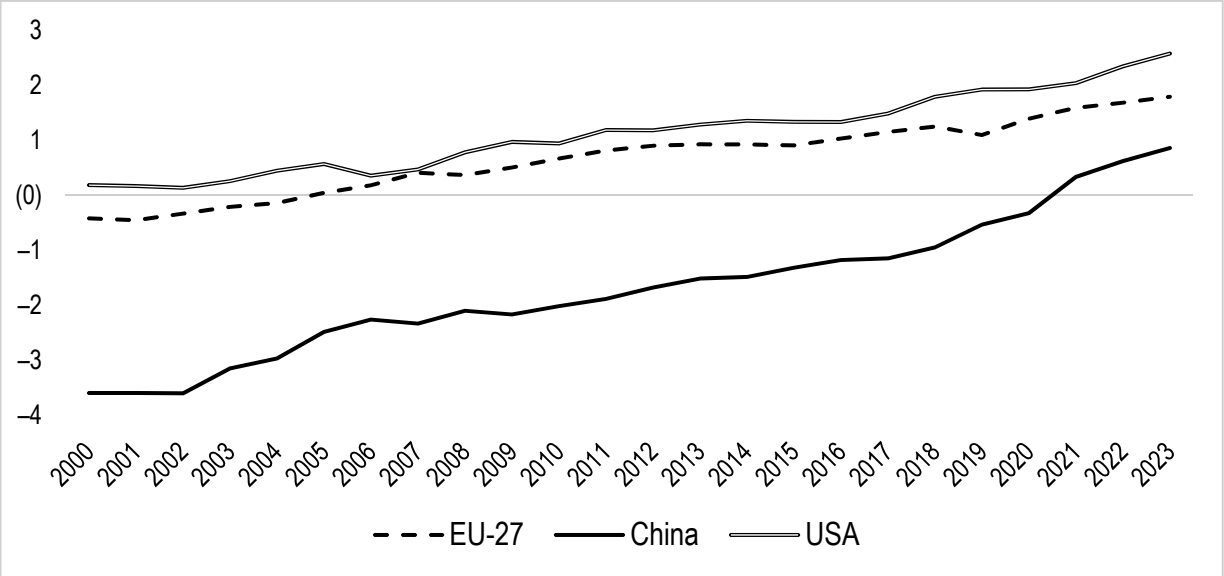

Fig. 3. **Composite index of the 'Technology' subblock of the 'Global competitiveness' block**

*Source: A*uthors' elaboration.

outstripping the level of the EU. Hence, China unambiguously bets on technological growth as a basis of its strategic autonomy in the world economy.

Infrastructure

Securing domestic infrastructure is of top priority for long-term national competitiveness. First and foremost, it refers to maintaining the performance of seaports, improving ICT technical potential, and upgrading logistic infrastructure.

As can be seen in *Fig. 4*, the USA maintains leadership among the three analysed technological cores in this domain. The European Union continuously lags behind the 'American core' with co-directional dynamics of the index. Chinese lagging behind the USA and the EU appears more evident and constant. The country barely manages to sustain a stable trajectory of ICT and logistics infrastructure development.

The USA is leagues ahead of other technological cores in transport infrastructure advancement, as suggested in *Table 5*. In 2023, the respective indices for the USA totalled 50.4, whereas for the EU it was only 48.6 and for China, even more modest, 38.1. Notably, over the course of the first decades of the XXI century, the American transport infrastructure development has been generally high, a trend supported by the index values steadily exceeding 60. Over the period of 2000–2011, China successfully upgraded its transport infrastructure — a respective index increased from 28.0 to 38.1 points. However, in the following years, no dynamics were observed.

Ecology

Figure 5 suggests that since the turn of the XXI century, both the EU and the USA have progressed in the transition to a 'green' economy, in spite of the fact that the USA moderately ceded their leading position to the EU after 2010. China, on the other hand, significantly lags behind the other major technological centres of the world economy regarding ecological aspects. The convergence between respective values of the index

Table 4
R&D expenditures, % of GDP, 2000–2023

Technological core	2000	2005	2010	2015	2020	2023
EU-27	1.76	1.78	1.97	2.12	2.30	2.32
China	0.89	1.31	1.71	2.06	2.41	2.56
USA	2.62	2.50	2.71	2.79	3.47	3.67

Source: The authors' elaboration of the United Nations Development Programme database. URL: https://www.undp.org/ (retrieved on 20.03.2025).

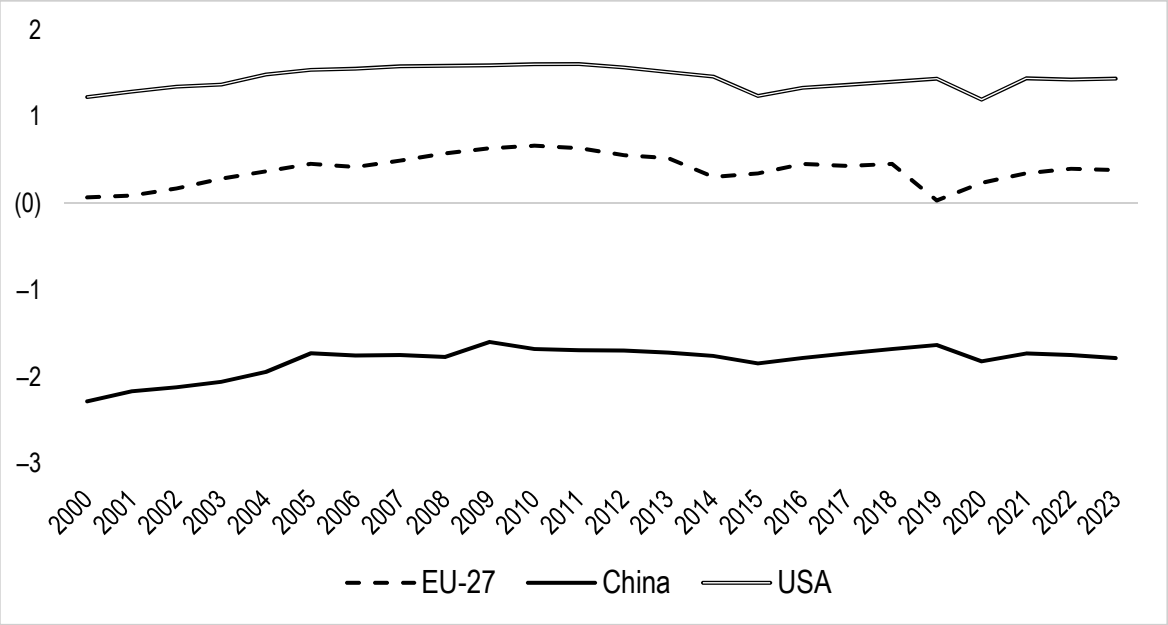

Fig. 4. **Composite index of the 'Infrastructure' subblock of the 'Global competitiveness' block**

Source: Authors' elaboration.

Table 5
UNCTAD Transport Infrastructure Index, 2000–2023

Technological core	2000	2005	2010	2015	2020	2023
EU-27	52.10	53.30	55.10	49.20	44.90	48.64
China	28.30	34.10	37.80	36.80	37.30	38.09
USA	64.70	65.20	64.80	58.50	55.00	58.40

Source: Authors' elaboration on UNCTAD Data Hub. URL: https://unctadstat.unctad.org/EN/ (retrieved on 10.03.2025).

for the three technological cores is absent during the whole studied period.

From 2000 to 2023, the European Union has successfully reduced the amount of CO_2 emissions by 10% (*Table 6*).

The United States managed to reduce CO_2 emissions by a substantial 24%. Concurrently, since the turn of the XXI century, China has demonstrated exactly the opposite dynamics. The amount of carbon emissions produced in China increased by a drastic 278% over the last two decades. In our opinion, considering the scale of the Chinese economy, such a tendency basically annihilates the efforts of the global community to promote a low-carbon economy.

By examining the composite index of the 'Global competitiveness' block, one can infer that over the whole interval under consideration, the USA demonstrated a continuous strengthening of competitive positions in the world economy (*Fig. 6*).

During the period of 2000–2023, the European Union has not sacrificed competitive positions

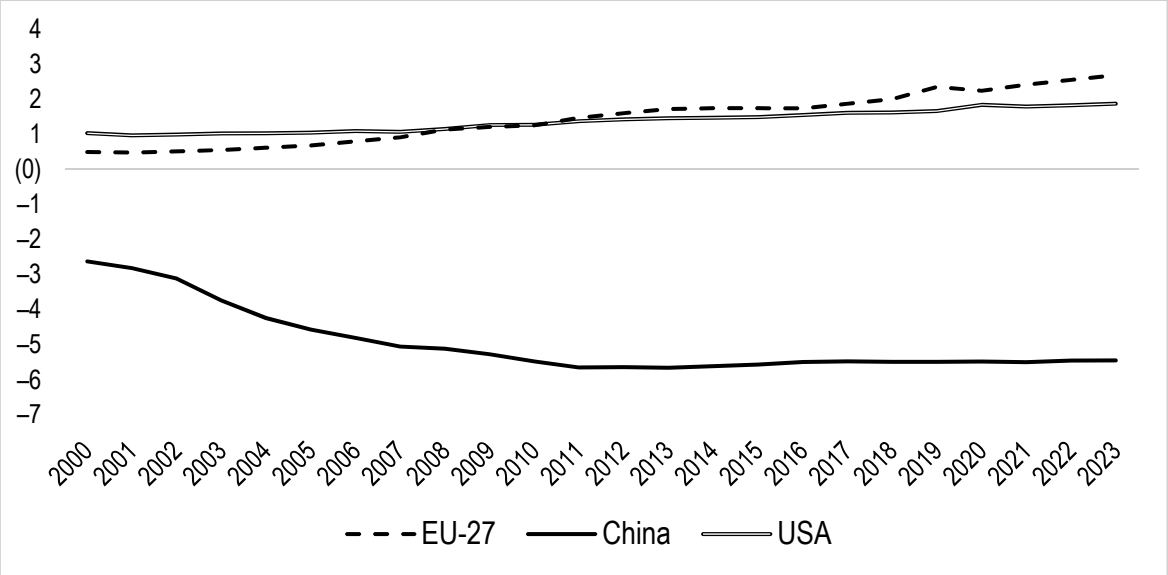

Fig. 5. **Composite index of the 'Ecology' subblock of the 'Global competitiveness' block**

*Source: A*uthors' elaboration.

Table 6

CO_2 emissions, index, 2000=100 points, 2000–2023

Technological core	2000	2005	2010	2015	2020	2023
EU-27	100.00	103.78	96.00	86.48	73.35	90.50
China	100.00	174.58	252.82	294.93	324.58	377.70
USA	100.00	99.53	93.41	86.02	74.31	75.80

Source: Authors' elaboration on World Bank Open Data. URL: https://data.worldbank.org/ (retrieved on 11.03.2025).

among technological cores. In the XXI century, China became a considerably larger geoeconomic power capable of preserving its actorness amidst global competition. The convergence of production and technological potential of the three cores is observed, which indicates the formation of a polycentric order in the global economy.

Figure 7 suggests that, according to the model, technologies and infrastructure are the most critical prerequisites of global competitiveness. The obtained results echo existing research on the role of innovations and servicing infrastructure, which supports the validity of the proposed methodology.

4.2. Strategic autonomy

Self-sufficiency in critical economic sectors

Figure 8 presents the composite index of the 'Self-sufficiency in critical economic sectors' subblock. Its values indicate that the USA is fairly independent from other countries in R&D and ICT. This allows American high-end manufacturing to leverage the risks of shocks originating in the global economy. China incrementally improves its self-sufficiency in critical industries. In 2023, the EU's domestic supply share in total R&D and ICT services consumption equals 87% and 83%, respectively, a level which might be considered low (*Table 7*). China's share of domestic value-added in the R&D sector is around 94%, whereas in the ICT industry it is only 88%. The USA maintains high self-sufficiency in both sectors.

Independence from products and final markets

Today, lowering dependence on foreign markets and specific traded products is one of the mainstays of achieving strategic autonomy of a national economy. To estimate the composite index of the 'Independence from products and final markets' subblock, the authors apply the Theil concentration index calculated separately for products and geographical partners in both exports and imports (*Fig. 9*).

The European Union is, to a large extent, independent from trade partners and certain goods among technological cores under consideration. The

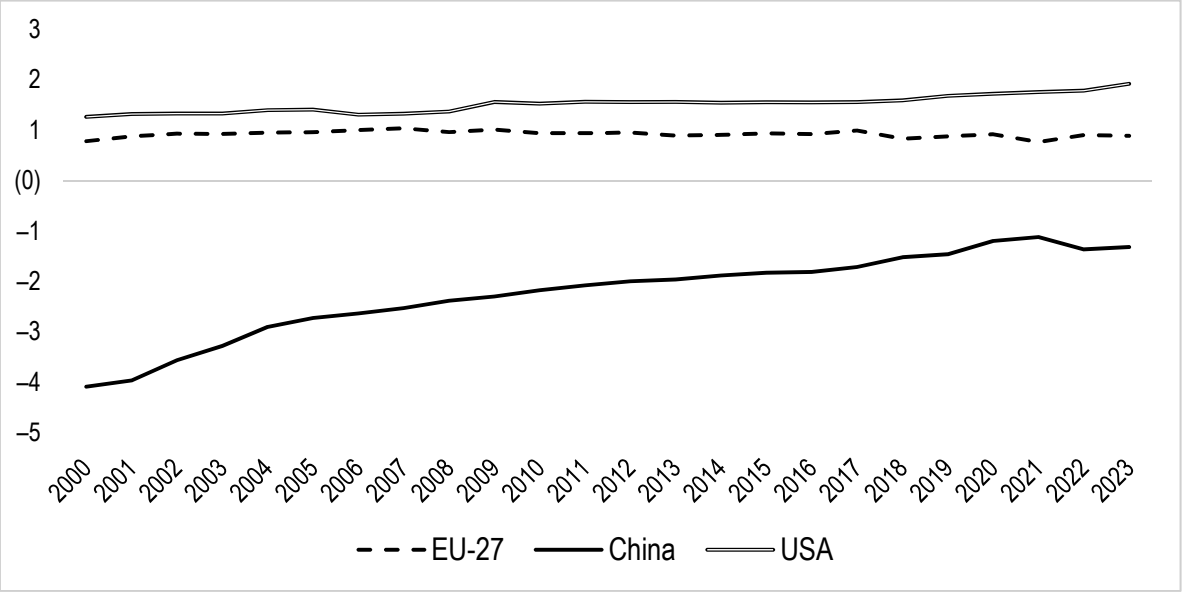

Fig. 6. **Composite index of the 'Global competitiveness' block**

Source: Authors' elaboration.

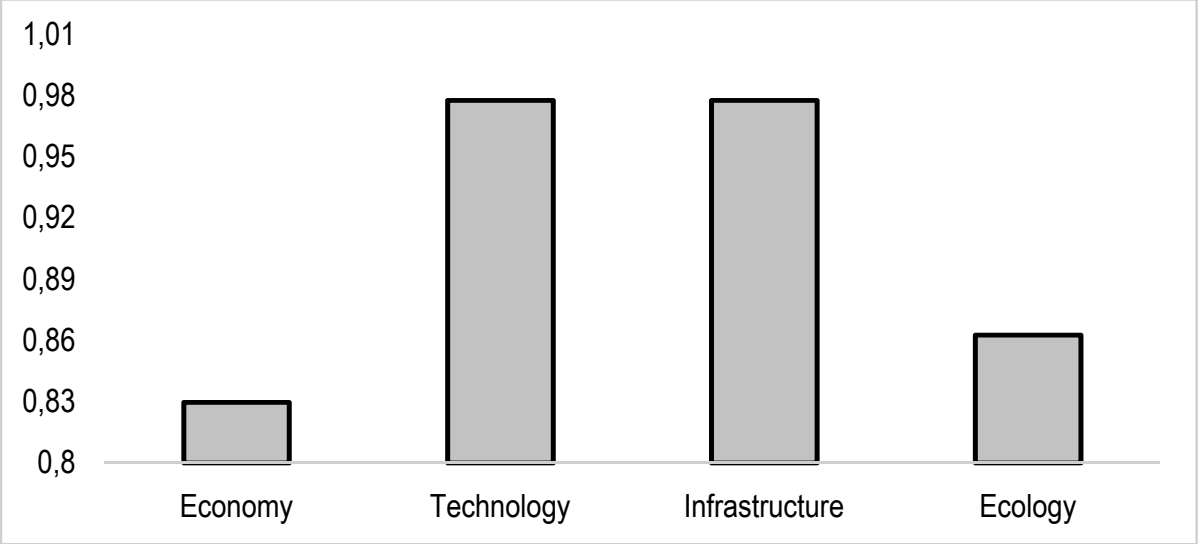

Fig. 7. **Aggregate contribution of specific subblocks in the composite index of the 'Global competitiveness' block, 2000–2023**

Source: authors' elaboration.

USA and China are much more dependent on the structure of their foreign trade. Nonetheless, China gradually diversifies its trade ties between different products and geographical partners. A considerable achievement of China is a notable expansion of the number of final markets: the Theil index has slumped from 3.0 points in 2000 to 2.1 points in 2023.

Resource autonomy

An important aspect of attaining strategic autonomy of a national economy is resource autonomy. The term 'resource' used in the calculation of the respective index (*Fig. 10*) encompasses arable land, natural resources, and energy in its various forms. In order to quantifiably estimate the self-sufficiency of technological cores in critical resources, the authors study the share of arable land, as well as the UNCTAD Index of accessibility of natural resources and the Index of energy accessibility.

As of 2023, the most autonomous in natural resources among technological cores is the European Union (*Fig. 10*). At the same time, the United States demonstrated a comparable trend. China's resource autonomy is relatively weak; however, by 2023, its gap with the EU and the USA will have considerably shortened.

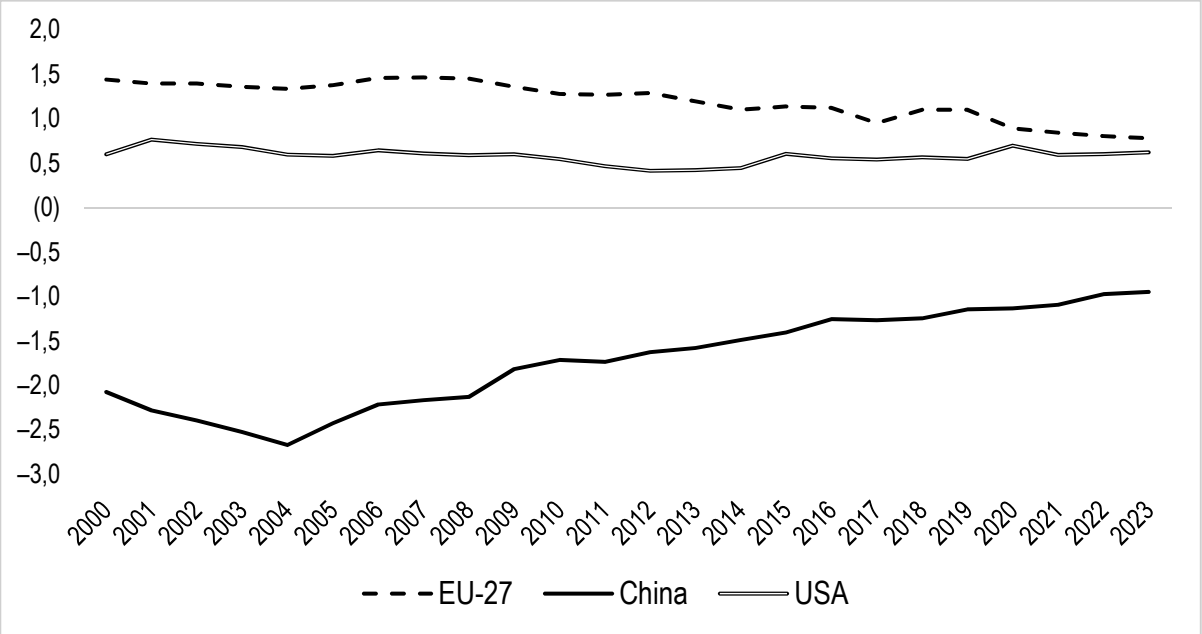

Fig. 8. **Composite index of the 'Self-sufficiency in critical economic sectors' subblock of the 'Strategic autonomy' block**

*Source: A*uthors' elaboration.

Table 7

Share of domestic value-added in total R&D expenditures, %, 2000–2023

Technological core	2000	2005	2010	2015	2020	2023
	Domestic value-added, % of total R&D expenditures					
EU-27	93.68	93.22	92.99	90.69	88.52	87.17
China	87.70	77.60	85.41	87.88	92.07	94.15
USA	96.85	96.01	94.99	94.93	96.10	96.56
	Domestic value-added, % of total ICT consumption					
EU-27	91.71	91.29	90.04	85.62	85.65	83.39
China	91.73	90.55	91.69	89.47	88.66	87.94
USA	97.05	96.60	95.92	95.47	95.60	95.66

Source: authors' elaboration on OECD Data Explorer. URL: https://www.oecd.org/en/data/datasets/oecd-DE.html (retrieved on 11.03.2025).

According to *Table 8*, in 2023, the share of arable land in the EU was 24.7% — the greatest level among all three technological cores. This can be viewed as a serious competitive advantage for the European economy in terms of food security. The USA is placed second, with the respective index being equal to 16.5%. China has the lowest share of arable land in the sample, at only 11.4%.

Accessibility of natural resources is the parameter in which China maintains sustained leadership; in 2023, the value of the respective index for the country totalled 39%. In the same period, the EU's value of the index was equal to 25%, while for the USA it amounted to 27%. Meanwhile, China experiences a dramatic decline in the index value, having lost 10 p.p. since 2000.

Figure 11 presents the composite index of the 'Strategic autonomy' block.

The European Union remains the most autonomous among all three technological cores under study, despite its weakening over the last years. In its turn, the United States continues to be self-sufficient in critical economic sectors, while it is still reliant on several geographical passports in foreign trade. At the very turn of the XXI century, China was heavily dependent on external resources, technologies, and final markets. Nonetheless, over the past fifteen years, the country has gradually improved its autonomy, coming close to matching the EU and the USA in relative terms. This indicates a tendency among technological cores to attain strategic autonomy, which

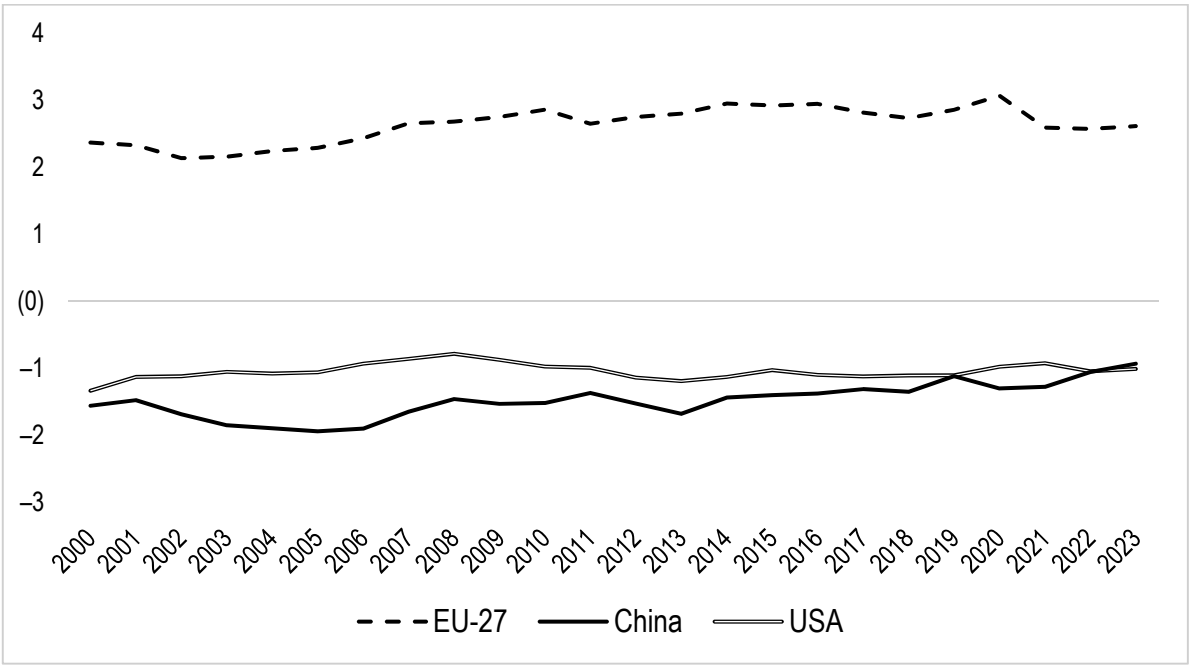

Fig. 9. **Composite index of the 'Independence from products and final markets' subblock of the 'Strategic autonomy' block**

*Source: A*uthors' elaboration.

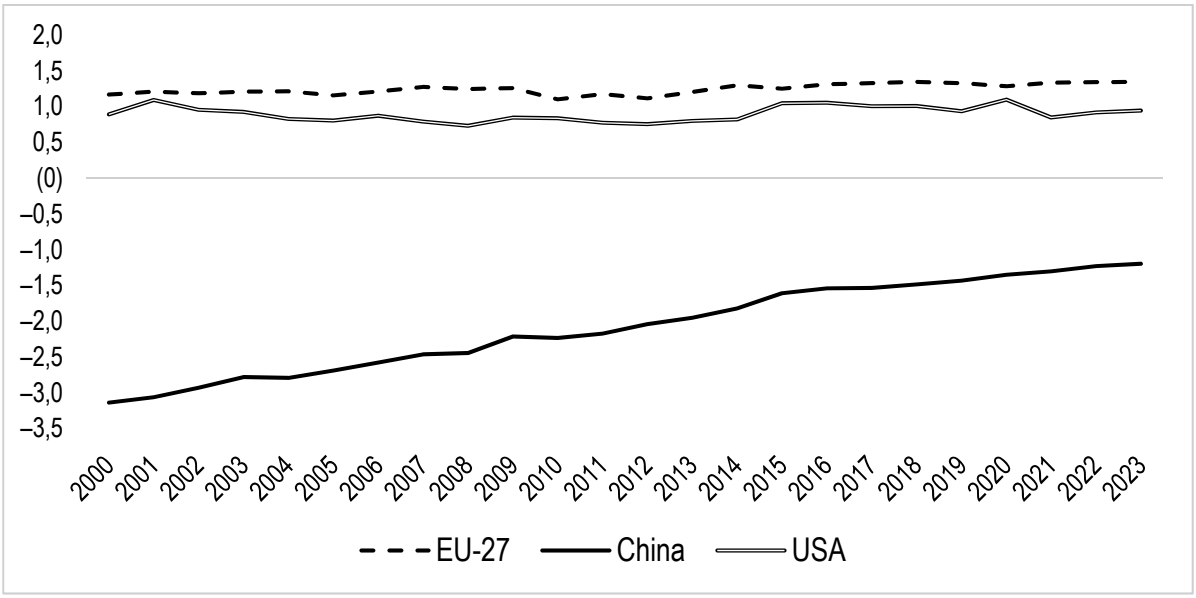

Fig. 10. **Composite index of the 'Resource autonomy' subblock of the 'Strategic autonomy' block**

Source: Authors' elaboration.

is also an argument in favour of the formation of a polycentric world order.

Finally, the composite index of the world economy technological core development calculated for the EU, the USA, and China is depicted in *Fig. 12*. It reveals several overarching trends of technological cores' formation in the XXI century.

Before the global financial crisis of 2008–2009, the general level of technological core development of the EU and the USA was comparable. Afterwards, an expanding gap between these two cores is observed; thus, the United States is now the largest technological core of the world economy with respect to both global competitiveness and strategic autonomy. The negative trend attributable to the European Union aligns with a commonly held academic conception of a serious crisis that the European economy is now facing. The above propositions are convincingly voiced by M. Draghi in his report entitled 'The future of European com-

Table 8

Arable land (% of total land) and UNCTAD Index of natural resources accessibility, 2000–2023

Technological core	2000	2005	2010	2015	2020	2023
	Arable land (% of total land)					
EU-27	27.41	25.99	25.30	24.99	24.85	24.72
China	12.68	12.85	12.80	12.24	11.58	11.38
USA	19.15	18.88	17.68	17.10	16.83	16.48
	UNCTAD Index of natural resources accessibility					
EU-27	29.60	28.10	27.80	25.80	24.80	24.77
China	47.80	48.10	47.50	42.00	39.80	39.16
USA	30.60	30.80	28.30	24.70	25.10	26.57

Source: authors' elaboration on UNCTAD Data Hub. URL: https://unctadstat.unctad.org/EN/ (retrieved on 10.03.2025).

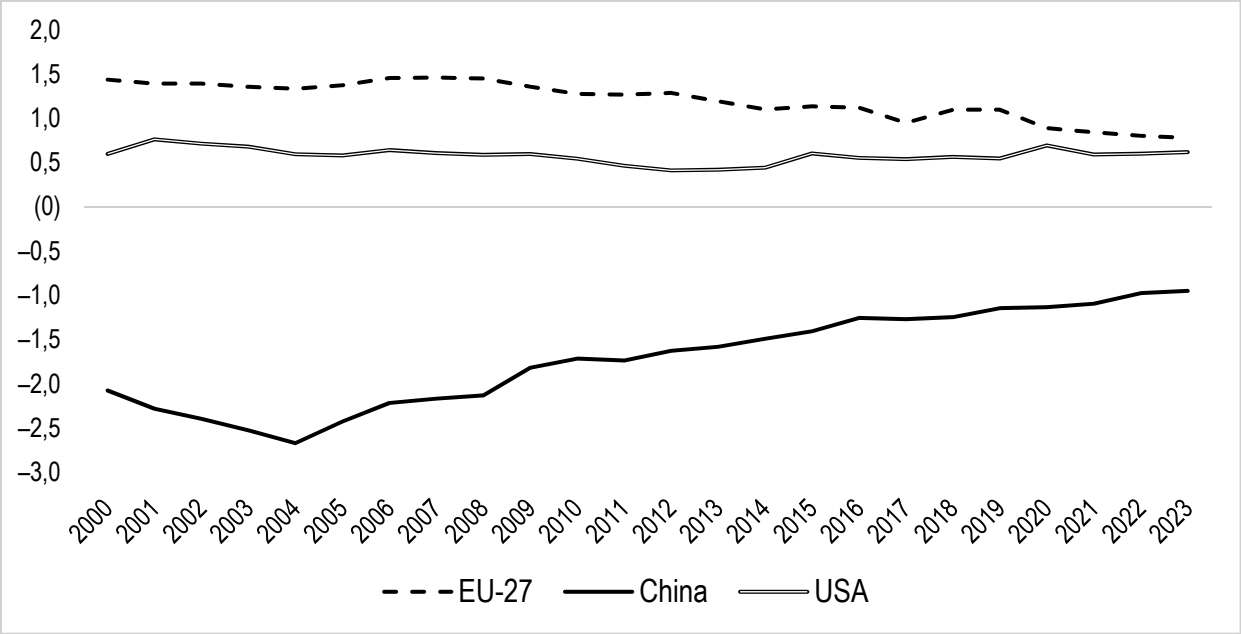

Fig. 11. **Composite index of the 'Strategic autonomy' block**

*Source: A*uthors' elaboration.

petitiveness'.[4] Nowadays, the European Union confronts a series of challenges posed by a diminishing share of its economy in global GDP, increasing dependence on resource and component supplies. This trend is particularly evident in electric car manufacturing, where a sheer amount of critical raw materials (i.e., dysprosium, neodymium, etc.) is supplied by China. In the present study, a growing dependence of the EU on vitally important services sectors (ICT and R&D) has been uncovered. The problem is not yet fully elaborated in academia. Meanwhile, the European Union favours a highly diversified foreign trade profile that is essentially a prerequisite for the long-term sustainability of a technological core amidst crises in the world economy [41].

Conceptually, the obtained results correlate with existing research. Russian researchers [42] highlight that an accelerated growth of China as a global technological superpower is largely predetermined by a unique combination of institutional reforms and effective structural policy, as well as a high capital accumulation ratio (reaching 44% of GDP). Another crucial factor behind Chinese technological core formation is a transition from a simple export-led model to a strategic positioning in the world economy — promoting new integration initiatives (BRICS, SCO), financial institutions, etc. [43].

[4] European Commission. The Draghi report on EU competitiveness. URL: https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en

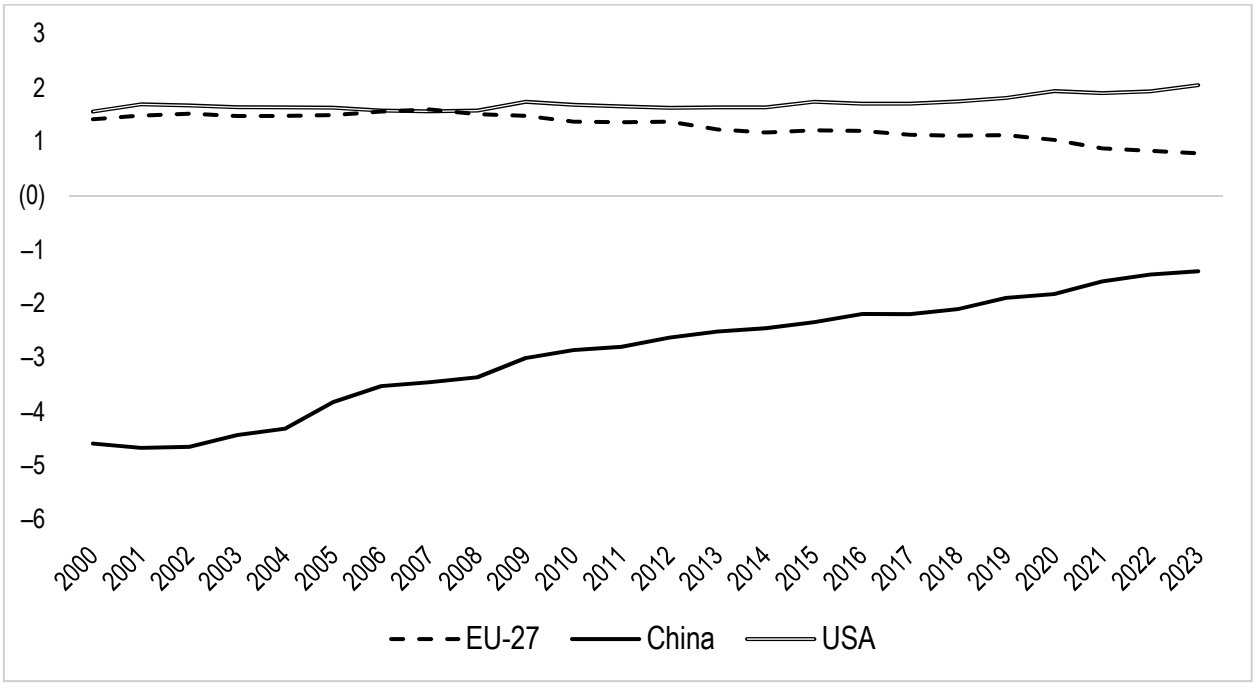

Fig. 12. **Composite index of the world economy technological core development calculated for the EU, the USA, and China, 2000–2022, with zero being a medium level**

Source: Authors' elaboration.

Summing up, over the course of the first quarter of the XXI century, China is rapidly reducing the gap with the USA and the EU. Nonetheless, according to our estimations, the variation coefficient of the difference between values of the composite index for three technological cores amounted to 34% in 2023, indicating a persisting high level of Chinese lagging behind the EU and the USA.

5. Conclusions

This article presents approaches to constructing an integral index of the formation of technological cores of the world economy, using the USA, EU and China as the empirical base. The integral index includes key indicators of global hypercompetition and strategic autonomy of technological cores in the context of a growing trend towards neo-protectionism. The baseline indicators are publicly available, which ensures the reproducibility of our results and allows for the assessment of the index dynamics in the future. In addition, the applied principal component method as a tool for combining individual indicators into a single index also allowed for obtaining separate sub-indices for individual blocks of hypercompetition and strategic autonomy. This facilitates the search for the root causes of trend development and the transformation of relationships between technological cores.

The empirical estimation of the proposed composite index indicates a qualitative growth of the competitive positions of China in the world economy. At the same time, our calculations indicate the existing gap between the PRC and the "Western" cores. According to the obtained values, the competitive positions of the EU and the USA are maintained at approximately the same level. At the same time, after the 2008 crisis, the situation of the European core has worsened [44].

In conclusion, it is worth highlighting some of the individual results that shed light on current aspects of the formation and development of the technological cores of the global economy. Firstly, as the analysis of the economic complexity indicator showed, the EU industry produces more complex and knowledge-intensive products than the USA and China. Secondly, in terms of the amount of investment in R&D in relation to GDP, China has currently overtaken the EU indicator, continuing its confident growth. Thirdly, the United States maintains its leadership in terms of the development of transport and logistics infrastructure. Since the beginning of the XXI century, China has experienced a stagnation in this sphere. Fourthly, China is showing negative dynamics in carbon di-

oxide emissions, the volume of which has increased almost threefold over the past two decades. Fifth, the European technological core is strengthening its strategic dependence in the key service sectors of the new order. In other words, high-end manufacturing in the EU is increasingly served by external technologies and communications. Sixth, the geographical structure of EU foreign trade is more diversified between individual sales markets than in the case of the USA and China. Last but not least, our analysis of the natural resource availability index showed that the PRC currently maintains a confident leadership in the degree of self-sufficiency in natural resources, primarily in critical raw materials of the new technological order.

To conclude, the presented method of constructing the integral index allowed for the identification of the current trends of three modern technological cores of the world economy, namely the USA, the European Union and China. The obtained results confirm the accelerated strengthening of the geoeconomic position of China. Future research could focus on examining the correlation between the novel index and the indicators of a country's or macroregion's institutional and political structure.

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Role of Civilizational Culture in Establishing a New Era in China–Arab States Economic Relations

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ABSTRACT

On May 30, 2024, Beijing hosted the 10th jubilee ministerial meeting of the China-Arab States Cooperation Forum (CASCF). It intended to open broad horizons for developing China-Arab relationships, based on a common future and civilizational dialogues. Hence, the **subject** of the present study is constituted by analyzing the role of civilizational culture in establishing a new era in China — Arab states trade and economic relations. The **purpose** is to identify most significant features of the Chinese and Arab cultures and their relevant business practices, which could assist in navigating more easily while conducting cross-cultural business communications at the levels of states, companies, and individual entities. The **relevance** of the research relates to the growing importance of non-confrontational political, economic, and cultural tools of "soft power" in enhancing Beijing's role across the MENA region. The **scientific novelty** of the article stems from the use of a vast variety of sources in Arabic, Chinese, and Russian, inaugurating some of them into scientific domain. The list of the **methods** includes comparative and systems analysis, as well as the empirical method of field research, sampling, observation, grouping, generalization, and systematization, following historical, convergent, and synergetic **approaches**. The **results** of the study enabled the authors to make recommendations about organizing future expert discussions and scientific publications with the comparative analysis of the Chinese and Arab cultures. The authors **concluded** that sharing common ethic fundamentals by the Chinese and Arabs could create a favorable ground for fulfilling the Arab dimension of China's Global Civilization Initiative.

Keywords: civilizational culture; multi-cultural dialogue; MENA region; China-Arab relations; China's Global Civilization Initiative; China-Arab States Cooperation Forum; business communications; international economic relations

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ОРИГИНАЛЬНАЯ СТАТЬЯ

Роль цивилизационной культуры в установлении новой эры в экономических отношениях Китая и арабских государств

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АННОТАЦИЯ

30 мая 2024 г. в Пекине состоялась 10-я юбилейная министерская встреча Форума сотрудничества Китая и арабских государств (CASCF). Она была призвана открыть новые горизонты для развития китайско-

арабских отношений, которые основывались бы на общем будущем и цивилизационных диалогах. **Предметом настоящего исследования** является анализ роли цивилизационной культуры в установлении новой эры в торгово-экономических отношениях между Китаем и арабскими странами. **Цель** состоит в том, чтобы выявить наиболее существенные черты китайской и арабской культур и связанных с ними деловых практик, что могло бы облегчить выстраивание кросс-культурных деловых коммуникаций на уровне государств, компаний и физических лиц. **Актуальность исследования** связана с растущей значимостью неконфронтационных политических, экономических и культурных инструментов «мягкой силы» в контексте усиления роли Пекина в Ближневосточном регионе. **Научная новизна** обусловлена использованием широкого круга источников на арабском, китайском и русском языках с введением ряда из них в научный оборот. Перечень **методов** включает в себя сравнительный и системный анализ, а также эмпирический метод полевых исследований, методы выборки, наблюдения, группировки, обобщения и систематизации — при следовании историческому, конвергентному и синергетическому **подходам**. **Результаты исследования** позволили авторам сформулировать рекомендации по организации будущих экспертных дискуссий и научных публикаций со сравнительным анализом китайской и арабской культур. Авторы пришли к **выводу** о том, что наличие общих этических основ у китайцев и арабов может создать благоприятные условия для успешной реализации арабского измерения китайской Глобальной цивилизационной инициативы.
Ключевые слова: цивилизационная культура; мультикультурный диалог; регион Ближнего Востока и Северной Африки; китайско-арабские отношения; Глобальная цивилизационная инициатива; Форум сотрудничества Китая и арабских государств; деловые коммуникации; международные экономические отношения

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1. Introduction

Different civilizations and countries have developed their own cultural traditions, which largely influence and even determine their communications and business behavior. Facing the acceleration and enhancement of globalization processes around the world, the importance of such traditions in terms of facilitating cross-cultural communications, as well as solving interstate difficulties and avoiding tensions in international trade, has been increasing. Hence, research in this particular area has acquired particular relevance, for instance, in light of the growing Arab-Chinese trade, energy, investments, and technological cooperation related to Beijing's "Belt and Road" global transport initiative. Those facts logically explain the reason for choosing the subject of the present article.

European studies historically distinguish the main dichotomies (dimensions) of national cultures and the factors that shaped them [1, p. 69]. According to M. Weber, modern capitalism and its rationality are associated with the peculiarities of national mentality. Thus, in his famous work "The Protestant Ethic and the Spirit of Capitalism", he raises most important issues related to the formation of rational economic thinking under the influence of a certain sociality, conditioned by national religion and culture [2, p. 6]. C. Joinson emphasizes the importance of the concept of cultural sensitivity, manifesting itself in sincere concern for people from other cultures. Such cultural sensitivity requires decision makers to understand the way of thinking of those who live in other cultures, since this is what primarily influences the success of interstate projects and organizational processes in intercultural spaces [3, p. 4]. K. Polanyi calls the national socio-cultural background a "restraining factor" for economic development of a country and a region, while social institutions, in his view, ensure the harmonious development of any state and society [4, p. 255]. D. Landes, after examining the "successes of minorities in foreign lands" (Chinese in Southeast Asia, Jews and Calvinists in Europe, etc.), came to the conclusion that culture, with its deep values and attitudes, determined the economic behavior of masses, pushing them to carry out certain acts of economic activity [5, p. 38].

In turn, G. Hofstede defines culture as a collective mental programming and a part of the predetermination of our perception of the world, common with other representatives of our nation, region or group and distinguishing us from representatives of other nations, regions, and groups [6, p. 36]. He also argues that features of national culture and mentality could serve as tools for solving many problems in the interaction of representatives of different countries. In national culture, Hofstede

identified the following dichotomies: Individualism/Collectivism, Power Distance, Uncertainty Avoidance, Masculinity/Femininity. Subsequently, K. Leung, M. Bond, and S. Schwartz added the fifth dimension, namely, attitude to time (short-term and long-term), also called the "Confucian dynamism factor." Remarkably, the process of further research proved that those parameters alone were not enough to truly understand the modalities of economic behavior of the inhabitants of the East, although at the same time they allowed for understanding the behavior of Europeans and North Americans quite well [7, p. 73].

Therefore, in the era of globalization and growing economic interdependencies, the practical imperative of overcoming an objective disadvantage of studying Western cultural traditions separately from the Eastern (Oriental) ones, and vice versa, similarly to the existing studies of individual Eastern cultures, determines the need to compare different civilizations and cultures, finding their outstanding common and unique features. This task becomes particularly relevant for analyzing not just regular cultures but civilizational cultures with thousand-year histories, such as the Chinese civilizational culture covering vast political-geographic areas.

Taking into account the above-mentioned, an important common feature of the Chinese and Arab cultures is embodied by their civilizational character, characterized by oriental identity and uniqueness; they are either still largely geographically isolated in the case of China or covered by the broader Islamic world in the case of the Arabs. Not by chance, in the 1990s, Samuel Huntington singled out the Sinic (Chinese) and Islamic civilizations separately from the Western civilization. In his view, the Sinic civilization relates to all of Vietnam, mainland China, including the Chinese island of Taiwan, but without the "Western" Hong Kong, along with both Koreas [8, p. 26–27]; meanwhile, the Islamic civilization includes Arab countries, or the Arab world (*Al-Watan Al-Arabi* in Arabic). For the purpose of the present article, the notion of the Arab world applies to the vast geographical area encompassing 21 member countries of the League of Arab States (LAS), excluding the remote Comoros, i.e., the macro-region of the Middle East and North Africa (MENA) with the adjacent Horn of Africa.[1]

Interestingly enough, Huntington's approach at least partly correlates with the later gradation of civilizations proposed by a leading Russian neo-Eurasian philosopher, A. Dugin, who calls both the Chinese civilization and the Semitic civilization of the borders (which includes the Arab-Islamic civilization) civilizations "beyond the West" in Eurasia [9, p. 21; 10, p. 492]. Another substantial marker of the civilizational nature of both cultures is constituted by the self-perception of their identities, which is in the Chinese case linked with the emerging paradigm of states-civilizations (civilization states). Not by chance, the Armenian researcher H. Bardakchyan calls China a paradigmatic example of a state-civilization, referring to the longevity and clear cultural continuity of Chinese dynasties and political regimes [11, p. 11].

Quite naturally, the issues of cultural determinacy of economic and social life of people, recognized by Chinese thinkers for many centuries, still create a subject of deep study in the context of returning to the imperial ideas about the superior uniqueness of the Chinese civilization. For instance, Ma Zhiqing notes that cultural development is a decisive factor in the development of a national economy, i.e., a more developed culture means a more developed economy. Importantly, the same author notes that the creation of regional trade alliances, such as the European Union and the North American Free Trade Agreement, couldn't eliminate the influence of cultural differences on interethnic dialogues [12, p. 17].

On a more practical level, Song Yilin, studying the features of Chinese national corporate culture, says that national corporate culture, being a set of common values, credos and codes of conduct, represents a key element of management and long-term development [13, p. 85]. Li Guizi, for his part, outlines that in China, the Confucian culture, which has been dominating for many centuries, produces a profound influence on customs, moral ethics, life views, values, and other civilizational traditions of the Chinese nation. At the same time, in the era of inter-country competition and economic globalization, traditional culture keeps playing

[1] The notion of the Middle East and North Africa (MENA) is broadly used in both scientific and expert domains, being reflected in documents of the United Nations, the World Bank, and other international organizations: MENA. United Nations Global Compact. N/d. URL: https://unglobalcompact.org/engage-locally/mena (accessed on 09.01.2025); Middle East and North Africa: Overview. The World Bank e-resource. 15 Dec 2021. URL: https://www.worldbank.org/en/region/mena/overview (accessed on 11.01.2025).

either a positive role in promoting or a negative role in restraining the development of corporate governance practices [14, p. 216].

At the same time, the Arab world, although geographically not localized but covered by the Islamic civilization, will forever remain the cradle of the Islamic religion as such. Importantly, Islam (which currently unites more than 2 billion followers) has been no less, if not more, influential than Confucianism in China and has been deeply influencing the economic and social life of Arab countries from the very top to the bottom and vice versa, forming nearly 1400-year-long traditions of civilizational culture. Moreover, since the 1990s' post-Cold War ideological crisis, the importance of those traditions and relevant rules has been constantly increasing across the whole MENA region.

Thus, the fundamentals of Arabs' ethics (*akhlaq* in Arabic), business behavior, and trade, such as permitted activities (*halal*) vs. taboos (*haram*) are consecrated by the provisions of the Holy Quran, hadiths of Sunnah, and their interpretations by prominent Oriental thinkers, such as Imam Mohammed al-Bukhari (810–870), who is recognized as the most distinguished scholar of Hadith in Islamic history [15]. The authors also referred to the relevant historical and contemporary views presented by R. Abdel Hamid, H. Basmisirli, Z. Muttaqin, and other scholars, covering the basic ideas of Arabism, Islamic morality, *halal*, and Arab hospitality vs. excessive behavior (*israf*), along with the basic rules of Islamic banking.

In summary, this study focuses on analyzing how civilizational culture contributes to establishing a new era in trade and economic relations between China and Arab states. Hence, the authors, fulfilling the *purpose* of the research, outlined the most significant features of the Chinese and Arab civilizational cultures related to their business practices in the general context of building the Chinese-Arab partnerships at the present stage. Such analysis could assist in navigating more easily while conducting cross-cultural business communications at the levels of states, companies, and individual entities. Meanwhile, the *relevance* of the selected topic relates to the growing importance of non-confrontational political, economic, and cultural tools of "soft power" in enhancing Beijing's role across the MENA region, bearing in mind that the relevant experiences could become advantageous for Russia and other countries. The *scientific novelty* of the article stems from the use of a vast variety of sources in Arabic, Chinese, and Russian, inaugurating some of them into the scientific domain.

2. Materials and methods

The goals and objectives of this study are implemented by using the methods of comparative and systems analysis, as well as sampling, observation, grouping, comparison, generalization, and systematization.

The method of comparative analysis as prioritized by the authors enabled them to identify common and distinct features of the Chinese and Arab civilizational cultures and business ethics. Those influence cross-cultural communications, trade, and economic relations between the People's Republic of China and different Arab states. Hence, the present article could be fully recognized as a comparative one.

At the same time, the historical analysis of practical and theoretical material allowed the authors to draw appropriate conclusions. In that, they referred to a scope of notions and works previously developed by European, Chinese, and Arab scholars, among them R. Lewis's model of cultural types, as well as relying on their own business, diplomatic, and academic experiences of dealing with Arab countries and China.

The convergent approach is based on the acknowledgment of the fact that China and the Arab countries have become key and important players in the emerging multipolar world. It implies the synthesis of accumulated data aiming to formulate recommendations for doing mutual business.

The synergetic approach provided the authors with an opportunity to take a closer look at the current and future harmonization of the China-Arab dialogue, taking into account mental, religious, legal, ethical, and professional peculiarities of the Chinese and Arab civilizational cultures, which nowadays serve as either catalysts or inhibitors of qualitative transformations of bilateral and multilateral relations between states.

Specifically, the authors used the empirical method, conducting a series of expert interviews with business and academic professionals to identify distinctive features of business behavior and the ethics of negotiations inherent to Arabs and Chinese. From May to October 2024, ten (10) senior employees of multinational corporations and companies from the People's Republic of China

were interviewed on condition of anonymity, both in face-to-face conversations and with the use of remote technologies in Beijing, Qingdao, Shenzhen, and Moscow. Those business entities operate in Russia and Arab countries, specializing in the manufacturing and sales of large household appliances and consumer electronics, as well as the automobile industry. The respondents included five (5) CEOs and heads of overseas offices of the above-mentioned Chinese companies, three (3) brand development directors, and two (2) human resources (HR) managers.

During the same period, parallel field research of the Arab civilizational culture was carried out using both interviews and visual observation. The personal meetings, negotiations, and online conversations covered ten (10) representatives of business, academic, and expert circles of Egypt, Lebanon, the United Arab Emirates, Syria, and Yemen (Aden). Among them were one (1) head of a Russian-Arab business council, one (1) head of a Federation of Industrial Chambers, one (1) industrialist and merchant, two (2) top employees of a service company, one (1) franchise specialist, one (1) corporate and arbitration lawyer, one (1) business consultant, and two (2) top representatives of university administrations involved in the training of economic specialists.

Eventually, the empirical methods allowed the authors to gain access to uncodified data, individual opinions, and reputed experts' assessments, which contributed to a certain increase of knowledge related to the Chinese and Arab civilizational cultures, especially as part of a mutual comparison.

3. Results and discussion

3.1. Fundamentals of the Chinese civilizational culture and business approaches

Chinese civilization has gained more than 5,000 years of continuous history. In the "cycle of chaos" of successive dynasties, the traditional Chinese family continued to maintain authentic Chinese culture in a relatively stable status quo. Despite certain periods of upheaval, including the active foreign presence in China during the Mongol rule or the Opium Wars, those civilizational values were not abandoned but became an important part of the Chinese cultural code, harmoniously integrated into the modernization of contemporary China.

Among the striking features of Chinese traditions, it is worth highlighting the family hierarchy. The most respected members of the family are grandparents. Then, in descending order, come parents, children, grandchildren, and great-grandchildren. The Father is endowed with special patriarchal features, since he bears all responsibilities for providing for and protecting the family. The wife and children occupy a subordinate position. In a modern Chinese family, gender roles often change: if a woman works, the family structure becomes more matriarchal. Nevertheless, the tradition of respect for elders and care for younger ones continues to be reproduced.

In business, this civilizational tradition is manifested by the perception of the owner of the enterprise as the father of the family with the corresponding attitude. The value of traditional family ethics in China lies in the ethical responsibility of family members for the common cause, shown both in everyday and economic life [16, p. 85]. This helps to smooth out the contradictions that arise in the process of economic modernization, using Chinese families in administrative ethics, as well as management of business and the state. In the modern logic of "integration of family and country" within the framework of economic modernization, China follows centuries-old traditions of integrating life, nature and man, just perceiving the whole world and society as one family [17, p. 85].

Family spirit as a key feature of the Chinese business culture is also seen in the prevalence of family-run businesses. Such small and medium-sized businesses constitute the backbone of the Chinese economy, receiving significant government support in the form of simplified taxation and benefits. As the head of the HR department of the largest Chinese manufacturer of household appliances noted, it is now very common to find enterprises where three to four generations of one family work together. Here, Chinese business partners look like a clan: the head of the company is usually called *laoban* by subordinates, which could be translated as "the highest respect and command." As noted by Wan Jiangxin [18, p. 23], during negotiations with the Chinese side, this special attitude towards the Boss is especially pronounced, since in China "corporate culture is the culture of the Boss." The family spirit of a Chinese delegation is also reflected in mutual assistance, collectivism, and the absence of selfishness in decision-making.

Closely connected with the perception of all the states of the world as a large family is the Chinese concept of the "middle state" (*Zhongxin zhi guo*). The ancient Chinese shaped the earth as a square with China in its center. The geographical position of China contributed to the idea that it was the center of the world. Isolated from the rest of the world by natural barriers (mountains and seas), the Chinese created a civilization that adopted virtually nothing from contacts with any other people at the same stage of development as them, right up until the middle of the 19th century. Thus, the Chinese world order was represented by China, located in the center, and the barbarian periphery — all other states. *Fig. 1* illustrates the structure of this world order:

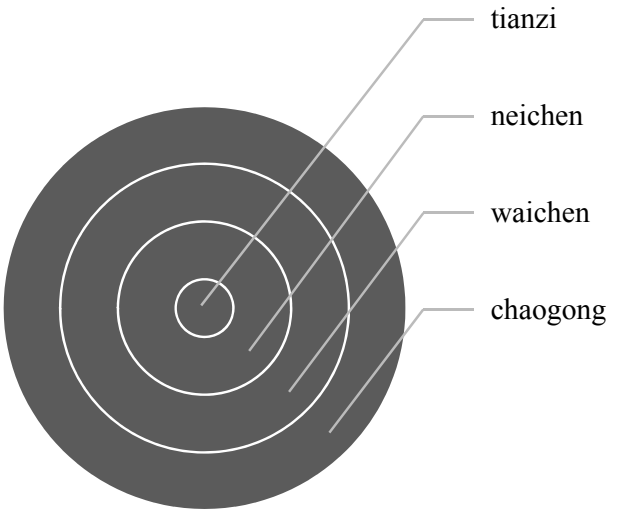

Fig. 1. **The structure of the world order in ancient China**

Source: Compiled by the authors.

The following categories are distinguished:

- *tianzi* — son of heaven, head of the middle state, emperor;
- *neichen* — close confidant of the emperor;
- *waichen* — foreign subjects, vassal territories;
- *chaogong* — foreign subjects who brought tribute on a permanent basis.

At the head of everything was the emperor *tianzi*, to whom all things were subordinated. The immediate circle included *neichen*, i.e. imperial nobility, ministers, and assistants. *Waichen* and *chaogong* were representatives of the territories under Chinese rule. This concept was the idea of an ideal state in the period before and during the Qin Dynasty. During the Han Dynasty, this concept became a reality, and the entire region of East Asia was included in the tribute system, the core of which was Chinese civilization [19, p. 70].

In addition to the above categories, northern, southern, western and eastern barbarians were also distinguished on the external contour of communication with the world. Thus, the world in Chinese was represented by the central state *tianxia zhongxin* (the center of the Celestial Empire, i.e. China) and the barbarian periphery (other states). At different times, representatives of other peoples were treated either with contempt or condescension. As the brand development director of a large Chinese company in the telecommunications sector notes, in local business culture this is manifested by the fact that the Chinese in general are indulgent towards foreign partners who do not speak Chinese but can establish very close friendly contacts making big concessions and discounts to those representatives who speak or at least study Chinese. In contrast, the foreigners who speak Chinese fall into one of the categories of the circle shown in *Fig. 1*, thus, becoming part of the Chinese world.

This is also reflected in the specifics of accepting Western business practices. As a rule, they are not accepted in their pure original forms, undergoing "Chinese modernization," over time acquiring Chinese national characteristics and eventually becoming part of the Chinese inner world [20, p. 5]. Hence, under the Chinese model, any mixture of traditional business culture represented by Confucianism and the market economy's rules is implanted into the long-term business practices of local entrepreneurs through mutual transformation and complementary integration under the motto of Chinese wisdom, as it is said in the Chinese Global Civilization Initiative [21].

Richard Lewis places the Chinese among the nations of the reactive culture [22, p. 102]. Thus, the Chinese business culture gives great value to friendship and family harmony, which is reflected in the negotiation process through flowery speeches and the absence of direct dialogue in order to avoid confrontation. It also respects patience, persistence, and perseverance. During talks, the Chinese usually listen to their vis-à-vises silently and calmly, reacting very carefully to proposals. As the director of an overseas office of a major Chinese consumer electronics company notes, the Chinese rarely use the word "*no*" in negotiations; instead, they say *daoshihou* ("when the time comes"). Extremely long silences make people from the West think that their Chinese partners have nothing to say, but in fact,

they just need time to make a balanced, usually collective decision. Naturally, in Chinese corporate behavior, whereas hierarchy and the abovementioned family spirit are important, decisions are often made in the interests of the whole team.

During negotiations with the Chinese, as the general director of the overseas representative office of a major Chinese electric vehicle manufacturer emphasizes, it is particularly important to observe Chinese ceremonial etiquette, which is an integral part of the Chinese civilizational culture, embodying Chinese virtues. Meaningfully, the Analects of Confucius says, "If you do not learn etiquette, you will not be able to stand up," which means that only by paying special attention to politeness and etiquette can one achieve goals. Here, it is worth mentioning the following details [23, p. 119]:

1. *Appearance*. The Chinese are very careful about their clothes, shoes, and accessories. They usually dress modestly but neatly, not allowing themselves to be careless. Women prefer to wear simple jewelry to demonstrate a sense of elegance and generosity. Any bright clothes, according to the Chinese, leave the other side with the impression of instability and frivolity.

2. *Behavior*. As noted above, the Chinese are careful and polite in negotiations, trying to gain the respect of others. In a favorable situation, one shouldn't show pride or happiness, while if the situation is unfavorable, one shouldn't be sad.

3. *Dining etiquette*. Here, the Chinese pay more attention to the seating order. It is viewed as an important symbol, allowing one to distinguish between higher and lower ranks: people with their ranks in descending order sit from south to north on the western side of a table. Thus, the place in the farthest position is recognized as the most prestigious, while the place closest to the door is the most modest.

4. *Greetings and farewells*. In ancient times, "bowing" and "kneeling" were common. Nowadays, a handshake typically takes their place. However, in a particularly friendly atmosphere, the Chinese may bow when saying goodbye as a sign of special respect. Special greeting etiquette includes the etiquette of exchanging business cards.

According to the precepts of Confucius, the Chinese try to achieve harmony during negotiations. "Harmony is the most valuable thing, and harmony brings wealth." That is why the Chinese are almost never late for meetings but arrive early. They believe that to ensure the success of the final talks, one can sacrifice own interests and time, showing respect for the interlocutor.

As the development director of a major Chinese automaker says, the Confucian business spirit in China puts "righteousness" above "profit." In negotiations and transactions, a *junzi* (noble man) must adhere to the basic principle of putting justice above profit. Just pursuing one's egoistic interests won't bring any success, possibly leading to a one-time profit deal without a long-term value. The main goal of negotiations, according to the Chinese, is to achieve mutually beneficial cooperation. This goal is coined in a main Chinese treatise of antiquity, namely, the "Historical Notes" [24, p. 68]. Therefore, the Chinese highly value personal communication and the establishment of long-lasting and stable friendly relations.

Friendly relations with Chinese businessmen are often ensured through congratulating them on traditional Chinese holidays. As the brand development director of a Chinese manufacturer of household appliances and refrigeration equipment admits here, the following rule applies: if you are a Buyer, you will be congratulated, but if you are a Seller, congratulations are expected from you. Another element of the Chinese business culture is about building sustainable partnerships via shared meals. Hence, the Chinese are very sensitive to sharing dinner or lunch, quite frequently drinking alcohol. People believe that during a shared meal, partners exchange energy and establish Confucian harmony, paving the way for future joint projects.

Similarly, if it comes to the modern Chinese political system, one should mention the special role of the Communist Party of China (CPC) in shaping the local business environment by establishing strong contacts between government agencies and the private sector. The CPC attracts attention of entrepreneurs, trying to integrate them into harmonious public-private partnerships (PPPs) and joint ventures (JVs) on national and international levels and usually delegating CPC's members to appropriate business entities.

3.2. Fundamentals of the Arab civilizational culture and business approaches

Many Arab societies keep their traditional tribal structure (Libya, Mauritania, the Gulf Coopera-

tion Council (GCC) monarchies, Somalia, and Yemen) based on *nassab*, i.e. tribal or family-clannish identity [25, p. 77]. Thus, the Saudi royal family rules Saudi Arabia, while the Al Nahyan and Al Maktoum dynasties are in charge of the UAE's Abu Dhabi and Dubai Emirates, respectively. Representatives of influential tribes (*banu* in Arabic) [26, p. 137] hold most prestigious positions in the state and leading raw materials companies, being treated with demonstrative respect.[2]

Another significant ethical component of the Arab civilizational culture is embodied by the hierarchy of identities (*hawiyyat*), historically based on the fundamental notion of Pan-Arabism (*'Urubah* in Arabic), invented by Abdel Rahman al-Kawakibi, a 19th-century Syrian philosopher [27, p. 1] and then supplemented by the concepts of Pan-Arab identity (*al-hawiya al-qaumiya*) and country-level identity (*hawiya qutriya*) [28, p. 1]. Hence, Arabs first of all perceive themselves as Egyptians, Emiratis, Syrians, Yemenis or even South Yemenis, etc., while at the upper level they name themselves Arabs apart from non-Arabs or foreigners/strangers (*ajanib*). This is constantly and openly illustrated by the interviews with the Arabs in all the above-mentioned states. Such hierarchy affects different-level relationships, starting from selling entry tickets to museums to *ajanib* at prices much higher than those for national citizens and Arabs[3] and up to facilitating projects with foreign partners, preferably through Arab intermediaries.[4]

Given the relative openness of Arab societies in the era of globalization, diplomatic protocol, etiquette, and corporate ethics appear to be international in nature. However, Arab rulers try to preserve the Arab identity[5] amidst outer attempts to impose on them the Western consuming culture. Although nowadays, the demonstrated adherence to Sharia law by Arabs often coexists with their "free" behavior in non-Muslim countries, for example, in Europe or even Arab countries with secular regimes and Christian inner enclaves, such as Lebanon.[6]

Originally, Arab etiquette was formed on the basis of Muslim hospitality (*ikram al-deif*) [29], although its initial imperatives, such as benevolence, generosity, keeping the word, and mutual respect, had emerged during the pre-Islamic period of *Jahiliya* within the Bedouin code of courage (*muruwwa*) [30, p. 72]. Subsequently, they became enshrined by the Holy Quran and Sunnah, however, no longer at any cost, but with the avoidance of excessive consumption (*israf*) [31, p. 2].

According to Richard Lewis's model of cultural types, Arabs belong to the nations of the multi-active culture [32, p. 42–46] focused emotionally on communications more than results. Arab businessmen can run several projects at once or, on the contrary, use the tactics of dependency, relying on the state, family, or "workhorses" from *ajanib*. Another important feature of the Arab civilizational culture is linked with the higher status of Islamic narratives in the scale of values as compared to the tasks of making profits, along with the obligations to help people in need, especially during the holy month of Ramadan.

Many Arabs are characterized by a loose attitude to time, for instance, ignoring the passing of time, which is viewed as an event- or personality-related subjective commodity [32, p. 55–57]. Thus, being late for meetings with unfamiliar people and junior partners appears to be common, although Arab officials and businessmen always try to come on time for the negotiations with trusted or promising partners.[7]

The establishment of contacts with representatives of government agencies and business circles of Arab countries could be ensured either by delegation exchanges or on the sidelines of fairs and exhibitions, as well as with the assistance of diplomats and business associations and, most importantly, by pieces of advice from reputed people, who enjoy broad experience of cooperation with

[2] Those sensitive facts are sometimes admitted by Arabs themselves, although strictly on condition of anonymity. For instance, as told by a top employee of an Emirati service company in Abu Dhabi in a conversation with an author of the article.

[3] Price for an adult entry ticket to the Egyptian museum in Cairo is only 30 EGP for Egyptians and all Arab citizens in comparison with 550 EGP for other nationalities. The Egyptian Museum official web-site. URL: https://egyptianmuseumcairo.eg/ticket-opening-hours/ (accessed on 12.12.2024).

[4] Based on the field data accumulated by an author of the article throughout 2017–2024, during providing business consultancy to ensure entries of Russian companies to the markets of Lebanon, Saudi Arabia, Syria, and the UAE.

[5] The UAE Vision 2021 National Agenda. United Arab Emirates: The Cabinet. URL: https://uaecabinet.ae/en/national-agenda (accessed on 12.12.2024).

[6] This fact was discussed with a Lebanese corporate lawyer, who proved that such behavior doesn't meet legal restrictions.

[7] For instance, neither the interviewed Lebanese corporate lawyer nor two leaders of Syrian business associations were late for meetings with an author of the article.

China and the Middle East states.[8] In all cases, it is recommended to establish offline personal contacts, even if preceded by the online correspondence. Since even in the digital era, Arabs still highly appreciate face-to-face communication.[9]

Holiday greetings could also be useful for strengthening relationships, starting from sending e-postcards and up to presenting gifts. Primarily, we are talking about various Muslim holidays, including all of Eid al-Adha, marking the completion of Hajj; Eid al-Fitr, related to the end of Ramadan; Mawlid, celebrating the birthday of Prophet Muhammad; and Raas al-Sanah al-Hijriyah, i.e., Islamic New Year. During acquaintances and meetings, it is customary for Arabs to exchange gifts and souvenirs almost equal in size and value, while Muslims often exchange *tasbeeh* prayer beads.[10] Alcohol, pigskin products, perfumes, and other women's personal items could not serve as gifts.

Besides, Arabs prefer to use personal connections to solve complex issues. Their style of doing business is ultimately determined by religious traditions, family clannish interests, or friendly relations, following *akhlaq*, inspired by the Holy Quran and Sunnah [33] together with *halal* trade [34]. A major rule of Islamic banking is related to the prohibition of *riba* interest profit, whereas confidence is secured by the exclusion of uncertainty (*gharar*), obliging a client to provide all necessary data to the bank, which in turn is obliged to avoid ambiguity in the contract. Following the ban on making profits without effort (*maisir*), lotteries are also prohibited [35, p. 77–78]. As usual, defending their own reputation, Islamic banks try to take into account life difficulties of their customers, such as losses of health or salary, allocating all collected fines to charity projects. Thus, the list of key cultural narratives of Islamic banking implies partnership, humanism, and deep connection with ethics.

Along with the prohibition of *riba*, the Sunnah does not allow *al-majhul* (selling unknown products), *al-muhaqala* (sale of an unprepared product, such as futures) [36], *al-mukhadara* (sale of goods before certifying its quality [37]), *al-mulyamasa* (when the sale is considered to take place after the buyer touches the goods), *al-munabaza* (blind exchange) [37], and *al-muzabana* (sale of goods not delivered to the point of sale, unless otherwise agreed by the terms of the transaction) [38]. Upon concluding transactions, a Muslim is always obliged to comply with *halal* not overstating the prices of goods, which, however, does not rule out the traditional oriental ritual of market bargaining.

Facing deep differences in mentality, foreigners should discuss with Arabs in advance the fundamental terms of a project or contract, filling out *Minutes of the meeting* after each round of talks.[11] Before the start of a business meeting in Arab countries, especially in the GCC monarchies, the guests are invited to a "waiting room" (*majlis* in Arabic) for 15–20 minutes [39]. After an Arab host comes out to meet the guests, he or she enters the relevant room prior to them. This old tradition dates back to *Jahiliya*, when a Bedouin entered the tent first to demonstrate the absence of danger. Upon completion of a successful meeting, the guests could be seen off by the main negotiator in person.

The inaugural small talk, which contains such phrases as *al-salamu alaykum* (peace be upon you), *sabah al-kheir* (good morning), *naharukum as-said* (good day), *Masaa al-kheir* (good evening), or just *marhaban* (hello), is followed by personal questions. Those include *keyfkum* (how are you) and *keyf al-ailah* (how is your family), yet they do not ask about the health of a wife or husband. At the moment of greeting people for the first time, Arabs emotionally express their happiness by saying *tasharrafna* (it's an honor for us) and replying with *fursah saeedah* (it's a happy opportunity). Two usual forms of addressing elderly people are *sheikh* and *ustaz* (teacher in Arabic). In conversations, one should not mention the issues related to the internal politics of Arab countries, the personalities of their leaders, and Israel, also refraining from criticizing Islam and elaborating on health topics.

In all cases, a man introduces himself to a woman first, with the exception of meetings with theologists and tribal leaders (*sheikhs*). Younger people and those who occupy lower official positions are presented to the elders. A single man

[8] During a series of interviews with an author of the article, a Lebanese-Syrian entrepreneur spoke about his positive personal experiences of helping his colleagues in facilitating useful contacts with business people from China.

[9] This hypothesis was proved by two Emirati participants and two top university officials in Egypt and South Yemen in their conversations with an author of the article.

[10] As numerously approbated in 2017–2024, in communications between an author of the article and Arab representatives.

[11] As shown by real practices of communicating with Arabs in Lebanon, Syria, and the UAE, enjoyed by an author of the article in 2017–2024.

should introduce himself first to a married man, similarly to a single woman introducing herself first to a married woman or a couple. When two men meet, they shake their right hands (since the left hand is considered unclean in Islam), demonstrating mutual good intentions [40, p. 87]. Old friends usually hug, touching each other three times on both cheeks [41, p. 6]. Remarkably, a person can shake hands with an Arab woman only if she extends it first.

Preferably, the age, official position, and social status of chief negotiators need to match or at least be comparable to each other. At the same time, young people shouldn't flaunt their elite education, unless they have essential work experiences. On the contrary, a person should refer to his/her title [40, p. 87]. Those include the degrees of Professor, Associate professor, Assistant professor, and PhD together with the professional title, such as engineer, medical doctor, etc., since Arabs have always shown respect for them regardless of the person's age. Aristocracy and VIPs must be addressed as Your Highness or Your Excellency. A married woman is called Madame, while yet an unmarried girl is addressed as Anisa (mademoiselle in Arabic). Despite the growing use of English, a good knowledge of Arabic by foreigners is still highly appreciated by Arabs. However, a member and especially the head of a foreign delegation, shouldn't act as an interpreter, since the Arab partners may regard this as a visible depreciation of personal status.

As Chinese, Arabs very rarely use the word "no," preferring to say *Inshallah* (if God allows) in all situations, which seem ambiguous or unclear to them [40, p. 87]. Thus, the expression of *bukra Inshaalah* (tomorrow, if God allows) has become a byword, not guaranteeing the fulfillment of a promise. Otherwise, an Arab partner will say *ghadan* (definitely, tomorrow).[12]

Frequently, Arab businessmen try to transfer initial communications into a friendly format by inviting promising foreign partners to "informal" lunches or dinners. The goal is to get to know those people better, grasping their weaknesses with an eye to obtain maximum future dividends. Strong Arabic or Turkish coffee (*qahwa* or *bunn*) is served as a welcome drink, usually with cardamom (*al-hel*) and without sugar (*qahwa sada*). It is prepared in a long-nosed copper pot named *dallah* and afterwards poured into a small cup of *finjan*. Before eating, the Arabs pronounce the phrase *Bismillahir Rahmanir Raheem*, which in Arabic means "In the name of God, Most Gracious, Most Merciful" [42, p. 172], to be followed at the end of the meal by the exclamation of *Alhamdulillah* (Praise be to God).

Before serving soups and main dishes of the Arab cuisine, all guests are offered a set of cold and hot snacks (*mezzah*, accompanied by spirits or *mukabbilyat* without them). In conclusion, sweet desserts (*hilvayat*) are served. After eating, time comes to distribute Arab oil perfumes, moistening the skin behind the ears, as well as lighting some incense. At the moment of farewell, the heads and hands of the participants could be sprayed with rose water.

During the Holy Month of Ramadan, which demands strict fasting during daylight hours, there are no lunches for Muslims, while dinners are held in the form of *iftars* after the sunset [43]. However, they create real possibilities for establishing contacts not only between Muslims and Arabs but also between non-Muslims and non-Arabs as well.[13]

Arabs, particularly in Egypt and the GCC monarchies, usually appear at official events in national clothes. Those include *jalabiya* (a long loose shirt), *keffiyeh* (head scarf), *'ukal* hoop, and sandals made of leather, which is convenient in hot climate.

3.3. Comparative analysis of the Chinese vs. Arab civilizational culture

Logically, patterns of communications manifested by both the Chinese and Arab cultures in different spheres, including economy and trade, can't help reflecting fundamental distinctive features inherent to reactive and multi-active cultures. Although, one should keep in mind Richard Lewis's important acknowledgment that "personal traits can occasionally contradict the national norm" [32, p. 43].

Hence, following Lewis's description, the main differences could be summarized as follows (see *Table*).

While the Chinese culture has more features of civilization due to the rather monolithic territory

[12] This fact was repeatedly proved by personal contacts of an author of the article with Arab partners in Egypt, Lebanon, Syria, and the UAE.

[13] This assessment is based on the field data accumulated by an author of the article during his stint as a senior Russian diplomat in Syria (2014–2017), whereas he regularly attended iftars organized by the Damascus Chamber of Commerce and the Chamber of Industry of Damascus and Rural Damascus.

Table
Comparative brief of key features related to the Chinese and Arabs

Criteria	Chinese	Arabs
Ability to listen to a companion	Good listeners	Gregarious
Attitude to business	React	Do several things at once
Attitude to planning	Look at general principles, after that make slight changes	Plan grand outline only, after that could change plans
Attitude to project managing	See whole picture	Let one project influence another
Behavioral type	Introverts	Extroverts
Body language	Subtle body language	Unrestricted body language
Degree of patience	Patient	Impatient
Delegation of authority	Delegate to reliable people	Delegate to relations
Emotionality	Quietly caring	Emotional
Features of behavior	Silent	Talkative
Interruption of speech	Don't interrupt	Interrupt frequently
Mixing social and professional	Connect social and professional	Interweave social/professional
Perception of facts	Statements are promises	Juggle facts
Personal ambitions	Protect face of other	Seek favors
Preferred methods of gathering information	Use both first-hand and researched information	Get first-hand (oral) information
Punctuality, attitude to timetables and schedule	Yes, react to partner's timetable	No, timetable unpredictable
Saving of face tactics	Must not lose face	Have ready excuses
Style of telephone talk	Summarize well	Could talk for hours

Source: Compiled by the authors based on [32].

with a common history, the Arab culture, although more territorially fragmented, yet is still cemented by a stronger attachment not to philosophy and ethics, like in the Confucianism, but religion as such. Despite the existence of Caliphates during the early Middle Ages, the Arabs did not manage to re-create any similarly unified state during Modern and Contemporary times. However, right now, Islamic traditions gain more and more strength across the MENA region, covering even such former secular countries like South Yemen, which in the 1970–80s was known for its radical, leftist, and secular ideology of scientific socialism.

Politically, economically, and ideologically, today's China is more sovereignty-oriented than most Arab countries, although the GCC monarchies recently adopted ambitious national strategies of building XXI-century economies, among them the Saudi "Vision 2030" and Emirati "4th Industrial Revolution." Nevertheless, this doesn't apply to the borrowing of Western technologies, applicable to both Chinese and Arabs, although here China plainly takes an upper hand. Those peculiarities, however, explain more openness of certain Arab countries (a plain example is Egypt) towards the outer world in terms of both relying on financial donor help and Western-like business patterns.

Amazingly, but only at the first glance, common cultural features between the Chinese and Arabs also exist. Despite belonging to different cultural types, the Lewis's triangular model not by chance depicts these two Oriental nations standing on the same side of the triangle. Interestingly enough, from *Fig. 2* one could see that the Chinese and Arabs are separated from each other by four (4) positions only, which are occupied by the Koreans, Indonesians/Filipinos (considered by R. Lewis as a hybrid of multi-active and reactive cultures [32, p. 41]), Indians, and Iranians/Turks, in comparison with six (6) positions between the Arabs and Japanese. At the same time, the Chinese and Arabs stand 9–10 positions away from the Western-dominated linear-active cultural type, plainly represented by the Swiss, Germans, British, and White Americans.

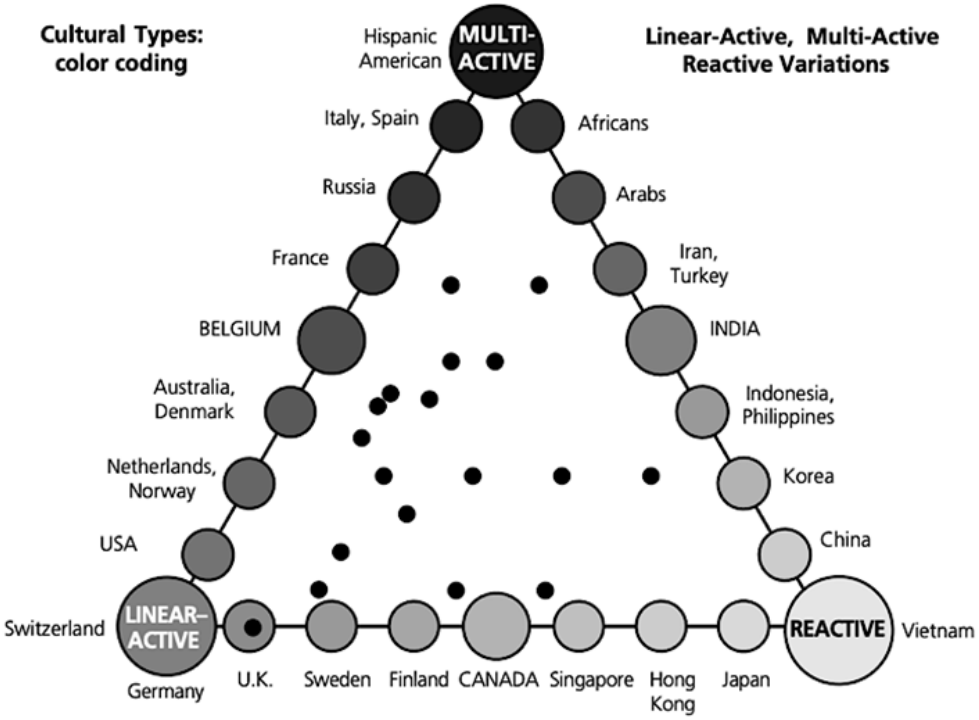

Fig. 2. **Lewis's Cultural Types Model**

Source: [32, p. 42].

Same R. Lewis rationally points out that both reactive and multi-active cultures are people-oriented in contrast with the job-oriented linear-active culture [32, p. 34]. This fact correlates with their common collective nature.

In parallel, the Lewis triangle and his follow-up research adequately prove that not all linear-active, multi-active, or reactive nations are similar in terms of key features, characteristics, approaches, ethical attitudes, and common values, which in turn is confirmed by the vast field experiences accumulated by the authors of the present article. Thus, the Arabs look more like the Chinese by always trying to avoid confrontations, not saying the word "no," and, thus, differing from many representatives of other multi-active nations, who, in Lewis's words, tend to confront emotionally [32, p. 34].

Significant common features of the Chinese and Arab ethics also imply traditional, if not to say patriarchal, family values. Firstly, they include descending family hierarchies, which demand obedience and honoring of the elders, such as grandparents and parents, but are not limited to them.

Secondly, despite the influences of globalization, natives in China and Arab countries still emphasize deep respect for those foreigners who demonstrate real knowledge and/or sincere will to study their culture, religion, ethics, and traditions. This is at most applicable to language proficiency skills.

Thirdly, the Chinese and Arabs, especially from the GCC area, both men and women, pay strong attention to clothing and dress codes as demonstrative tools to present personality. This fact must be taken into account for personal acquaintance and facilitating successful business communications.

Fourthly, as it comes to the general scale of ethics, people in China and Arab countries place moral values (justice, godliness, fear of God, etc.) above earthly imperatives related to profits or other commercial benefits.

Fifthly, the keys to establishing and improving friendly relations and long-term partnerships with Chinese and Arab entrepreneurs are often linked to congratulating each other on holidays, presenting gifts, and enjoying joint meals.

Remarkably, the above-described similarity between the Chinese and Arabs correlates with the East–West dichotomy of paradigms of power (*Fig. 3*), reflected by the hierarchies of major institutions of State, Individual, and Law. Those are either based on the Rule of Law and Protestant tradition in Western societies (i.e., human-centric, individualist) [44, p. 285] or blessed by Confucianism and Islam (religion-centric or state-centric, collective) in China and the Arab world, respectively.

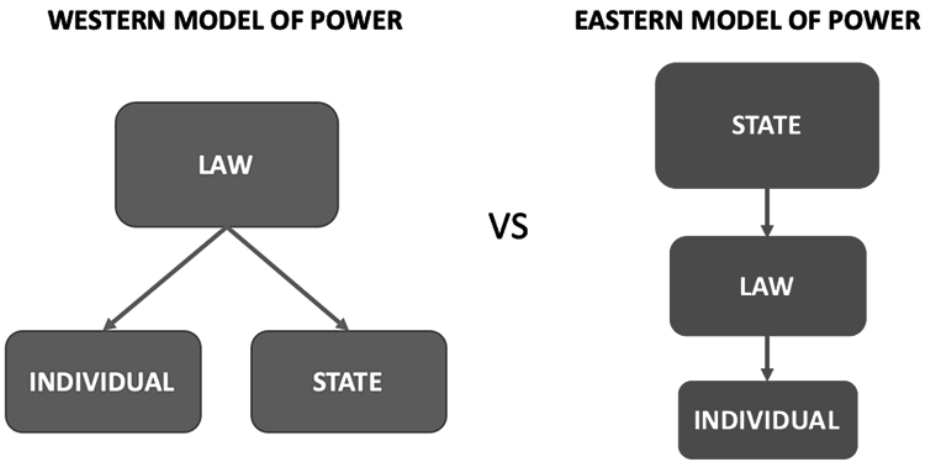

Fig. 3. **Dichotomy of Western and Eastern models of power**

Source: Produced by the authors of the article.

In a nutshell, all the above-mentioned characteristics bring the Chinese and Arabs closer to each other than it appears to be at first glance, therefore easing the tasks of doing business between the People's Republic of China and her Arab partners. Despite their long-distanced geographic locations, which have been determining huge civilizational, historical, traditional, religious, and language differences, common ethic perceptions and values often create human chemistries, assisting in building mutual trust and successful business stories.

4. Conclusion

From cross-cultural and business perspectives, sharing common ethical fundamentals by the Chinese and Arabs creates a rather favorable ground for fulfilling the Arab dimension of China's Global Civilization Initiative (GCI), which was put forward by President Xi Jinping on March 15, 2023, while delivering a keynote speech at the CPC in Dialogue with World Political Parties high-level meeting, following the inaugurations of the Global Development Initiative and the Global Security Initiative. It advocates the respect for the diversity of civilizations, based on the principles of equality, mutual learning, dialogue, and inclusivity [21].

The GCI's three main pillars, namely, respect for civilization diversity, flourishing people-to-people exchanges, and exploring paths toward modernization[14] [47], have been incorporated in the agenda of the China-Arab States Cooperation Forum (CASCF), which was established in January 2004, on the sidelines of the visit of then-President of China Hu Jintao to Egypt as a permanent mechanism of Arab-Chinese coordination on a vast variety of issues, covering world economy and politics, along with regional problems. Not by chance, the 10th anniversary CASCF ministerial meeting, held on May 30, 2024, in Beijing, highlighted among key priorities building the China-Arab community with a shared future, aimed to provide strategic guidance for continued "leapfrog growth" of China-Arab relations, opening a new era of China-Arab relations and creating a better future for the world.[15]

Altogether, the above-mentioned imperatives determine the importance of scrutinizing, by joint efforts of China and Arab states both ethical diversities and, more importantly, identifying common features, cementing China-Arab partnerships under the CASCF's umbrella and beyond. This task explains the significant practical usefulness of the current article, especially in light of China's plans to host the second China-Arab States Summit in 2026. Here, Russia's long-term experience of cooperation with the Arab world, based on previous Soviet achievements, could also be in demand.

The objective limitations of conducting even a general comparative analysis of the Chinese and Arab civilizational cultures in a single scientific

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research paper due to its limited size forced the authors to concentrate attention only on selective, although major, points, not going into further details. Which was reflected in the titles of the article and its sections. Yet, they couldn't help briefing the broad audience of the journal of publication about the main pillars and fundamentals of the Chinese and Arab civilizational cultures related to the future implementation of the Arab dimension of the Chinese Global Civilization Initiative.

For the same reason, the authors were not able to deeply cover the issues related to the business ethics patterns inherent to the Chinese and Arab civilizational cultures. Nevertheless, they recognize this article as an inaugural one in a series of research papers, such as articles and maybe even a collective monograph, which could contain much bigger materials on this particular topic. Here, one could remember a famous Chinese saying, attributed to Lao-Tse and translated into English as "A journey of a thousand miles begins with a single step".

The authors also plan to conduct a new field analysis via using sincere personal communications with more reputed Chinese and Arab business professionals, university teachers, and academic experts.

Finally, as the last but not the least, the concise nature of the material didn't prevent the authors from formulating two concrete recommendations linked to the GCI's Arab dimension. Among them:

- organizing a series of scientific-practical discussions dedicated to the comparative analysis of the Chinese and Arab civilizational cultures, business ethics, and business behavior to work out relevant codified practical instructions, summarized in collections of scientific papers. Those discussions (forums, conferences, seminars, round tables, etc.) could be facilitated preferably in China as the country of the GCI's origin with the participation of orientalists from Arab countries, Russia, India, Japan, Singapore, as well as USA, UK, France, Germany, and other Western powers, thus, enabling them to exchange views and already accumulated practices;
- publishing a series of collective articles in top scientific journals in Arab countries and China, covering concrete issues of cross-cultural communications between Chinese, Arabs, and other nations, paying more attention both to their theoretical fundamentals and practical modalities to overcome effectively the existing challenges and other difficulties.

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Financial Transparency and Performance of Microfinance Institutions in Ethiopia

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ABSTRACT

The **subject** of this study is the relationship between financial transparency and the financial performance of microfinance institutions (MFIs) in Ethiopia. The research focuses on four core dimensions of transparency: external auditing, public disclosure, compliance with accounting standards, and timeliness of financial reporting, examined through the theoretical frameworks of agency theory and stakeholder theory. The **purpose** of the study is to determine how these transparency dimensions influence institutional profitability, measured by return on assets (ROA), in a donor-dependent and regulation-intensive environment. The relevance of the research arises from persistent governance challenges, inconsistent reporting practices, and the strategic importance of MFIs in promoting financial inclusion and socio-economic development in emerging markets. The **scientific novelty** lies in the development of a hybrid conceptual framework that integrates international theoretical models with Ethiopia-specific institutional conditions and in the application of a mixed-methods approach that combines econometric analysis with qualitative insights from industry executives. The **methodology** includes fixed-effects regression analysis of a balanced panel of 13 licensed MFIs for the period 2015–2024, supported by thematic analysis of semi-structured interviews. The **results** demonstrate that external auditing, public disclosure, and compliance with accounting standards significantly enhance ROA, while delays in financial reporting reduce profitability. Qualitative findings confirm that transparency improves institutional credibility, donor trust, and operational efficiency, but its implementation is constrained by capacity limitations, regulatory inconsistencies, and divergent stakeholder expectations. The authors **conclude** that transparency should be viewed not only as a compliance obligation but also as a strategic driver of resilience, competitiveness, and sustainable growth in Ethiopia's microfinance sector.

Keywords: financial transparency; microfinance institutions; return on assets; agency theory; stakeholder theory; emerging markets; Ethiopia

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ОРИГИНАЛЬНАЯ СТАТЬЯ

Финансовая прозрачность и деятельность микрофинансовых институтов в Эфиопии

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АННОТАЦИЯ

Предметом данного исследования является взаимосвязь между финансовой прозрачностью и финансовыми результатами микрофинансовых организаций (МФО) в Эфиопии. Исследование сосредоточено на четырех основных аспектах прозрачности: внешнем аудите, раскрытии информации для общественности, соблюдении стандартов бухгалтерского учета и своевременности финансовой отчетности, рассматриваемых с точки зрения теоретических основ теории агентств и теории заинтересованных сторон.

Цель исследования — определить, как эти аспекты прозрачности влияют на рентабельность учреждений, измеряемую рентабельностью активов (ROA), в условиях зависимости от доноров и интенсивного регулирования. **Актуальность** исследования обусловлена сохраняющимися проблемами управления, непоследовательной практикой отчетности и стратегической важностью МФО в содействии финансовой доступности и социально-экономическому развитию на развивающихся рынках. **Научная новизна** заключается в разработке гибридной концептуальной модели, интегрирующей международные теоретические модели с институциональными условиями, специфичными для Эфиопии, а также в применении смешанного подхода, сочетающего эконометрический анализ с качественными выводами руководителей отрасли. **Методология** включает регрессионный анализ с фиксированными эффектами сбалансированной группы из 13 лицензированных МФО за период 2015–2024 гг., подкрепленный тематическим анализом полуструктурированных интервью. **Результаты** показывают, что внешний аудит, публичное раскрытие информации и соблюдение стандартов бухгалтерского учета значительно повышают рентабельность активов (ROA), в то время как задержки с представлением финансовой отчетности снижают рентабельность. Качественные результаты подтверждают, что прозрачность повышает авторитет учреждения, доверие доноров и операционную эффективность, но ее реализация сдерживается ограниченными возможностями, несоответствиями в регулировании и расхождениями в ожиданиях заинтересованных сторон. Авторы приходят к **выводу**, что прозрачность следует рассматривать не только как обязательство по соблюдению требований, но и как стратегический фактор устойчивости, конкурентоспособности и устойчивого роста микрофинансового сектора Эфиопии.

Ключевые слова: финансовая прозрачность; микрофинансовые организации; рентабельность активов; теория агентств; теория заинтересованных сторон; развивающиеся рынки; Эфиопия

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1. Introduction

Over the past two decades, Ethiopia's microfinance sector has expanded rapidly, catalyzed by policy incentives, donor engagement, and rising demand for inclusive financial services. Today, over 40 registered microfinance institutions (MFIs) operate nationwide, serving millions of low-income and rural clients often excluded from the formal banking sector.[1] These institutions play a vital role in poverty alleviation, rural development, economic inclusion, and small business financing, offering microcredit, savings, and financial literacy services to underserved populations.[2] Microfinance is particularly promising for business creation in Ethiopia, enabling entrepreneurs to access capital with fewer barriers than traditional banks, thus fostering economic growth [1].

Despite these achievements, the sector faces persistent structural and governance challenges. Many MFIs suffer from undercapitalization, weak internal controls, and inconsistent reporting standards, all of which undermine stakeholder confidence and long-term financial performance. A central concern is the variation in financial transparency practices — particularly in external auditing, public disclosure, compliance with accounting standards, and timely financial reporting [2, 3]. These dimensions are globally recognized as key enablers of financial credibility and institutional performance, yet their application remains uneven across Ethiopian MFIs [4].

Defining Institutional Efficiency: In the context of this study, institutional efficiency refers to an MFI's ability to achieve its objectives effectively, encompassing financial, operational, and social dimensions. Financial efficiency, the primary focus of this study, is measured by Return on Assets *(ROA*), reflecting profitability and resource utilization. Operational efficiency includes cost management (e.g., cost per borrower), while social efficiency involves outreach to underserved populations (e.g., number of clients served). This study focuses on financial efficiency due to its critical role in donor-driven MFIs and the availability of reliable financial data in Ethiopia, though operational and social efficiency are acknowledged as complementary dimensions that warrant further exploration [5, 6].

The global microfinance literature widely links financial transparency to enhanced performance and investor trust. Evidence from Latin America,

[1] National Bank of Ethiopia. Annual Report 2022. Addis Ababa: National Bank of Ethiopia; 2022. URL: https://www.nbe.gov.et/publications/annual-bank-report/

[2] World Bank. The Global Findex Database 2021: Financial inclusion, digital payments, and resilience in the age of COVID-19. Washington, DC: World Bank; 2021. URL: http://documents.worldbank.org/curated/en/099818107072234182

Eastern Europe, and Sub-Saharan Africa shows that institutions with robust transparency mechanisms tend to report higher ROA, better access to capital, and stronger stakeholder engagement [7]. However, little is known about how these relationships manifest in Ethiopia's donor-dependent and regulation-intensive microfinance ecosystem, where MFIs compete with banks for clients while serving distinct market segments. Existing Ethiopian studies have largely focused on board composition or regulatory supervision with limited attention to a comprehensive, multidimensional assessment of transparency's direct impact on institutional performance [8, 9].

This research addresses this gap by evaluating how four core components of financial transparency — external auditing, public disclosure, accounting standards compliance, and timeliness of financial reporting — affect the financial performance of Ethiopian MFIs, measured by *ROA*. Drawing on agency theory and stakeholder theory, the study develops a hybrid analytical framework to explore both managerial alignment and stakeholder trust mechanisms. The novelty of this study lies in its integration of mixed methods, combining panel data analysis with executive interviews to offer a rich, context-sensitive understanding of transparency's performance implications in Ethiopia.

The study's objective is to empirically test the hypothesis that higher transparency is positively associated with improved MFI financial performance, while reporting delays negatively affect profitability. By addressing an important empirical and policy gap, this research contributes to the advancement of financial governance literature in emerging markets and informs regulatory and managerial strategies aimed at strengthening Ethiopia's microfinance sector.[3]

2. Literature review

2.1. Defining financial transparency

In this article, institutional efficiency is understood as the combined ability of MFIs to achieve both economic outcomes (profitability, stability, sustainability) and social outcomes (outreach, inclusion, poverty reduction). While this study uses *ROA* as the primary indicator, institutional efficiency is multidimensional. Financial transparency involves the public, complete, accurate, and prompt release of an institution's financial performance, internal controls, and policies. It encompasses not only the existence of financial information but also its quality and accessibility, enabling stakeholders to make informed decisions [10]. For microfinance institutions, which rely heavily on donor capital and public trust, transparency is critical to maintaining credibility and operational legitimacy.[4] According to International Integrated Reporting Council (IIRC), transparency is particularly vital for financial institutions in under-regulated environments, where stakeholder trust must be carefully established.[5]

2.2. The importance of transparency in the financial sector

In the broader finance literature, transparency has been shown to improve capital allocation efficiency, reduce financing costs, and enhance corporate governance. Bushman et al. argue that it reduces information asymmetry between managers and stakeholders, leading to better decision-making [11]. Ball further contends that transparency improves market discipline and risk management [12]. In MFIs, which balance financial and social goals, transparency is essential for gaining donor trust and ensuring financial performance [5]. Lack of transparency can lead to public distrust and funding withdrawal, undermining institutional viability.

Institutional efficiency in MFIs: Institutional efficiency in microfinance extends beyond financial performance to include operational and social dimensions. Financial efficiency, often measured by *ROA*, reflects profitability and resource utilization. Operational efficiency includes metrics like cost per borrower or loan processing time, while social efficiency captures outreach, such as the number of clients served or loans to marginalized groups [13]. While this study focuses on financial

[3] National Bank of Ethiopia. Annual Report 2022. Addis Ababa: National Bank of Ethiopia; 2022. URL: https://www.nbe.gov.et/publications/annual-bank-report/; World Bank. The Global Findex Database 2021: Financial inclusion, digital payments, and resilience in the age of COVID-19. Washington, DC: World Bank; 2021. URL: http://documents.worldbank.org/curated/en/099818107072234182

[4] The new microfinance handbook: A financial market system perspective. Washington, DC: World Bank Publications; 2013. URL: https://openknowledge.worldbank.org/handle/10986/12272

[5] International Integrated Reporting Council (IIRC). International framework. IIRC; 2021. URL: https://www.integratedreporting.org/resource/international-ir-framework/

efficiency due to its measurability and relevance to donor accountability, transparency likely influences operational efficiency (e.g., through streamlined reporting) and social efficiency (e.g., by building client trust) [10]. These broader dimensions are critical but underexplored in the Ethiopian context.

MFIs as competitors and complements to banks: MFIs and banks operate in overlapping yet distinct segments of the financial market, particularly in developing economies such as Ethiopia [14]. Banks typically serve formalized clients with higher creditworthiness, requiring extensive documentation and credit history. MFIs, conversely, target underserved populations — such as rural clients, small businesses, and low-income individuals — with fewer bureaucratic requirements, lower documentation needs, and no reliance on prior credit history [15]. This makes MFIs a preferred choice for small entrepreneurs, enabling business creation and financial inclusion. However, MFIs often borrow from banks to fund their operations, creating a complementary relationship where banks provide capital and MFIs extend it to underserved regions with limited banking presence [16]. State regulation should foster the parallel development of both institutions to ensure adequate financial resources for the economy, particularly in Africa, where financial exclusion remains high [17]. Microfinance's role as a promising business financing method underscores its importance in fostering entrepreneurship and economic growth.

Contributions of microfinance pioneers: The modern microfinance movement owes much to Muhammad Yunus, whose establishment of the Grameen Bank in Bangladesh demonstrated microcredit's potential for poverty alleviation and business creation [18]. Yunus' model emphasized small, collateral-free loans to empower low-income entrepreneurs, particularly women, laying the foundation for global microfinance. Additionally, Isabelle Guérin's work highlights the social dimensions of microfinance, illustrating how it reshapes social relations and empowers marginalized groups through access to financial services [19]. These contributions underscore microfinance's dual financial and social goals, which inform this study's focus on transparency as a driver of performance.

2.3. Theoretical foundations

Agency theory is a strong foundation for understanding the role of financial transparency in MFI performance. Jensen and Meckling contend that agency issues are the outcome of principals' (e.g., donors, clients) and agents' (MFI managers) information asymmetry that can cause mismanagement [20]. In the donor-influenced Ethiopian MFI sector, public disclosure, external audit, compliance with IFRS, and timely reporting prevent asymmetry through the assurance of accountability [3]. External auditing (*EA*) ensures financial integrity, deterring opportunistic behavior, and public disclosures (*PD*) improve monitoring by stakeholders and align managerial action with profitability objectives such as *ROA* [4]. Accounting standards compliance (*ACS*) ensures reports are consistent and minimizes errors, and timely reporting (TFR) communicates operating performance, a requirement in controlled Ethiopia [21]. Agency theory therefore anticipates that transparency will increase *ROA* by reducing agency costs.

Stakeholder theory completes the vision by demanding consistency of the various stakeholder interests — donors, clients, regulators, and communities [22]. Transparency in Ethiopia, just like in most countries, where MFIs are endowed with social and financial objectives, creates trust, a prerequisite to access donor funds and client loyalty [15]. Disclosure to the general public and auditing provide credibility, capital upturning, and IFRS compliance and reporting on a timely basis meet regulatory and donor requirements, achieving financial stability [6]. Stakeholder theory asserts that more transparent MFIs better serve the needs of stakeholders more equally, improving *ROA* by improved access to capital and trust [23]. Both arguments point out transparency in interest alignment and performance-focused management suitable for the Ethiopian cooperative MFI environment.

2.3.1. A hybrid framework of transparency for donor-funded MFIs

This research recommends a hybrid transparency framework for donor-supported microfinance institutions (MFIs) in developing nations such as Ethiopia. It combines the agency theory and stakeholder theory models and, furthermore, considers nation-specific issues like donor reliance, ineffectual regulators, and poorly developed technology infrastructure. Moving beyond one-size-fits-all limitations of transparency frameworks, it provides a context-sensitive method to

reveal the way interventions in transparency can affect the efficiency and sustainability of institutions.

Core framework dimensions: The first of these is structured accountability through agency alignment, which is based on agency theory [19] and prioritizes structured processes like external audits and compliance with formal accounting standards. These processes minimize information asymmetry among managers (agents) and different principals — donors, regulators, and clients — each having different informational needs. In donor-dependent MFIs, information revealed is utilized for its transparency, and adaptive transparency mechanisms need to be created to address different demands by different groups of stakeholders. For instance, donors require the highest monetary precision, while clients might require conditions of loans and repayment transparency.

The second facet, stakeholder-centric engagement, draws on stakeholder theory [21], laying down participative and differentiated public disclosures. Given the low levels of financial literacy in Ethiopia, the structure promotes differentiated disclosure strategies — periodic exhaustive reports for external donors and simple and readable presentation forms for clients and community stakeholders. Not only does this participative approach improve stakeholder trust but also ensures long-term institutional sustainability by strengthening legitimacy and social license to operate.

The topic of dynamic timeliness adds a time aspect to standard transparency frameworks. Unlike standard models in which the availability of disclosures is of concern, this model accounts for the timeliness of financial reporting as the prime driver of operational responsiveness as well as stakeholder engagement. Timeliness in reporting reflects managerial competence and institutional integrity as perceived by donors as well as regulators.

The final dimension, technological integration, identifies emerging trends in digital finance. The application of digital systems — i.e., blockchain audit trails, cloud reporting platforms, and mobile messaging tools — can potentially reduce reporting costs and enhance real-time information sharing. These technologies are especially relevant for MFIs in low-resource environments, offering scalable solutions to increase transparency and accountability.

Relevance to the Ethiopian and African context: The framework is intended for the Ethiopian MFI setting of heavy donor reliance, weak regulation enforcement, and widespread financial exclusion. The pragmatic realities of such a setting are captured in the framework without compromising international transparency standards. Universality is increased by comparative experience from other African settings. Digital reporting mechanisms employed by Uganda, for instance, and the client-informed disclosure culture used in Kenya are good examples of good-fitting adaptations under similar constraints. Conversely, Nigeria's experience with over-regulation is a caution against tight transparency provisions. The framework thus implements an equitable, responsive approach with a bias towards institutional capacity as well as energizing stakeholder trust and fiscal responsibility.

2.4. Global empirical evidence

Recent contributions (2021–2025) further highlight these dynamics. For instance, [18] analyzes the dual financial and social efficiency of Indian MFIs, while [24] provides evidence from African MFIs using updated efficiency measures. [25] links digitization with improved transparency and performance, and [26] shows how FinTech integration affects profitability. [27] Explore how social performance interacts with efficiency globally. These newer findings align with and extend the evidence base for Ethiopia's MFI sector.

There exists strong cross-country empirical evidence to support the relationship of financial transparency with improved performance of microfinance institutions (MFIs). Transparency practices, such as external auditing, public disclosure, accounting standards compliance, and timely reporting, are linked to improved profitability, operational efficiency, and investor confidence. A 2022 study by Khandker and Koolwal found that transparent MFIs in Sub-Saharan Africa achieved higher *ROA* and client outreach due to enhanced donor trust [28]. Similarly, a 2023 analysis by Assefa and Murad confirmed that IFRS compliance reduced financial mismanagement in African MFIs, improving access to bank loans [29]. In Latin America, Hartarska and Nadolnyak (2007) found that regulated MFIs with robust disclosure practices achieved better sustainability and outreach [6]. In Sub-Saharan Africa, Cull et al. (2011) established that MFIs with credible external audits attracted higher investor

confidence and capital, boosting *ROA* [2]. Insufficient transparency practices, however, have led to crises, as seen in Bangladesh and India, where opaque reporting eroded trust [4]. Timeliness is also critical; a 2021 study by Owusu-Ansah and Leventis found that delayed reporting in emerging markets reduced funding access, impacting performance [30]. These findings underscore the need for localized research in Ethiopia's donor-driven market.

2.5. Empirical evidence in Ethiopian microfinance context

The microfinance industry in Ethiopia has grown significantly, driven by favorable policies and demand for rural financial services. According to the National Bank of Ethiopia (2022), over 40 licensed MFIs serve well over 5 million clients. However, challenges like poor capitalization and inadequate transparency persist. Larger MFIs, such as Amhara Credit and Saving Institution (ACSI), practice robust transparency, fostering trust, while smaller MFIs struggle with inconsistent disclosures [31]. A 2023 study by Tadesse and Bekele found that transparency enhances donor confidence and operational efficiency in Ethiopian MFIs [32]. Bogan (2012) noted that delayed reporting reduces funding access, particularly for rural MFIs. While transparency likely influences operational efficiency (e.g., cost management) and social efficiency (e.g., client outreach), this study prioritizes financial efficiency (ROA) due to its relevance to donor accountability and data availability [8].

2.6. Research gaps and scientific novelty

Although the global literature on MFI performance is extensive, significant gaps remain with respect to the role of financial transparency — particularly within the Ethiopian context. Existing studies on Ethiopian MFIs have not provided a systematic and multidimensional analysis of how financial transparency affects institutional performance. Specifically, there is a lack of empirical work that jointly evaluates the four core dimensions of financial transparency: external audits (*EA*), public disclosure (*PD*), compliance with accounting standards (*ACS*), and timeliness of financial reporting (*TFR*).

Previous research, including that of Bogan and Tchuigoua, acknowledges the importance of transparency but treats its components in isolation or only partially [8, 14]. Similarly, Quayes and Hasan and D'Espallier et al. emphasize governance structures such as board composition, yet do not directly assess the influence of transparency measures on financial indicators like Return on Assets (*ROA*) [7].

Furthermore, much of the international evidence originates from competitive, market-oriented financial systems, which may not be directly transferable to Ethiopia's distinct regulatory, donor-dependent, and cooperative-based MFI landscape. Regulatory oversight by the National Bank of Ethiopia and the widespread prevalence of member-based ownership structures heighten the importance of transparency as a determinant of stakeholder trust and institutional sustainability — an area insufficiently explored in existing research [4].

Additionally, prior studies often rely exclusively on secondary quantitative data and rarely incorporate practitioner perspectives or contextual nuances. There is a marked absence of mixed-methods research that integrates econometric analysis with qualitative insights to explore the complex and locally specific implications of transparency for performance.

This study addresses these critical gaps by offering a holistic examination of financial transparency's role in MFI performance in Ethiopia. It contributes to the literature through a mixed-methods approach, combining fixed-effects panel regression with in-depth interviews of key stakeholders. By analyzing all four transparency dimensions within a unified empirical framework, this study generates novel, context-sensitive evidence that enriches both local policy discourse and global understanding of transparency's role in microfinance. This study's focus on financial efficiency (*ROA*) addresses a critical gap in the Ethiopian context, but the broader dimensions of institutional efficiency — operational and social — remain underexplored, offering avenues for future research, particularly in comparing MFIs and banks.

3. Materials and methods

3.1. Research strategy and design

This research utilizes a mixed-methods study design that integrates quantitative econometric modeling and qualitative thematic analysis to analyze the effects of financial transparency on the performance of microfinance institutions (MFIs) in Ethiopia. The combination of quantitative and qualitative data enables methodological triangu-

lation that enhances the validity, richness, and policy implications of results.

The quantitative strand uses a causal-comparative panel design with a fixed-effects regression method to analyze whether the underlying determinants of financial transparency — external audit, public disclosure, accounting standards compliance, and timeliness in financial reports — are affecting Return on Assets (*ROA*). The theoretical basis is agency theory [17] and stakeholder theory [19] with special reference to transparency properties to align manager interests with external stakeholders' interests.

The qualitative element enriches the empirical study by introducing structured interview data from MFIs' managers. In this inductive approach, institutional process, mindset, and operating limitations on transparency are explored, thereby enriching quantitative findings' interpretation and placing it in the highly regulated, donor-centric microfinance context in Ethiopia.

3.2. Data sources and sampling procedure

The research employs a balanced panel of 13 licensed Ethiopian MFIs over 10 years (2015–2024) with 130 firm-year observations. The institutions account for about 34% of all the NBE-registered MFIs. The sample was selected on grounds of purposive sampling: (i) availability of complete and reliable financial data; (ii) variation in ownership structures; (iii) spatial dispersion; and (iv) size of the institutions.

Quantitative information was collected from audited financial reports, NBE regulatory reports, and secondary sources such as the Association of Ethiopian Microfinance Institutions (AEMFI) and MIX Market. ACSI, OCSSCO, DECSI, and region-based institutions, such as Kafa and Diredawa MFIs, are some of the notable MFIs in the sample.

Furthermore, semi-structured interviews were held with the board and senior managers of the 13 MFIs, and these provided us with good qualitative information on transparency practices, impact perception, and implementation issues. Combining panel data with executive interviews enhances the internal and external validity of the research.

3.3. Variable description and measurement

Dependent variable

- **Return on assets (*ROA*):** Defined as net profit after tax divided by total assets, *ROA* serves as the primary measure of financial performance and institutional efficiency [33].

Independent variables: Financial transparency indicators

- External Audit (*EA*): A binary variable coded as 1 if the institution is externally audited annually, 0 otherwise. Source: institutional audit reports and survey confirmation.
- Public Disclosure (*PD*): An ordinal scale (1–5) reflecting the frequency and comprehensiveness of financial disclosures. Assessed through content analysis of websites, annual reports, and survey data.
- Accounting Standards Compliance (*ACS*): A binary variable coded as 1 if the institution complies with International Financial Reporting Standards (IFRS) or equivalent national standards, 0 otherwise.
- Timeliness of Financial Reporting (*TFR*): A continuous variable representing the number of days between fiscal year-end and the public release of financial statements. Sources include regulatory filings and institutional websites.

Control variable

Institutional Size (LOG_{TA}): Measured as the natural logarithm of total assets. This control captures the scale effect on performance and is widely adopted in MFI performance studies.

All financial data are reported in Ethiopian Birr and adjusted for inflation where relevant.

3.4. Econometric model specification

To estimate the effect of financial transparency on institutional performance, the study employs a fixed-effects panel regression model. This approach controls for unobserved heterogeneity across MFIs and is justified by the Hausman test, which rejects the null hypothesis of no correlation between regressors and individual effects.

The model is specified as follows:

$$ROA_{it} = \alpha + \beta 1 EA_{it} + \beta 2 PD_{it} + \beta 3 ACS_{it} + \\ + \beta 4 TFR_{it} + \beta 5 LOG_{TA_{it}} + \mu_i + \lambda_{t+\lceil\_it},$$

where:

- ROA_{it}: Return on Assets for MFI *i* at time *t*.
- EA_{it}, PD_{it}, ACS_{it}, TFR_{it}: Financial transparency variables.
- LOG_{TAit}: Control for MFI size.
- μ_i, λ_t: MFI and time fixed effects.
- ϵ_{it}: Error term.

Robust standard errors are used to correct for heteroskedasticity.

3.5. Model diagnostics and robustness checks

To verify the robustness and reliability of the model estimates, the following diagnostic tests were conducted:

- Multicollinearity: Assessed using Variance Inflation Factor (VIF); all values were below the critical threshold of 10.
- Heteroskedasticity: Evaluated via the Modified Wald Test; robust standard errors were applied.
- Model specification: The Breusch-Pagan test supported the appropriateness of the linear regression model.
- Model selection: The Hausman test favored the fixed-effects specification over random-effects, confirming endogeneity concerns.

Robustness analysis

- Regional dummies: Introduced to account for geographic variation; inclusion did not significantly alter main results.
- Alternative specifications: A random-effects model was also estimated for comparison, yielding similar directional results but lower explanatory power, reinforcing the robustness of the fixed-effects approach.

3.6. Data analysis procedures

Quantitative analysis was conducted using Stata software. Descriptive statistics were first generated for all variables. Correlation matrices were reviewed to assess bivariate relationships and multicollinearity. Fixed-effects regression results are presented in tabular format with relevant statistical indicators.

Qualitative data from interviews were analyzed using NVivo. Responses were thematically coded, and findings were integrated with quantitative results to facilitate methodological triangulation. This integration enriched the interpretation of transparency's operational mechanisms and performance implications in the Ethiopian MFI sector.

4. Results and discussion

4.1. Descriptive analysis of key variables

This section presents an overview of the descriptive statistics for the key variables used in the analysis: Return on Assets (*ROA*), External Auditing (*EA*), Public Disclosure (*PD*), Accounting Standards Compliance (*ACS*), Timeliness of Financial Reporting (*TFR*), and Institutional Size (LOG_{TA}). The dataset comprises 130 firm-year observations from 13 licensed Ethiopian MFIs covering the period 2015–2024. Data were compiled from the National Bank of Ethiopia (NBE), institutional annual reports, and structured survey instruments.

The purpose of this analysis is to identify underlying patterns, heterogeneity, and preliminary associations between financial transparency indicators and institutional performance, thereby providing a contextual foundation for the regression analysis that follows.

4.1.1. Interpretation of descriptive statistics

Descriptive statistics of the main variables are presented in *Table 1*.

Financial performance [Return on Assets (*ROA*)]: Descriptive statistics reveal significant information regarding the financial performance and the transparency management of Ethiopian microfinance institutions (MFIs) during the study period. The Return on Assets (*ROA*) has an average of 2.25% and a standard deviation of 1.28%, revealing modest profitability in the industry and high performance variability. A minimum of –0.6% *ROA* reveals losing entities, while the maximum of 5.1% reveals high performance at the tail end. These differences are in accordance with Cull et al. (2011) study that highlights institutional governance, client type, local economic conditions, and transparency activities as key determinants of the performance of MFIs [2].

External Auditing (*EA*), captured as a binary variable, has a mean of 0.74, indicating that 74% of MFIs undergo regular external audits. However, a standard deviation of 0.44 reveals that a considerable proportion still operate without consistent audits, particularly smaller or newer MFIs. This underscores the need for regulatory enforcement to ensure universal adoption of auditing as a trust-building mechanism.

Public Disclosure (*PD*), measured on a 1–5 scale, is 3.4 with a 1.0 standard deviation, reflecting moderate transparency but with wide institutional variation. Low-scoring institutions have lower stakeholder trust, while high-scoring MFIs would gain from increased reputational capital. This is in line with [23], as they highlight public reporting as an important driver of performance.

Table 1
Descriptive statistics of the main variables

Variable	Mean	SD	Min	Max
ROA (%)	2.25	1.28	–0.6	5.1
EA	0.74	0.44	0	1
PD	3.4	1.0	1	5
ACS	0.65	0.48	0	1
TFR (days)	58	16	30	85
LOG_{TA}	6.9	1.3	4.2	9.5

Source: Compiled by the authors based on NBE filings, MFI reports, and survey data.

Accounting Standards Compliance (***ACS***), averaging 0.65 with a large standard deviation of 0.48, suggests that nearly two-thirds of MFIs comply with existing standards like IFRS, but there remain gaps to be filled. This absence of consistency justifies institutional capacity issues, validating Bushman et al.'s view that the quality of financial reporting is extremely significant for governance and performance [9].

Timeliness of Financial Reporting (*TFR*) is 58 days on average and between 30 and 85. While the mean indicates fairly effective reporting, the wide range indicates operating inefficiencies in most institutions. Delayed reporting will most likely undermine investor confidence and limit access to funds, as highlighted by [34], a concern of particular interest to donor-supported MFIs.

Institutional Size (LOG_{TA}) stands at 6.9, with a range of 4.2 to 9.5, as indicative of tremendous variations. Larger MFIs have a greater likelihood of being endowed with governance institutions and financial instruments, which translate into higher transparency and profitability, as according to [6].

Overall, the data reveal a sector heading in an open and better direction but one marked by institutional inequities that demand policy focus on a more equitable, sectorial improvement.

4.2. Correlation analysis

Table 2 presents the Pearson correlation coefficients among the study's principal variables: Return on Assets (*ROA*), External Auditing (*EA*), Public Disclosure (*PD*), Accounting Standards Compliance (*ACS*), Timeliness of Financial Reporting (*TFR*), and Institutional Size (LOG_{TA}). The analysis examines the direction and strength of correlations among financial transparency dimensions and MFI financial performance, in addition to testing for potential multicollinearity concerns prior to regression modeling.

4.2.1. Interpretation and diagnostic insights

Diagnostic test results reveal moderate, significant correlations between *ROA* and major transparency variables, revealing positive relationships with *EA*, *PD*, *ACS*, and LOG_{TA}, and a negative relationship with *TFR*. No multicollinearity problems are found, since all Variance Inflation Factors (VIFs) are less than the critical value of 5, with values from 1.6 to 2.1. These results confirm the appropriateness of the regression model and confirm the application of the selected variables in explaining the impact of financial transparency on the performance of Ethiopian MFIs.

4.3. Regression analysis: The effect of financial transparency on MFI performance

This section provides fixed-effects regression estimates analyzing the impact of financial disclosure on Ethiopian microfinance institutions' (MFIs) financial performance as reflected by Return on Assets (*ROA*). From panel data of 13 MFIs spanning the period 2015–2024, the model tests the impact of external auditing, public disclosure, accounting standards compliance, and financial reporting timeliness, holding constant institution size. The empirical findings clearly confirm the transparency facilitating effect for institutional profitability and sustainability (*Table 3*).

4.3.1. Discussion

The Hausman test-approved fixed-effects regression analysis confirms the significant influence of financial transparency factors on the financial performance of microfinance institutions (MFIs) in Ethio-

Table 2
Correlation matrix and VIF

Variable	ROA	EA	PD	ACS	TFR	LOGTA	VIF
ROA	1.00						
EA	0.48**	1.00					1.8
PD	0.43**	0.35**	1.00				1.9
ACS	0.40**	0.30**	0.28**	1.00			1.7
TFR	−0.32**	−0.25**	−0.20*	−0.22*	1.00		1.6
LOG_{TA}	0.50**	0.38**	0.32**	0.34**	−0.18*	1.00	2.1

Notes: $N = 130$. $^{**}p < 0.01$, $^{*}p < 0.05$. VIF calculated from auxiliary regressions.

Source: Compiled by the authors.

Table 3
Fixed-effects regression results for ROA

Variable	Coefficient	Robust SE	p-value	95% Confidence Interval
EA (External Audit)	1.05	0.20	0.000	[0.66, 1.44]
PD (Public Disclosure)	0.58	0.12	0.000	[0.34, 0.82]
ACS (Accounting Compliance)	0.89	0.18	0.000	[0.54, 1.24]
TFR (Timeliness of Reporting)	−0.03	0.01	0.015	[−0.05, −0.006]
LOG_{TA} (MFI Size)	0.46	0.10	0.000	[0.26, 0.66]
Constant	−1.60	0.40	0.000	[−2.38, −0.82]

Notes: $N = 130$ observations; Within $R^2 = 0.64$; $F(5,112) = 22.4$; $p < 0.001$. Fixed effects included for MFI and year. Data sources: NBE filings and MFI reports (2015–2024).

Source: Compiled by the authors.

pia. The model indicates a within R^2 of 0.64, which means that 64% of Return on Assets (*ROA*) variation in MFIs during the study period is explained by the transparency. Variables being examined — external auditing (*EA*), public disclosure (*PD*), accounting standards compliance (ACS), financial reporting timeliness (*TFR*) — and institutional size (LOG_{TA}). These findings provide strong empirical support for the research's main hypothesis: that higher levels of financial disclosure have a positive effect on institutional performance, whereas delayed reporting is harmful to it. The results are in line with theory models, namely agency theory [19], and provide an extension of previous empirical findings to the Ethiopian microfinance environment.

External Auditing (*EA*) demonstrates a strong, statistically significant association with *ROA* (coefficient = 1.05, $p < 0.001$). This result confirms that MFIs subject to regular external audits achieve better financial outcomes than those that are not. External audits play a pivotal role in ensuring the accuracy and integrity of financial disclosures, serving as an external validation mechanism that mitigates information asymmetry and managerial opportunism. As argued by agency theory, such mechanisms promote stakeholder trust and lower agency costs with the greater managerial observability. The results support Cull et al., who discovered that MFIs audited by external parties are more transparent and financially stable [2]. In the donor-driven Ethiopian financial sector, where stakeholder trust is central, mandatory audited institutionalization may build sector-level credibility, mobilize external funds, and finance sustainable performance.

Public Disclosure (*PD*) is similarly significant, with a positive effect on *ROA* (coefficient = 0.58, $p < 0.001$). MFIs that frequently disclose operational and financial information — through annual reports, audited statements, and social performance data — experience higher profitability. Public disclosure enhances transparency, facilitates stakeholder monitoring, and strengthens external credibility, particularly among donors, investors,

and regulators. The result validates theoretical assertions that transparency mechanisms reduce information asymmetry and boost confidence [9]. Empirical studies by Bogan and Mersland and Strøm similarly find that MFIs with robust disclosure practices attract more investment and perform better financially [8, 20]. In Ethiopia, where disclosure practices are inconsistent and enforcement mechanisms weak, standardizing and mandating disclosure protocols could strengthen institutional performance and stakeholder engagement across the sector.

Accounting Standards Compliance (*ACS*) is also positively and significantly correlated with *ROA* (coefficient = 0.89, $p < 0.001$). MFIs that adhere to International Financial Reporting Standards (IFRS) or comparable national accounting frameworks exhibit superior financial outcomes. This can be attributed to enhanced data reliability, consistency, and comparability — factors essential for strategic decision-making and risk management. The findings confirm the hypothesis that compliance with standardized accounting norms promotes internal discipline and boosts institutional credibility. This outcome echoes prior literature, including Barth et al., who affirm that high-quality financial reporting directly impacts firm-level performance by improving access to funding and reducing risk perception [35]. In Ethiopia, however, smaller MFIs often lack the technical and financial capacity to implement IFRS, leading to sectoral disparities. Thus, regulatory support and targeted capacity-building are critical to facilitating wider adoption and reaping the full performance benefits of standardized reporting.

The regression analysis reveals a statistically significant negative relationship between **Timeliness of Financial Reporting (*TFR*)** and Return on Assets (*ROA*), with a coefficient of –0.03 ($p = 0.015$). This indicates that each day of delay in publishing audited financial reports results in a 0.03 percentage point decline in *ROA*. Although seemingly marginal, cumulative delays — such as 30 days or more — can reduce profitability by nearly one full percentage point, a substantial drop in a sector where the average *ROA* is approximately 2.25%. This result confirms the *hypothesis* that delayed reporting adversely affects MFI financial performance.

Delays in financial reporting typically reflect deeper organizational issues such as weak internal governance, inefficient financial management, and poor prioritization of reporting processes. More critically, they erode stakeholder confidence, hinder timely decision-making, and compromise risk management capabilities. This finding aligns with agency theory [21], which posits that timely information reduces information asymmetry between managers and stakeholders. Empirical support is found in Owusu-Ansah, who demonstrated that delayed reporting in emerging markets reduces investor confidence and limits capital access [32]. On the other hand, timely reporting signals institutional discipline, enhances trust, and enables MFIs to respond effectively to dynamic financial conditions. This affirms prior research by Ball and Bushman et al., emphasizing the value of prompt disclosure in promoting market discipline and institutional resilience [14].

Further, **Institutional Size (LOG_{TA})** positively and significantly impacts *ROA* (coefficient = 0.46, $p < 0.001$). Large MFIs benefit from economies of scale, diversified portfolios, and more robust governance structures. Their broader resource base enables investment in newer technologies, training staff, and risk containment mechanisms. Such efficiencies are reflected in higher financial returns. The positive size-performance nexus is confirmed in literature [8], highlighting the importance of institutional size and maturity to profitability and sustainability. Large MFIs also benefit from greater market credibility, inducing donor funds, strategic alliances, and regulatory authority — enhancing their competitive position in the Ethiopian financial market.

Overall synthesis and regression evidence thus offer strong empirical evidence for the hypothesis that financial disclosure does indeed play an important part in the performance of Ethiopian MFIs in a financial way. Timeliness in reporting, external audit, compliance accounting, and disclosure are all determinants that become pivotal when it comes to profitability. Institutional size becomes conducive to their effect by causing operating efficiencies as well as strategic investment feasible. These findings are in line with theoretical frameworks (agency theory, stakeholder theory) and previous empirical studies, further confirming the multi-dimensionality of financial performance determinants in the microfinance sector.

In conclusion, transparency also enhances MFIs' ability to secure loans from commercial banks, re-

Table 4
Reliability test

Test Name	Statistic	Degrees of Freedom	p-value	Null Hypothesis (H_0)	Result	Implication
Modified Wald Test	$\chi^2 = 28.6$	13	0.002	Homoskedasticity (constant error variance across MFIs)	Reject H_0	Heteroskedasticity present; robust standard errors ensure reliable inference (Gujarati, 2003)
Breusch-Pagan Test	$\chi^2 = 1.2$	1	0.273	Correct model specification (no omitted variables or incorrect functional form)	Fail to reject H_0	Linear fixed-effects model is correctly specified, with no evidence of bias (Gujarati, 2003)

Notes: Tests conducted in Stata. Data: *N* = 130 (2015–2024).

Source: Compiled by the authors.

inforcing their complementary role in Ethiopia's financial system. By improving credibility through external audits and public disclosures, MFIs can access bank funding to expand operations, particularly in underserved rural areas where banks are scarce. This complementary dynamic supports financial inclusion and business financing, as MFIs extend credit to small entrepreneurs who lack the documentation or credit history required by banks. Regulatory frameworks should encourage this synergy to strengthen the financial ecosystem.

4.4. Diagnostic validity and model robustness

To test reliability and validity of fixed-effects regression estimates, diagnostic tests were run to test for heteroskedasticity as well as model specification. Results of the Modified Wald Test of groupwise heteroskedasticity and the Breusch-Pagan Test for specification are presented in *Table 4*.

Interpretation of diagnostic test results

The diagnostic tests validate the validity and stability of the regression model used in determining the relationship between financial transparency and MFI performance. The Modified Wald Test ($\chi^2 = 28.6$, $p = 0.002$) indicates that there is groupwise heteroskedasticity present, likely due to institutional heterogeneity in governance and size. Robust standard errors were applied to address this, which resulted in consistent and unbiased coefficient estimates, as urged by [29]. In addition, the Breusch-Pagan Test ($\chi^2 = 1.2$, $p = 0.273$) fails to reject the null hypothesis, confirming correct model specification and absence of omitted variable bias. The use of the most significant transparency variables — *EA*, *PD*, *ACS*, and *TFR* — along with institutional size (LOG_{TA}) and MFIs and time fixed effects, confirms a comprehensive and theory-constrained model. These results collectively confirm that the model is statistically sound and theoretically consistent, thereby establishing the credibility and empirical validity of the study's findings on financial transparency and institutional performance.

4.5. Integration of qualitative insights

To complement the quantitative findings, a qualitative inquiry was undertaken through structured interviews with 13 senior executives — including CEOs and board members — from a cross-section of Ethiopian microfinance institutions (MFIs), such as ACSI, OCSSCO, VisionFund, Meklit, and Kafa. The objective was to gain deeper insights into the practical perceptions of financial transparency and its implications for institutional performance. Using NVivo for transcription and thematic analysis, guided by [31], four key themes emerged, reinforcing and contextualizing the statistical results.

Audit credibility and institutional legitimacy were the most common themes. Nine respondents emphasized that external audits were necessary not just for compliance with regulations but also in order to establish legitimacy with donors and

regulatory agencies. One ACSI CEO described, "Audits send a message to donors that our finances are strong, and they lead to more loan disbursements and renewed partnerships." This finding is corroborated by the regression analysis, as external auditing (EA) demonstrated a strong positive correlation with *ROA* ($\beta = 1.05$, $p < 0.001$). Executives supported that audits reduce information asymmetry and uncover operating inefficiencies, thus indirectly contributing to financial improvement.

Public disclosure as a stakeholder engagement tool was the second dominant theme. Ten respondents recognized frequent public disclosures as instrumental in building trust with donors, clients, and partners. A board member from VisionFund remarked, "Regular disclosures demonstrate transparency and commitment, which are attractive to more clients and establish donor trust." This aligns with quantitative findings indicating a positive impact of public disclosure (*PD*) on *ROA* ($\beta = 0.58$, $p < 0.001$). Respondents viewed public disclosure not just as a regulatory obligation but as a proactive mechanism for enhancing institutional credibility and competitive advantage, particularly in a donor-dependent ecosystem.

Accounting compliance and operational efficiency emerged as the third significant theme. Eight participants associated compliance with international accounting standards (notably IFRS) with improved internal controls, error reduction, and greater international credibility. An OCSSCO executive noted, "Adopting IFRS reduced reporting mistakes and aligned us with global best practices, improving our credibility with international funders." This resonates with the regression results, where accounting standards compliance (*ACS*) positively affected *ROA* ($\beta = 0.89$, $p < 0.001$). Though acknowledged as resource-intensive, IFRS implementation was seen to yield operational streamlining and enhance audit preparedness.

Timeliness of reporting and reputational risk was a critical concern for eleven respondents. Participants voiced that delayed reporting signals internal inefficiencies and erodes stakeholder trust, particularly among smaller MFIs. A Meklit board member observed, "Delays in reporting are interpreted as red flags by donors — they question whether we're hiding something or just not capable." This sentiment reflects the regression outcome showing a negative relationship between timeliness of financial reporting (*TFR*) and *ROA* ($\beta = -0.03$, $p = 0.015$). Improved timeliness was linked to recent investments in financial infrastructure and seen as indicative of institutional maturity.

4.5.1. Challenges and conflicting perspectives on implementing transparency practices

Qualitative interviews with senior executives from 13 Ethiopian microfinance institutions (MFIs) revealed critical challenges and divergent perspectives that hinder the effective implementation of transparency practices. These findings enrich the contextual understanding of transparency in Ethiopia's donor-driven and regulated microfinance environment, highlighting operational, regulatory, and stakeholder-related complexities.

Capacity and resource constraints were the worst constraints, especially for the smaller-sized institutions. Meeting international accounting standards like IFRS and annual audits requires enormous financial and technical capacity that most of the rural-focused institutions do not have. Managers again indicated that compliance helps in realigning concentration and resources away from lending operations as a whole and provides a trade-off between governance and outreach. Greater institutional capacity and larger MFIs are well positioned to service the demands of transparency, creating uneven adoption industry-wide.

Inconsistencies in regulation enforcement also compromise efforts towards transparency. Since timely reporting is as much as the National Bank of Ethiopia (NBE) requires, enforcement tends to be inconsistent. Smaller MFIs reportedly have less than stringent sanctions for defaulting, compromising sector-wide trust. Regulators had mixed sentiments on regulatory policy: while some of them desired stricter punishment for the sake of accountability, others cautioned that retributive systems would decimate already frail institutions. Most demanded enhanced regulatory support and capacity-building programs customized.

Varied expectations of stakeholders also pose a significant challenge. Donors and partners abroad expect international-standard full disclosure, while domestic clients, especially those in rural communities, expect plain and simple communication. This inconsistency makes public disclosure strategy challenging because MFIs must meet external accountability requirements and cater to their client

base at the same time. Internal resistance was also mentioned by a few managers, as employees viewed audits and greater openness as intrusive or even revealing institutional vulnerabilities.

Lastly, *cultural and contextual barriers* like weak financial literacy and weak digital infrastructure make formal disclosure mechanisms less effective. Managers noted that rural customers trust interpersonal relations to a greater extent than formal disclosures and therefore need localized, culture-sensitive communication practices. These observations call for an integration of international standards of disclosure with local contexts so that practices are efficient as well as contextually relevant.

Synthesis of quantitative and qualitative evidence: The combination of qualitative and quantitative evidence gives a balanced perspective of transparency practices in Ethiopia's microfinance industry. Although regression analysis verifies the efficacy of the establishment of the positive association between transparency practices like external audits (*EA*), public disclosures (*PD*), and accounting standards compliance (*ACS*) and financial performance, qualitative interviews uncover operating, regulating, and cultural constraints that are a hindrance for its effective implementation. Of special interest is the paradox of theoretical transparency advantages versus operationally limiting factors. Transparency enhances institutional credibility, trust, and donor access but is subject to operationally limiting factors such as funds available, periodic non-enforcement of regulation, and other stakeholder demands. Small MFIs, for example, are confronted with difficulties in meeting IFRS compliance due to technical and funds-related constraints, while periodic non-monitoring by the National Bank of Ethiopia inhibits accountability. These impediments are the reasons why transparency benefits are not always achieved in institutions. In addition, delayed disclosure is generally the result of operational inefficiency and regulatory differences, while stakeholder misalignment — between donor expectations of full disclosures and client requirements of frugality — renders disclosure complicated.

This alignment means that transparency has to be viewed as an enabler of governance strategy, rather than a compliance function. Its success relies on sound regulation regimes, capacity building, and sensitization of the stakeholders to bridge the systemic issues and reconcile expectations and offer a unified strategy towards the sustainable development of the microfinance sector in Ethiopia.

5. Conclusion

This study provides empirical and qualitative evidence that financial transparency — operationalized through external audits, public disclosure, compliance with accounting standards, and timely financial reporting — plays a decisive role in enhancing the financial performance of microfinance institutions (MFIs) in Ethiopia. The analysis reveals that these dimensions of transparency are not merely regulatory obligations but strategic levers that influence stakeholder trust, institutional credibility, and profitability.

Among the key conclusions, external auditing emerges as the most influential factor, significantly boosting institutional performance by reducing information asymmetries and strengthening internal control. Public disclosure and compliance with standardized accounting frameworks also contribute meaningfully, signaling operational discipline and aligning MFI practices with global benchmarks. In contrast, delays in financial reporting are consistently associated with diminished profitability, underscoring the importance of timeliness as a core component of transparency. The findings clarify that financial efficiency, measured by *ROA*, is a critical but not exhaustive component of institutional efficiency, which also encompasses operational and social dimensions. While the study prioritizes financial efficiency due to its relevance to Ethiopia's donor-driven MFI sector, transparency likely enhances operational efficiency (e.g., through streamlined reporting) and social efficiency (e.g., by building client trust), as suggested by qualitative insights and global literature.

The practical relevance of these findings is immediate and actionable. For Ethiopian MFIs, investing in transparency mechanisms offers a viable path toward improved institutional resilience, stronger donor relationships, and enhanced competitive positioning. Regulators are encouraged to adopt differentiated oversight frameworks that balance enforcement with capacity-building, particularly for small and rural-based MFIs. Donors and development partners should direct support not only to programmatic interventions but also to governance infrastructure, including digital reporting platforms and staff training in financial management.

Future research may expand this study by examining causal mechanisms using longitudinal designs, exploring client perceptions of transparency, or testing the model in other African or emerging market contexts. As Ethiopia continues to deepen its financial inclusion agenda, transparency must be repositioned from a compliance formality to a foundational principle of sustainable microfinance development.

Limitations and future research directions

While this study provides insightful findings regarding the impact of financial transparency on the financial performance of Ethiopian microfinance institutions (MFIs), several limitations must be acknowledged. First, the analysis relies on secondary financial data, which may contain unobserved errors despite triangulation efforts. Future research could enhance reliability by using audited third-party data or primary longitudinal data collection.

Second, the study's focus on Return on Assets (*ROA*) as the sole metric for financial performance limits its scope to financial efficiency, potentially overlooking operational efficiency (e.g., cost per borrower) and social efficiency (e.g., client outreach, loans to marginalized groups). While *ROA* was chosen for its relevance to donor-driven MFIs and data availability, other indicators like Operational Self-Sufficiency (OSS) or number of clients served could provide a more comprehensive view of institutional efficiency. The use of terms like "stability," "sustainability," and "reliability" in the article may imply broader efficiency, but these were intended to reflect financial performance (*ROA*) unless otherwise specified. Future studies could incorporate multiple efficiency metrics to capture the multifaceted nature of MFI performance.

Third, the qualitative component, while rich, is based on interviews with 13 executives, limiting the diversity of perspectives. Including a broader range of stakeholders, such as clients or regulators, could provide deeper insights. Fourth, the focus on Ethiopia's unique regulatory and donor-dependent context may limit generalizability. Comparative analyses across other African or emerging market contexts, particularly examining MFI-bank dynamics, could validate and refine the findings.

Finally, the study's "narrow" focus on financial efficiency, while justified by data availability and donor priorities, does not fully address institutional efficiency's operational and social dimensions or the competitive and complementary roles of MFIs and banks. Transparency's potential to enhance cost management, client outreach, or bank loan access warrants further exploration. Overcoming these limitations offers opportunities for future research to examine transparency's broader impact on MFI viability and global microfinance literature.

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Corporate Social Responsibility in the Textile Industry in Russia: From its Origins to the Present Day

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ABSTRACT

The **relevance** of the study is due to the fact that corporate social responsibility (CSR) is an integral part of entrepreneurial activity focused on sustainable development. **Scientific problem**: It is traditionally believed that the concept of CSR originated in the United States in the mid-20th century and appeared in the modern Russian Federation only with the advent of transnational corporations at the end of the 20th century. However, historical data indicate deep-rooted traditions of socially responsible entrepreneurship in Russia long before their official recognition. **The purpose** of this work is to identify the practices of social responsibility by textile manufacturers in the Ivanovo region at the turn of the 19th and 20th centuries and compare them with the current state of the industry and the manifestation of CSR in it. **Methods**: More than 100 authentic historical documents from the collections of the Ivanovo State Museum of Local History named after Dmitry Burylin were analyzed, and D.G. Burylin's socially responsible activities were systematized according to the CSR pyramids of A. Carroll and N. Masoud. **The results** obtained showed that textile manufacturers of the past demonstrated economic, legal, social responsibility and were also engaged in philanthropic activities. This proves that the philosophy of responsible entrepreneurship existed in Russia long before its appearance in the modern sense, which allows us to rethink Russia's role in the development of the concept of corporate social responsibility. In addition, the authors conducted a comparative analysis of the largest textile enterprises in the Ivanovo region in the 1900s and 2020s. Some lag of modern enterprises has been revealed, both in economic development and in social activity. In this regard, it is advisable for modern enterprises to adopt the experience of the past and continue the traditions of social activity in the textile industry of the Ivanovo region.

Keywords: corporate social responsibility; textile industry; Ivanovo region; Russia; entrepreneur; philanthropy; patronage; charity; social guarantees and benefits; sustainable development

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ОРИГИНАЛЬНАЯ СТАТЬЯ

Корпоративная социальная ответственность в текстильной промышленности России: от истоков до современности

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АННОТАЦИЯ

Актуальность исследования связана с тем, что корпоративная социальная ответственность (КСО) представляет собой неотъемлемую часть предпринимательской деятельности, ориентирующейся на устойчивое развитие. **Научная проблема**: традиционно принято считать, что концепция КСО зародилась в США

в середине XX в., а в современной Российской Федерации появилась лишь с приходом транснациональных корпораций в конце XX в. Однако исторические данные свидетельствуют о глубоко укоренившихся традициях ответственного перед обществом предпринимательства в России задолго до их официального признания. **Цель** данной работы — выявить практики проявления социальной ответственности фабрикантами текстильной промышленности Ивановской области на рубеже XIX–XX вв. и сравнить их с современным состоянием отрасли и проявлением КСО в ней. **Методы**. Проанализировано более 100 подлинных исторических документов из фондов Ивановского государственного историко-краеведческого музея имени Д.Г. Бурылина, произведена систематизация направлений социально ответственной деятельности Д.Г. Бурылина по пирамидам КСО A. Carroll и N. Masoud. **Полученные результаты** показали, что текстильные фабриканты прошлого проявляли экономическую, правовую и социальную ответственность, а также занимались филантропической деятельностью. Это доказывает, что философия ответственного предпринимательства существовала в России задолго до ее появления в современном понимании, что позволяет переосмыслить роль России в развитии концепции корпоративной социальной ответственности. Дополнительно авторы провели сравнительный анализ крупнейших текстильных предприятий Ивановской области 1900-х и 2020-х гг. Выявлено некоторое отставание современных предприятий, как в экономическом развитии, так и в социальной деятельности. В этой связи современным предприятиям целесообразно перенимать опыт прошлого и продолжать традиции социальной деятельности в текстильной отрасли Ивановской области.

Ключевые слова: корпоративная социальная ответственность; текстильная промышленность; Ивановская область; Россия; предприниматель; филантропия; меценатство; благотворительность; социальные гарантии и льготы; устойчивое развитие

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1. Introduction

Social responsibility has many manifestations and, among other things, can be defined through the types of activities carried out in the interests of the employees. The first steps to socially responsible management in the past were the establishment of standard working hours, improvement of working conditions, provision of lunch breaks, and the opportunity to rest during the working day, as well as access to medical care, compensatory payments, help with housing, etc. All of the above contributed to a significant improvement in the quality of life of workers and their families. At present, the concept of corporate social responsibility is manifested in all sectors of the economy in developed and developing countries. Textiles occupy a special place among the sectors of the national economy, which is due to the special historical facts of its development.

The textile industry was the dominant sector of the Industrial Revolution during the late 19th and early 20th centuries, as evidenced by data on employment, demand for products, and the cost of capital invested [1]. It was in the textile industry that modern production methods began to be used en masse, machine technology was introduced, which, in turn, contributed to achieving high production rates compared to other industries. Thanks to the use of mechanization and improvement of industrial processes, at the turn of the 19th and 20th centuries, the textile industry reached its peak. Production became mass and more efficient. The obvious advantages of the development of the textile industry during this period, due to industrialization, expansion of sales markets, and active introduction of new technologies (steam engines, weaving machines and chemical processes), contributed to social changes that led to the transformation of the social structure. Workers in textile factories constituted one of the largest labor groups, which highlighted the growing issue of ensuring their quality of life and respecting their rights. In this regard, research into the social responsibility practices of textile manufacturers seems relevant.

The emergence of social responsibility among textile manufacturers is associated with several factors. One of them is the high rate of industrialization, in the context of which there is an awareness of the need to improve the working conditions of workers in factories, as this allows for an increase in labor productivity. The next factor should be attributed to attempts at social normalization. The activation of the workers' social movement in the second half of the 19th century, typical for European countries and the USA, also finds echoes in Russia from that period. For example, from the 1870s to 1897, there

was a reduction in the length of the working day from 14–16 hours to 11.5 hours [2]. In addition, the socially responsible activities of entrepreneurs in pre-revolutionary Russia were determined by Orthodox traditions, according to which high incomes had to be directed to charitable deeds and the public good [3]. Thus, existing ideological and traditional values, as well as growing public awareness of workers' problems and their demands for improved working conditions, stimulated textile manufacturers to implement social programs and initiatives.

Furthermore, many countries, including Russia, were already beginning to adopt laws that regulated working conditions and provided social guarantees for workers. Given this, manufacturers were forced to follow these standards and implement social programs to comply with the law. Another factor can be considered: the growing competition in this area. With the increase in the number of textile factories, the demand for skilled labor increased, and to retain such workers and attract new ones, changes in the social policy of enterprises were required.

At the turn of the 19th and 20th centuries, social responsibility of textile factories became the norm in Russia. From the second half of the 19th century, prominent Russian entrepreneurs began to develop a set of measures at their industrial enterprises related to the introduction of medical care, sanitary hygiene rules in factories and workers' barracks, as well as the organization of primary education for workers' children [3]. Ultimately, in the largest factories, the actions of factory owners and manufacturers result in extensive social programs for workers and employees, objectively aimed at improving the quality of work and life [4].

In the 20th century, after the socialist revolution, all textile enterprises were nationalized, and a number of social guarantees and standards were implemented within the framework of the command-administrative economic system. In the 21st century, as free economic relations returned, implementing the CSR concept at textile enterprises in the Ivanovo region has become important again.

The Ivanovo region is the textile capital of the country, with about 3,000 textiles and sewing enterprises concentrated here. The region produces 70% of Russia's cotton fabrics. According to Ivanovostat,[1] in 2024, industrial enterprises in the Ivanovo region shipped goods of their own production and performed work and services for a total of 404.837 billion rubles. In current prices (excluding inflation), this is 17 percent more than in 2023. Of this, exactly a third comes from textile production — 136.54 billion rubles.

Thus, we believe that using the example of the Ivanovo textile industry, we can trace the emergence of CSR in Russia long before its official recognition.

2. Materials and methods

The purpose of this study was to examine the social responsibility of textile enterprises in the Ivanovo region at the turn of the 19th and 20th centuries using the example of D. G. Burylin's factories, as well as modern practices of social responsibility of textile enterprises in the region.

To develop the research algorithm, the first stage of the study involved studying scientific papers on the topic of entrepreneurship and archival documents. This study was conducted using the method of studying retrospective sources that recorded historical facts and information about the manifestation of social responsibility by entrepreneurs, as well as archival documents confirming this.

At the next stage, to confirm the hypothesis about the manifestation of social responsibility in its modern understanding by textile manufacturers of the past, a modern model of corporate social responsibility (CSR) was chosen — the pyramid of A. Carroll, which consists of a hierarchy of responsibility: at the base is the economic factor, then comes legality, then ethics, and at the top is charity [6, 7]. The authors also used a modification of A. Carroll's pyramid made by N. Masoud in 2016 [8].

At the final stage of the study, the authors conducted a comparative analysis of the economic and social activities of textile enterprises in the Ivanovo region at the beginning of the 20th century and at the beginning of the third decade of the 21st century. For this purpose, analytical reports on the state of textile production in the region, presented in open sources, as well as data provided by the executive authorities of the Ivanovo region, were used.

The materials on the topic of the study included various sources concerning the development of the textile industry of the Ivanovo region at the turn of the 19th — 20th centuries, as well as data on the current state of the industry. The sources can be grouped into the following categories:

[1] Mokretsov M. Textile production by the end of 2024 accounted for a third of the entire industry of the Ivanovo region. Ivanovo Live. URL: https://ivanovolive.ru/news/22759

• scientific works in the field of the history of the development of the textile industry in pre-revolutionary Russia and the origins of the development of corporate social responsibility in its modern sense;

• archival documents from the depository of the State Budgetary Institution of the Ivanovo Region "Ivanovo State Museum of Local History named after D.G. Burylin";

• the modern concept of CSR, developed by various authors, including the CSR pyramid of A. Carroll and N. Masoud [6–8];

• statistical data and analytical reports of the executive authorities of the Ivanovo region on the regulation of social and labor and related economic relations between the Government of the Ivanovo region, the regional association of trade union organizations, and the regional association of employers;

• information on the state of the textile industry in the Ivanovo region, presented in open sources, including the Internet.

3. Results

Historically, the textile industry of Russia has come a long way from a handicraft subsistence economy to the formation of large industrial centers in the Moscow and Ivanovo regions [9].

Moscow textile industry

In the history of Moscow textile production, several dynasties of manufacturers can be distinguished, which made a significant contribution to the development of the industry. One of the most famous dynasties of textile manufacturers in Moscow was the Morozovs dynasty. It began its activity at the end of the 19th century and invested heavily in the development of the textile industry. The Morozovs factories were known for their high-quality textiles, as well as social and cultural programs for workers. Social responsibility at the Morozovs' textile factories was demonstrated in the desire to improve working conditions for workers by creating safe and comfortable working conditions in production [10]. Workers were required to comply with safety regulations and were provided with the opportunity to undergo regular medical examinations. Factories sought to comply with labor laws, including compliance with working hours, wages, and vacation pay. At Morozovs' enterprises, workers received medical care, inexpensive but high-quality food, and primary and vocational education [11].

Another famous dynasty was the Stroganovs, who founded their textile factories in Moscow in the 19th century. They also invested heavily in the industry and became some of the most successful entrepreneurs in the textile industry. The factories implemented social programs for workers, such as training and professional development, medical care and social support. The Stroganovs also actively participated in public and charitable events, supporting local communities and providing assistance to those in need.[2]

Also worth noting is the Popovs dynasty, which also played an important role in the development of the textile industry in the Moscow region. They founded a number of successful factories and contributed to improving the working and living conditions of workers at their enterprises [12].

Textile products manufactured by the Shchukins family business, famous textile manufacturers, such as bed linen, towels, blankets and other textile products, were popular among consumers due to their high quality and variety of products. The Shchukins are also known for their innovative approaches to production and constant improvement of technologies, which ensured the high competitiveness of their products in the textile market. In addition, the Shchukins paid great attention to labor protection, providing safe working conditions for their workers, carrying out preventive measures, and training personnel in safety rules [12].

Ivanovo textile industry

The economic activity of the peasants of the village, and later the city of Ivanovo-Voznesenskoye (now Ivanovo), led to this region becoming the largest center for the production of *chintz* in pre-revolutionary Russia [13]. Manufacturers from this city played a significant role in the economic life of the country and made a significant contribution to the development of the textile industry. The most famous dynasty in the region is considered to be the Burylin textile manufacturers, which reached the peak of its economic development at the turn of the 19th and 20th centuries, when Dmitry Gennadyevich Burylin was in charge.

[2] State Budgetary Institution of the Ivanovo Region "the Ivanovo State Museum of Local History named after Dmitry Burylin" Official website. URL: https://igikm.ru/

A study of historical archival documents of the Burylin dynasty of textile manufacturers allows us to find confirmation that they were indeed aware of their social responsibility in relation to the conduct of business at enterprises, in terms of striving to improve the working conditions of their employees by creating better working conditions, providing opportunities for education, as well as the opportunity to take care of workers' health and safety.

The documents stored in the state archive, in the funds of the D.G. Burylin Museum, in the regional scientific library, eloquently testify to the reputation of Dmitry Gennadyevich as a kind, decent and honest person and a proactive defender of the city's interests. For example, he organized the improvement of the city's central boulevard, purchasing trees and shrubs at his own expense. He was the founder and trustee of various health and educational institutions, which implied not only participation in their management but also the direct allocation of significant sums for their improvement.[3] From 1872 he held various positions in 57 city and public institutions. The Ivanovo State Museum of Local History has a document containing a list of institutions in which he participated in the period from 1872 to 1919.[4]

The innovativeness of D.G. Burylin's enterprise is confirmed by the employment of a chemical engineer from France, V.A. de la Croa, for fabric coloring. The Ivanovo Museum of Local History holds a contract for the employment of V.A. de la Croa dated 16.01.1912.[5]

At the factories of D.G. Burylin, a Health Insurance Fund was created, the Rules of which show concern for the condition of workers and the possibilities for them to receive medical care. The Ivanovo Museum of Local History contains the Rules for the participants of the fund, which establish the rules for providing medical care to workers of the spinning-weaving-bleaching, calico-printing and brewing-dyeing factories.[6] A newspaper clipping about the hospital for craftsmen and workers in Ivanovo in 1910 provides data on the costs of its maintenance and treatment of patients. All this demonstrates the manifestation of social responsibility and confirms the desire to ensure financial transparency of business activities.[7] Factory workers were also elected to the hospital council, which is mentioned in the surviving Letter of the Ivanovo-Voznesensk City Mayor addressed to D.G. Burylin regarding the meeting of factory owners on elections to the Council of the Hospital of Unskilled Workers.[8]

The factories had rules that established the rights and obligations of both the owner and the factory workers, the requirements for labor discipline, the procedure for making payments, determining guarantees and working conditions, etc. These rules were put in each worker's paybook so they could learn them. Thus, the Ivanovo State Museum of Local History named after Dmitry Burylin contains Payroll Book No. 188 of Ulita Fedorovna Matveyeva, a sorter in the bleaching department of the D.G. Burylin Paper Products Manufactory.[9]

The owner of the factory was charged with the responsibility of taking measures to ensure the welfare and order at the enterprise, the procedure for issuing wages was specified, etc. The established internal regulations specified the schedule of work start and end times, the duration of time for rest, lunches and breakfasts, and prescribed the conditions for using the apartments, baths, etc. arranged for workers at factories. Particular attention was paid to compliance with safety requirements when handling machines, fire safety, etc. The Ivanovo State Museum of Local History keeps the Internal Regulations for the Bleaching Department of the D.G. Burylin Paper Products Manufactory in Ivanovo-Voznesensk.[10]

D.G. Burylin's factories had insurance against industrial accidents. The Ivanovo State Museum of Local History holds a copy of the agreement between the Board of the Ivanovo-Voznesensk "Society for Mutual Insurance of Manufacturers and Plant Owners from Accidents with Their Workers and Employees" and the peasant I. Ya. Printsev on the issuance of a one-time compensation for the death of his daughter from an accident that occurred at the factory of the "Partnership of Manufactures of D.G. Burylin".[11]

[3] State Budgetary Institution of the Ivanovo Region "the Ivanovo State Museum of Local History named after Dmitry Burylin" Official website. URL: https://igikm.ru/

[4] Depository catalog number: Ivanovo Regional Museum of Local History (further briefly) IRMLH 2582. URL: https://www.goskatalog.ru/portal/#/collections?id=29454807

[5] Depository catalog number IRMLH 3131. URL: https://www.goskatalog.ru/portal/#/collections?id=33913134

[6] Depository catalog number IRMLH 2650. URL: https://www.goskatalog.ru/portal/#/collections?id=30583997

[7] Depository catalog number IRMLH 2752/3. URL: https://www.goskatalog.ru/portal/#/collections?id=35788694

[8] Depository catalog number IRMLH 63679. URL: https://www.goskatalog.ru/portal/#/collections?id=33074057

[9] Depository catalog number IRMLH 77670. URL: https://www.goskatalog.ru/portal/#/collections?id=49303726

[10] Ibid.

[11] Depository catalog number IRMLH 3146. URL: https://www.goskatalog.ru/portal/#/collections?id=33920192

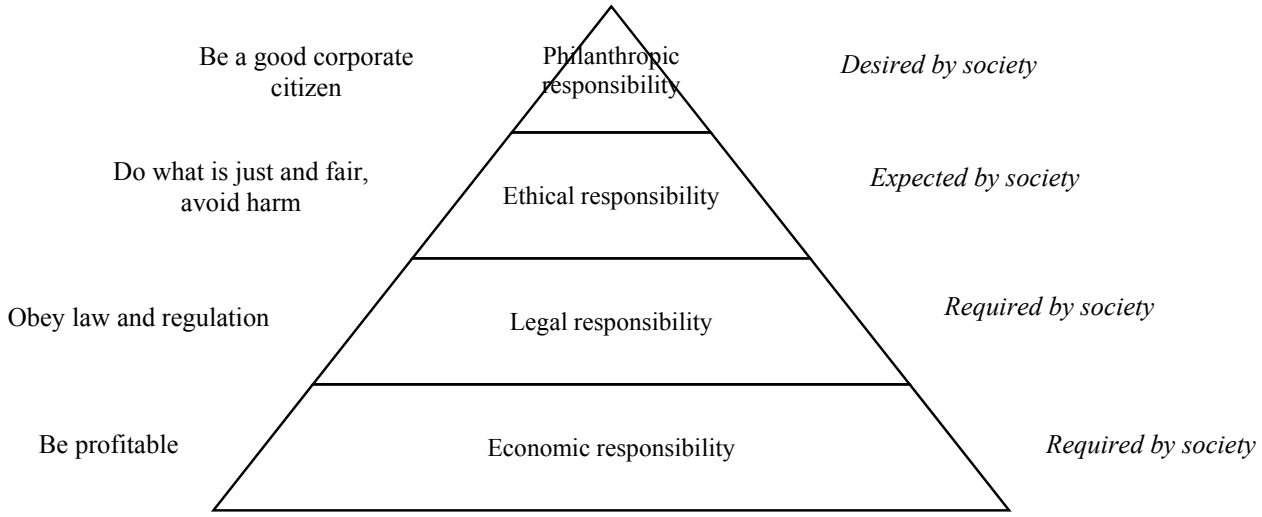

Fig. 1. **Carroll's modified classic pyramid model of CSR**

Source: [7 p. 8].

Table 1

Systematization of social responsibility of textile manufacturer D.G. Burylin by levels of the CSR pyramid of A. Carroll

Levels of social responsibility	**Factors of manifestation of social responsibility in factories D.G. Burylin**
Economic responsibility: to increase profits, create quality products, oblige employees to show personal responsibility, etc.	Introduction of new technologies, expansion of production. The factory produced elastic, calico, twill, jacquard fabrics. Products of Burylin factories received gold and silver awards at international and all-Russian exhibitions. In 1895, the manufacturing facilities were completely transferred to stone buildings, equipped with steam heating, ventilation, electric lighting and the most advanced technology of the time
Legal responsibility: establishing and adhering to business principles: honesty, transparency, safety, maintaining reputation, establishing trust, etc.	Approval of internal regulations and the Charter of factories, which established the rights and obligations of both the manufacturer and the workers. Compliance with the law and maintenance of law and order and welfare in factories and residential buildings. Establishment of a local crown police and manufacturing department in the village of Ivanovo
Ethical responsibility: compliance with rules of conduct, requirements are the same for everyone, etc.	Provision of medical care to workers and their families by organizing a special fund (bol'nichnye kassy). Construction of barracks to provide workers with housing. Construction of household facilities (bathhouses). The factory financed the insurance of workers and employees, and the maintenance of housing and outpatient care
Philanthropic responsibility: charity, environmental protection, support for education, healthcare, volunteering, etc.	The factory maintained several houses for free apartments for specialists for its workers. The factory had a two-year men's school with a four-year course, for the maintenance of which 2.5 thousand rubles were spent annually. For children of poor parents, free charity dinners were organized at their own expense, and funds were allocated to help the poor, and gifts were purchased for children from orphanages for the New Year. In 1904, on Burylin's initiative and with his personal funds, a wooden church from the 17th century was preserved. In 1912, he built a retaining wall with a wave-shaped lattice and planted a linden alley. Financing of general and vocational educational institutions in the city of Ivanovo. Establishment of a museum

Source: Developed by the authors.

Dmitry Gennadyevich Burylin paid great attention to education, especially primary education; he was a trustee and organizer of schools for craftsmen and workers, as well as their children. The Ivanovo State Museum of Local History holds a Letter from the Inspector of Public Schools, I. Lyubimov, addressed to D.G. Burylin, on the organization of a primary school.[12] Like the entire city elite, he was a member of the boards of trustees of a number of educational institutions. Among the recipients of his money were a technical school, a drawing school, a women's vocational school, the Uspenskaya and Afanasovskaya parochial schools, as well as a zemstvo school in Khutorovo [14].

D.G. Burylin was a passionate collector; he started with a collection of fabrics and then began to travel around the world and collect exotic antiquities and even acquired entire collections. The first demonstration of exhibits collected by Burylin took place in 1903, and then he built a separate building for the museum, which was ceremoniously opened at the end of December 1914.

As can be seen from the conducted research of the historical facts of the activities of the manufacturer D.G. Burylin, who operated in the small provincial town of Ivanovo-Voznesensky, his social activity was in no way inferior to the capital's patrons and philanthropists. At the same time, it is important to emphasize that, despite this, the level of well-being of factory workers remained unsatisfactory, which later led to the socialist revolution.

After the socialist revolution of 1917, one of the representatives of the Burylin family continued to manage the factory under the control of the workers' committee, and in 1919, when the enterprise was nationalized, he left the following message: "Workers, I implore you by the living God, do not ruin the economy. I do not spare myself, the factories are beauties, how much of my sweat and blood went into them" [14]. These words also convey the meaning of the manifestation of social responsibility of an entrepreneur for his enterprise.

4. Discussion

The results and conclusions of the study conducted by the authors on the socially responsible activities of textile manufacturers in pre-revolutionary Russia can be compared with the model of corporate social responsibility proposed by Professor Archie Carroll in 1991. He presented his model as a pyramid consisting of a hierarchy of responsibility: at the base is the economic factor, followed by legality, then ethics, and at the top is charity (*Fig. 1*). A. Carroll's pyramid is recognized as an outstanding contribution to the conceptualization of CSR in the 20th century [15].

A comparison was made of the manifestation of social responsibility in the factories of D.G. Burylin with the description of the factors specified in the model of A. Carroll, the content of which confirms the presence of elements of social responsibility in textile production in pre-revolutionary Russia (*Table 1*).

Thus, we see that already at the end of the 19th — beginning of the 20th century, Russian textile manufacturers implemented all aspects of CSR according to the concept of A. Carroll. However, this model has been repeatedly criticized since it was developed in the USA and for companies from the USA, which makes it difficult to use in other countries, especially developing ones [16–18]. In this regard, a researcher from Jordan proposed his own interpretation of the CSR pyramid (*Fig. 2*). In this model, the basic responsibility, as in A. Carroll's pyramid, is economic responsibility — this is what commercial organizations exist for. At the second level there is a glocal responsibility, which takes into account the global and local agenda in the field of environmental protection, preservation of cultural and ethnic heritage, resolution of socio-economic problems, etc. The entrepreneur's motto at this level is "think globally, act locally." At the third level of the responsibility hierarchy are legal and ethical responsibilities together, and at the fourth level is corporate philanthropy.

Next, we will systematize the socially responsible activities of D.G. Burylin and his associates in the international CSR pyramid (*Table 2*).

Thus, the use of the modern international CSR pyramid allows us to more fully disclose all aspects of D.G. Burylin's socially responsible activities, since it became possible to supplement the classical approach with activities in the area of solving urban development issues, as well as preserving cultural heritage through collecting and subsequently establishing a museum accessible to the public.

In general, textile manufacturers of the late 19th and early 20th centuries were characterized by expansion of production, introduction of advanced

[12] Depository catalog number IRMLH 2819/8. URL: https://www.goskatalog.ru/portal/#/collections?id=34075864

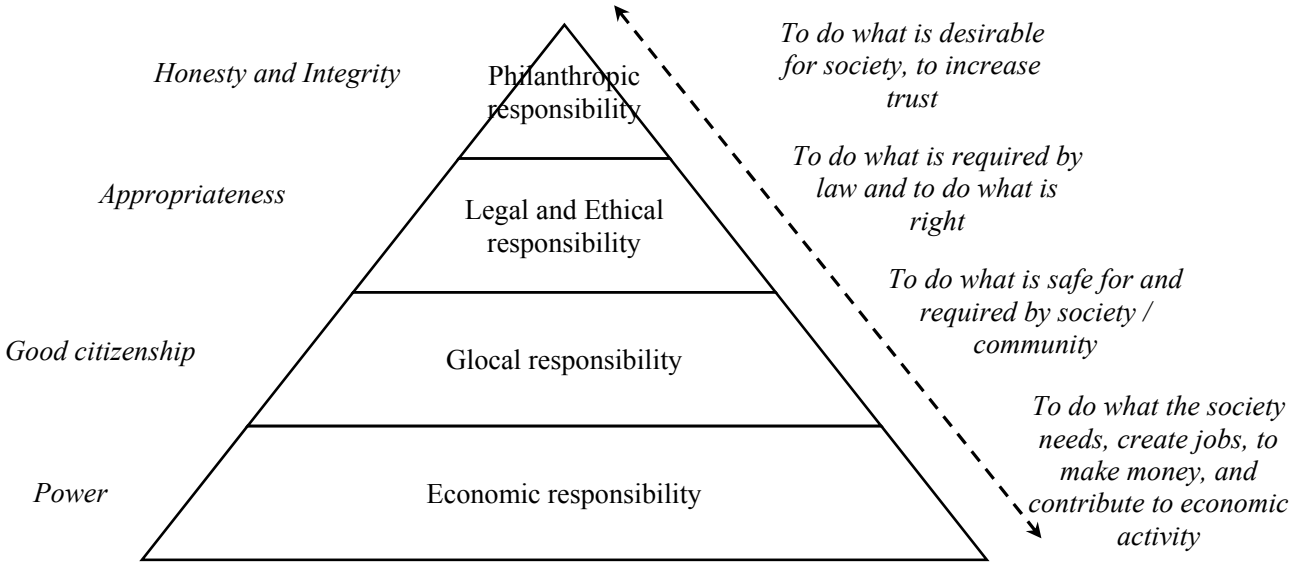

Fig. 2. **International Pyramid Model of CSR**

Source: [8]

technologies and capital growth — economic responsibility, attention to the problems of urban development — glocal responsibility, compliance with legal requirements and ensuring workers' rights relevant to that historical stage of society's development — legal and ethical responsibility, charity and funding of educational, medical, and cultural institutions — philanthropic responsibility.

Current state of the textile industry in the Ivanovo region

As already mentioned, the Ivanovo region is the center of textile production in Russia. According to the results of 2023, the top-20 largest textile enterprises of the Russian Federation shipped goods for a total of 50.68 billion rubles. Nine of these twenty enterprises, including the first three leaders in revenue, are located in the Ivanovo region. In total, these enterprises of the Ivanovo region shipped goods for 31.19 billion rubles.[13]

The authors compared the production volumes of the three largest textile factories associations of the early 20th century (Kuvaevs, Burylins, Yamanovskies) from the Ivanovo region in 1902 and nine largest textile enterprises of this region in 2023 (LLC "TD Tekstil", LLC "IvMashTorg", LLC "Galtex", LLC "KhBK NAVTEX", LLC "Ultrastab", LLC "Ivanovsky Melangeevy Kombinat", LLC "Kolobovskie Tkani", LLC "Bolshaya Tekstilnaya Manufaktura"). The conversion of the pre-revolutionary ruble into modern money was carried out at the average annual price of gold for 2023 according to the Central Bank of the Russian Federation,[14] since the tsarist ruble was equal to 0.77g of gold [19]. As a result, it was established that the three largest factories of the early 20th century were twice as ahead of the nine largest textile enterprises of the present day in terms of annual revenue (*Table 3*). This lag of modern textile enterprises is due to the fact that currently 55% of textiles sold in Russia are imported,[15] and in pre-revolutionary Russia net imports were negative [20], and Russia increased its exports to the countries of the East (Iran, China). The level of annual wages in the industry is currently also lower than it was in pre-revolutionary Russia, but working conditions 120 years ago were much more difficult: the working day was 11.5 hours long, modern occupational safety standards did not exist and, as a result, were not implemented (dampness, stifling air, high temperatures, etc.), which led to a high percentage of occupational diseases [2].

Next, we will present the results of the analysis of the CSR practices of modern textile enterprises in the Ivanovo region according to the A. Carroll pyramid based on the analytical reports of the regional executive authorities (*Table 4*).

[13] Top 20 Russian fabric manufacturers for 2023. URL: https://пошев.рус/blog/top-20-rossijskikh-proizvoditelej-tkani

[14] Official gold exchange rate in rubles per gram according to the Central Bank of Russia. URL: https://investfunds.ru/indexes/224/

[15] Review of the textile and light industry of Russia for 2023. URL: https://www.rctest.ru/Documents/%D0%A0%D1%8B%D0%BD%D0%BE%D0%BA%20%D0%9B%D0%95%D0%93%D0%9F%D0%A0%D0%9E%D0%9C%20%D0%B7%D0%B0%202023_%D0%B8%D1%82%D0%BE%D0%B3.pdf

Table 2

Systematization of social responsibility of textile manufacturer D.G. Burylin by levels of the international CSR pyramid N. Masoud

Levels of social responsibility	Factors of manifestation of social responsibility in factories D.G. Burylin
Economic Responsibility	See "Economic Responsibility" in *Table 1*
Glocal responsibility	Improvement of the city of Ivanovo-Voznesensk (for example, landscaping the boulevard on Aleksandrovskaya Street). Collecting fabrics, preserving and transmitting cultural traditions by creating a large collection of old Ivanovo cotton printed textiles. Expanding the collection with other artifacts. Establishing a museum. The search for a compromise solution to the problem of the fire hazard of small wooden buildings on the one hand and depriving the local population of housing they had just built on the other hand. It resulted in a petition to prohibit the demolition of wooden buildings on small plots in the city and to allocate city land free of charge in vacant places to Ivanovo residents who were losing their small plots, giving them up to two years to move their houses to new lands
Legal and Ethical Responsibility	See "legal responsibility" and "ethical responsibility" in *Table 1*
Philanthropic Responsibility	See "Philanthropic Responsibility" in *Table 1*

Source: Developed by the authors.

Table 3

Comparison of income of textile enterprises of Ivanovo region in 1902 and 2023

Parameters	Volumes
Revenue of the largest textile enterprises of the Ivanovo region, 1902	12.79 million rubles
Revenue of the largest textile enterprises of the Ivanovo region, 1902, converted to modern money at the cost of gold	62.56 billion rubles
Revenue of the largest textile enterprises of the Ivanovo region, 2023	31.19 billion rubles
Average annual wages of textile factory workers, 1902	159 rubles
Average annual wages of textile factory workers, 1900, converted to today's money at the value of gold	774 thousand rubles
Average annual wages of textile factory workers, 2023	457 thousand rubles

Source: Developed by the authors.

The results show the following:

1) the modern textile industry of the Ivanovo region is one of the key for the region, textile enterprises make a significant contribution to the socio-economic development of the region. At the same time, in terms of income levels and economic efficiency, modern textile enterprises lag behind their historical counterparts, primarily due to the changing global market conditions;

2) a number of social guarantees and benefits that were introduced by pre-revolutionary manufacturers on a voluntary basis are now part of the social guarantees provided at the legislative level, and modern textile enterprises also provide additional social benefits on top of this, therefore, the well-being of modern workers is generally higher than 120 years ago, but this is due, first of all, to the general development and humanization of social and labor relations and the reduction in the number of dependents (children and elderly parents) among workers, etc.;

3) at the level of philanthropic responsibility, according to available data, the contribution of modern textile enterprises of the Ivanovo region is insignificant compared to the patronage of manufacturers of the past. This is due, firstly, to the fact that the income of textile enterprises turned out to be lower than that of their analogues of 120 years, therefore, modern enterprises do not have sufficient funds for charitable activities. Secondly, textile enterprises of the Ivanovo region are mainly represented by small

Table 4

Systematization of social responsibility of modern textile enterprises of the Ivanovo region by levels of the CSR pyramid of A. Carroll

Levels of social responsibility	Factors of manifestation of social responsibility of textile enterprises of Ivanovo region
Economic responsibility: to increase profits, create quality products, oblige employees to show personal responsibility, etc.	Revenue growth of textile enterprises by 26% in 2023. As part of the national project "Labor Productivity and Employment Support", a number of sample flows (the result of optimization of production/auxiliary processes based on the formed infrastructure for the development of the production system) have been implemented at textile enterprises (for example, LLC "Trikotazh Natalie", Ivanovo Textile Company, etc.), as a result, on average, work in progress was reduced by 36%, process time by 27%, and output increased by 32%. In December 2023, LLC "Mercury" launched an investment project "Creation of production of brushed knitted fabric of increased comfort, including innovative heat-resistant fabric based on aramid fibers." LLC "Ultrastab" has established production of over 40 types of import-substituting geotextile materials used in the construction of motorways, railways, hydraulic structures, airfields, as well as in landscaping. The weaving line produces wide fabrics made of polyester and polypropylene
Legal responsibility: establishing and adhering to business principles: honesty, transparency, safety, maintaining reputation, establishing trust, etc.	Protection and safety of labor and improvement of working conditions of workers, provision of social guarantees and benefits for workers within the framework of legal norms established by labor legislation. A number of textile enterprises have concluded collective labor agreements regulating social and labor relations (for example, LLC "KhBK NAVTEX"). Textile enterprises are included in the list of the largest taxpayers of the Ivanovo region, filling the regional budget with their tax payments (for example, LLC "TD Tekstil", LLC "IvMashTorg", LLC "Galtex", LLC "KhBK NAVTEX" and others). At the same time, the industry agreement regulating social and labor relations in the textile industry was concluded until the end of 2023, and no new agreement was concluded for subsequent periods
Ethical responsibility: compliance with rules of conduct, requirements are the same for everyone, etc.	In addition to the social guarantees established by law, textile enterprises provide many benefits to employees with children: one-time payments at the birth of children, on Mother's Day, Knowledge Day, provision of additional vacations, medical insurance, free vouchers to health resorts, organization of holidays and competitions for children of employees, provision of gifts to children of employees, free distribution of fabrics at the birth of children, etc. (OJSC "KhBK Shuyskie Sitsy", LLC "Galtex", LLC "KhBK NAVTEX", etc.). Free provision (compensation of part of the cost) of memberships to sports organizations (fitness clubs, swimming pools, gyms, ice arenas, winter bases, etc.). Insurance of family members of employees under corporate insurance programs. Provision (compensation of rental costs) of housing. Lifetime payment to the pension (with indexation) for employees who have worked at the enterprise for 15 years (upon their retirement)
Philanthropic responsibility: charity, environmental protection, support for education, healthcare, volunteering, etc.	In 2023, an additional partnership agreement was concluded to create and develop educational and production clusters between textile enterprises and the Government of the Ivanovo Region. The region's enterprises are actively developing a new direction for themselves — the production of natural fabrics from flax and hemp, as well as recycling and the launch of secondary processing of raw materials ("Laut Recycling", "Lider Tex", "EcoMir", "Krasnaya Vetka"). Conducting cultural and leisure events for employees and their families (Family Recreation Day, Victory Day, Children's Day, Knowledge Day, Winter Fun, New Year's party for employees' children, excursions around the region and the Central Federal District, etc.)

Source: Developed by the authors.

legal entities that are not required to fully disclose information about their social activities. In this regard, it is possible that the lack of information does not allow us to draw other conclusions about the philanthropic activities of textile enterprises;

4) in modern CSR practice, an important aspect is ensuring environmental protection, which is reflected in the production of textiles from recycled materials at a number of modern textile enterprises in the Ivanovo region. 120 years ago, the environmental agenda was not as acute as it is now, but even then D.G. Burylin was engaged in landscaping of Ivanovo;

5) in the practice of implementing CSR, textile enterprises strive to develop all the main directions, however, there are growth points, among which, in particular, the need to conclude an industry agreement for a new period after 2023, as well as increasing the competitiveness of products in order to increase revenue and, as a result, the emergence of funds for significant charitable projects.

Recent scientific research confirms that the concept of CSR in terms of social responsibility and charity has become ingrained at the cultural level among today's Russian managers [21], although environmental aspects are still not deeply understood [22, 23]. At the same time, it is in modern Russia that the manifestation of CSR by entrepreneurs has a greater impact on the financial performance of their business than in economically developed countries [24]. In addition, the tradition of studying CSR considers that its origins are in Western European countries and the USA, explaining corporate charity by Christian (Catholic and Protestant) philosophy [15]. Research emphasizes that CSR in Russia has previously been poorly studied [25]. The history of the development of CSR in Russia has been completely overlooked by researchers, or, on the contrary, it has been emphasized that in Russia, as in other post-Soviet countries, this concept is superficial in nature [22] and is only at the stage of inception or implementation [26]. However, the results we obtained indicate just the opposite.

Thus, a comparison of the practice of implementing economic and social activities of pre-revolutionary and modern textile factories in the Ivanovo region shows that modern enterprises need to pay attention, first of all, to their economic efficiency, increase the competitiveness of products, and enter new markets, including foreign ones, to equal the income level of pre-revolutionary factories. Higher incomes will allow companies to raise wages for workers and expand social and charitable programs.

5. Conclusion

The issues of corporate social responsibility and ensuring sustainable development are currently very relevant because of the aggravation of environmental, socio-economic and political problems in almost all regions of the world. Traditionally, corporate social responsibility has been considered to be the result of the transformation of corporate relations in the 20th century, when large corporations realized that their economic success depended not only on the effectiveness of their core operational processes but also on how ethically they conducted their business and extended their responsible behavior to the environment.

The authors conducted a study of historical facts concerning the socially responsible activities of textile manufacturers in Russia at the turn of the 19th and 20th centuries. Particular attention is paid to the activities of industrialist Dmitry Gennadyevich Burylin from Ivanovo, as a representative of provincial entrepreneurs on the one hand, but also a large industrial center on the other. As a result of studying archival documents presented in the funds of the Ivanovo State Museum of Local History named after Dmitry Burylin, the main directions of his social activity were determined. This analysis allowed us to see manifestations of CSR in the work of the factory and in the personal charitable activities of D.G. Burylin himself. The results we obtained indicate that corporate social responsibility in the 19th — 20th centuries was not limited to Western European countries and the USA but was widespread among Russian entrepreneurs.

Then, the facts of the manifestation of social responsibility of D.G. Burylin and his enterprises were systematized in accordance with the CSR pyramid of A. Carroll, as well as in accordance with the improved international CSR pyramid. The latter allowed a comprehensive examination of the social activity of the manufacturer D.G. Burylin.

As a result of the original author's approach, which consists of examining the activities of industrialists in pre-revolutionary Russia from the point of view of the modern concept of Corporate Social Responsibility, it was possible to determine that already 120 years ago in pre-revolutionary Russia the social responsibility of entrepreneurs was realized, and the history of CSR can and should be expanded beyond the countries of Western Europe and the USA geographically and the boundaries of the 20th century historically.

At the final stage, the authors compared the results of economic activity of the largest textile enterprises of the Ivanovo region according to data from 1902 and 2023, as well as the practice of their socially responsible activities. It has been found that although the welfare of workers is generally at a higher level at present, this is largely due to the state's social policy but not the activity of manufacturers themselves. It is important for textile enterprises themselves to adopt the historical experience of pre-revolutionary manufacturers, who allocated significant funds to social activities, which is only possible if their products are highly competitive.

However, our study is not free from some limitations. Thus, we have examined in detail the representation of the CSR only by example of D.G. Burylin, while other representatives of the entrepreneurial community of pre-revolutionary Russia are only mentioned in passing. In this regard, the problem of the emergence and development of the CSR in Russia requires a more detailed study with reference to archival materials not only from Ivanovo but also from other regions of Russia. Further research will allow us to study in more depth the role of Russian entrepreneurs in the history of CSR development in the world.

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M.A. Ponomareva — conceptualization, editing, organization of a scientific expedition to The Ivanovo State Museum of Local History named after Dmitry Burylin.
M.A. Gagarina — review, editing and preparation of a list of sources.

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ORIGINAL PAPER

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Efficiency of Public Social Security Expenditure: A Cross-Country Study Using Factor Analysis and Advanced Machine Learning

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ABSTRACT

Research objectives. Contemporary global challenges, such as demographic shifts, the climate crisis, and rapid technological transformation, necessitate innovative approaches to managing social security systems. This study addresses the urgent need for tools to enhance the efficiency of Financial-Investment Models of Social Security (FIMSS), particularly under constrained fiscal resources and heightened uncertainty. The aim is to develop and validate a comprehensive approach for assessing FIMSS efficiency, incorporating modern challenges and public finance management specifics. **Methods.** By integrating ratio analysis, factor analysis, and advanced machine learning techniques, including gradient boosting (XGBoost), this study establishes a robust, multi-level framework for efficiency evaluation. The dataset covers 38 Organisation for Economic Co-operation and Development (OECD) countries, Russia, and China over the period 2005–2022, enabling cross-country comparisons, with regression analysis limited to a subsample of 26 countries due to data availability. **The scientific novelty** lies in introducing the EffCoverSP indicator, which accounts for social protection coverage and employing partial dependence plots (PDP) to uncover nonlinear relationships among socioeconomic factors, extending macroeconomic theories of social system sustainability and social justice frameworks. **Results** reveal that FIMSS efficiency is driven by moderate budgetary expenditures, public debt below 50% of gross domestic product, a Gini index of 0.37–0.43, urbanization of 63–74%, and fertility rates of 1.55–1.7. **The practical significance** lies in the potential application of this approach to reform FIMSS, enhancing their sustainability and adaptability to global challenges, thereby informing evidence-based policy decisions.

Keywords: FIMSS; social security; social expenditure; economic inequality; XGBoost; budgetary expenditure efficiency; poverty; effective social protection coverage; social policy

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ОРИГИНАЛЬНАЯ СТАТЬЯ

Эффективность государственных расходов на социальное обеспечение: кросс-страновое исследование с использованием факторного анализа и продвинутого машинного обучения

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АННОТАЦИЯ

Цели исследования. Современные глобальные вызовы, такие как демографические сдвиги, климатический кризис и быстрые технологические трансформации, требуют инновационных подходов к управлению системами социального обеспечения. Настоящее исследование отвечает на острую необходи-

мость в инструментах для повышения эффективности финансово-инвестиционных моделей социального обеспечения (ФИМСО), особенно в условиях ограниченных фискальных ресурсов и повышенной неопределенности. Цель состоит в разработке и валидации комплексного подхода к оценке эффективности ФИМСО, учитывающего современные вызовы и специфику управления общественными финансами. **Методы**. Комбинация коэффициентного, факторного анализа и методов машинного обучения создает комплексный и многоуровневый методический подход к оценке эффективности ФИМСО. Набор данных охватывает 38 стран Организации экономического сотрудничества и развития (ОЭСР), Россию и Китай за период 2005–2022 гг., что позволяет проводить межстрановые сравнения, при этом регрессионный анализ ограничен подвыборкой из 26 стран из-за доступности данных. **Научная новизна** заключается во введении показателя эффективного покрытия населения программами социальной защиты (EffCoverSP) и использовании графиков частичной зависимости (PDP) для выявления нелинейных связей между социально-экономическими факторами, расширяя макроэкономические теории устойчивости социальных систем и рамки социальной справедливости систем социального обеспечения. **Результаты** показывают, что эффективность ФИМСО определяется умеренными бюджетными расходами, государственным долгом ниже 50% ВВП, индексом Джини 0,37–0,43, урбанизацией 63–74% и уровнем рождаемости 1,55–1,7. **Практическая значимость** заключается в потенциальном применении этого подхода для реформирования ФИМСО, повышая их устойчивость и адаптивность к глобальным вызовам, тем самым способствуя принятию обоснованных политических решений на основе доказательств.

Ключевые слова: ФИМСО; социальное обеспечение; социальные расходы; экономическое неравенство; XGBoost; эффективность бюджетных расходов; бедность; эффективное покрытие программами социального обеспечения; социальная политика

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1. Introduction

The long-term transformation cycle of social security systems aligns with demographic, technological, and economic cycles. The evolution of social security (SS) prior to the emergence of the Bismarckian model can be characterized as a prolonged period dominated by the concept of decentralized social security, during which the state played a less significant role in the economy compared to contemporary conditions.

In modern contexts, the potential of decentralized social security models proves insufficient to support sustainable socioeconomic development, particularly in advanced economies with high levels of urbanization. In the 21st century, the state's role as the primary actor in social security has become indisputable and vital for any highly developed post-industrial economy with elevated social standards. However, slowing population growth and increasing demographic pressures have begun to undermine the efficiency of social security systems, posing risks to their long-term financial sustainability. This has led to a global rise in public debt and necessitated unpopular reforms in the social spheres of many countries. Further increases in budgetary expenditures allocated to the operation of financial and investment models of social security (hereafter FIMSS[1]) have become exceedingly challenging for high-income countries. The current demographic situation compels governments to either seek additional sources of funding for social expenditures or gradually reduce them as a percentage of gross domestic product (GDP).

A recent report of the International Labour Organization[2] (ILO) highlights a narrative deserving particular attention. The report focuses on the so-called triple planetary climate crisis, encompassing climate change (global warming), environmental pollution, and biodiversity loss. The structural transformation of economies resulting from climate-focused financial policies may lead to increased poverty, unemployment, inequality, and slower economic growth in many countries [1].

Addressing future existential crises in social security financing requires coordinated efforts across countries and the application of tailored

[1] The Financial-Investment Model of Social Security (FIMSS) is defined as a framework for organizing financial relations associated with managing social risks and addressing other objectives in the field of public social security.

[2] ILO. World Social Protection Report 2024–26 Universal social protection for climate action and a just transition. URL: https://www.social-protection.org/gimi/Media.action?id=10982 (accessed on 10.01.2025).

methods of public administrative, financial, and monetary regulation. The constraints of limited financial resources, high levels of uncertainty, and adverse demographic trends underscore the need to develop and substantiate strategies for enhancing the efficiency of FIMSS. In this context, the development of a comprehensive approach for analyzing FIMSS efficiency, aimed at enabling objective and multifaceted monitoring of efficiency-enhancing processes, remains highly relevant.

The objective of this study is to develop and test a novel, comprehensive approach for analyzing the efficiency of FIMSS, aligned with contemporary challenges in the management of social security finances.

2. Literature review

The relevance and practical significance of evaluating the efficiency of public expenditure in the context of global challenges are indisputable, as evidenced by a substantial body of scientific research and thematic publications by global organizations [2].

The issue of efficiency evaluation is addressed in the scientific literature through various approaches. These include simple methods based on ratio analysis [3–5], graphical data representation [6], and methods involving data ranking and clustering based on indices, composite indicators, or individual coefficients [7–9].

Foreign empirical studies predominantly focus on cross-country comparisons, examining the efficiency of public expenditure by analyzing specific indicators across a broad sample of countries or territorial units within a single country[3] [2] or within a limited sample based on specific criteria [10–12].

The most common approaches to analyzing the comparative efficiency of public expenditure involve constructing efficiency frontiers using methods such as Free Disposal Hull (FDH) and Data Envelopment Analysis (DEA) [2, 3, 13, 14]. However, as FDH and DEA efficiency metrics often provide limited insight into the causality of high or low efficiency, they are frequently combined with other research methods in empirical studies.

Another common approach in the literature involves efficiency assessments based on Agent-Based Stock-Flow Consistent (AB-SFC) modeling [15, 16]. Limitations of this method at its current stage of development include the inherent constraints of macroeconomic models and challenges in aligning them with the real dynamics of socio-economic processes due to the large number of parameters and uncertainty factors [17].

Machine learning methods, particularly gradient boosting techniques, are less commonly applied in the context of public expenditure efficiency evaluation. Nevertheless, their successful application in healthcare and insurance suggests significant potential for tasks such as forecasting public expenditure, evaluating the efficiency of social programs, and analyzing risks. For instance, XGBoost has been utilized for data classification [18, 19] and forecasting macroeconomic, budgetary, and other indicators [20–23]. Numerous studies highlight XGBoost's high accuracy, performance, reliability, and computational speed compared to traditional regression analysis methods, which is particularly relevant given the well-known limitations of classical regression analysis, such as heteroskedasticity, autocorrelation of residuals, and data stationarity issues [24–27].

Based on the literature review, the following research hypothesis (H1) is formulated: The efficiency of FIMSS is determined by the ability of public social security systems to minimize poverty and ensure adequate coverage of social protection programs while maintaining moderate levels of budgetary expenditure and public debt, under the influence of nonlinear contextual factors (inequality, urbanization, and fertility rates).

3. Materials and methods

3.1. Overview of the research methodology

Afonso et al. (2010) define the efficiency of public expenditure as the minimization of costs while achieving specified social outcomes, such as poverty reduction [2]. Drawing on the findings of prior studies [17, 24], a comprehensive approach for evaluating the efficiency of FIMSS is proposed. This approach enables the analysis of budgetary efficiency at the level of subnational entities within a single country, as well as cross-country comparisons (*Fig. 1*).

In this study, the efficiency of FIMSS is defined as the system's ability to ensure a high standard of living through adequate coverage of social risks and broad access to social security programs with

[3] Most commonly, the research methodology design follows this exact approach.

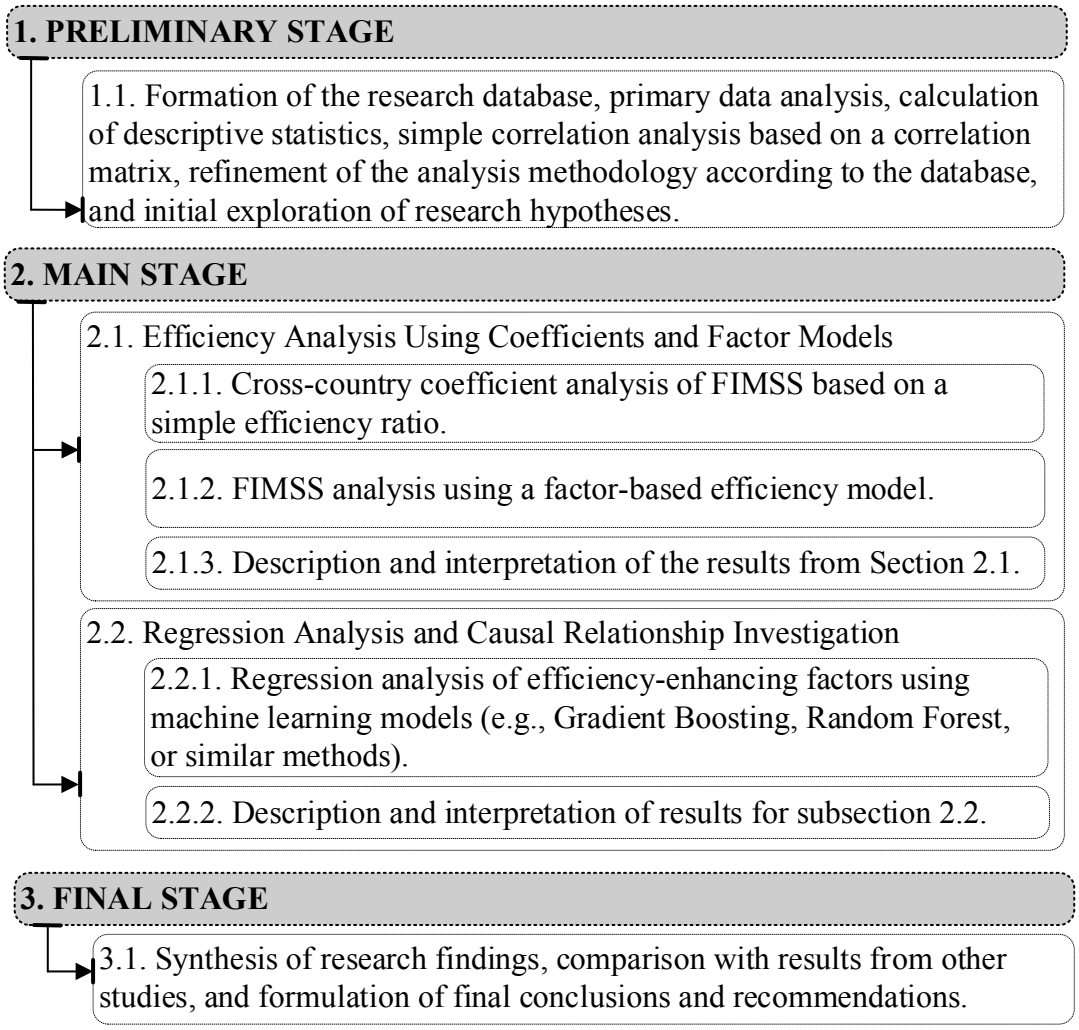

Fig. 1. **Overview of the approach for conducting a cross-country analysis of FIMSS efficiency**

Source: Compiled based on the research materials.

minimal budgetary expenditures, aligning with the principles of economy and effectiveness outlined in the Budget Code of the Russian Federation (BCRF).

Ratio and factor analysis are based on a combination of four interrelated coefficients. Public expenditure on social security within state-managed FIMSS (as a percentage of GDP) per 1% of the poor population, as a relative efficiency coefficient, is presented in formula (1) [17, 24].

$$K1 = \frac{TotGovSSS2GDP}{PPovLM50}, \quad (1)$$

where: *TotGovSSS 2GDP* — public expenditure on social security (GovSoex2GDP) and healthcare; *PBPovLM*50 — the share of the population with incomes below 50% of the median per capita income.

The coefficient K1 serves as a relative measure of FIMSS efficiency, reflecting the volume of budgetary expenditure on social security and healthcare (as a percentage of GDP) per 1% of the "poor" population (those with incomes below 50% of the median per capita income). Its economic significance lies in evaluating the intensity of budgetary resources allocated to supporting the most vulnerable population groups.

A high K1 value may indicate either excessive expenditure or insufficient effectiveness of public social protection programs if they fail to reduce the share of the poor population.

Healthcare expenditure is included in the FIMSS efficiency assessment approach because it provides social guarantees for free medical care, reducing poverty risks associated with medical expenses. This aligns with Organisation for Economic Co-operation and Development (OECD) standards, where healthcare constitutes a significant portion of budgetary social expenditure for most countries. While *K*1 can be used to analyze FIMSS efficiency, for accurate interpretation, it

is recommended to transform the denominator of Formula 1 by replacing *PBPovLM50* with (*1 — PBPovLM50)*, i.e., the share of the "non-poor" population (those with per capita incomes above the subsistence minimum or 50% of the median per capita income).

Denoting the share of the population with incomes above 50% of the median per capita income as *PBPovLM50*, formula (1) is reformulated as shown in formula (2).

$$K2 = \frac{TotGovSSS2GDP}{1 - PBPovLM50} = \frac{TotGovSSS2GDP}{PUPovLM50} \rightarrow min, \quad (2)$$

where: *PUPovLM*50 — the share of the population with incomes above 50% of the median per capita income.

The coefficient *K*2, defined as the ratio of budgetary expenditure on social security and healthcare (as a percentage of GDP) to the share of the "non-poor" population, serves as a key criterion for FIMSS efficiency. Its economic significance lies in assessing how effectively budgetary resources contribute to maintaining a high standard of living for the majority of the population (those with incomes above the poverty threshold). A lower *K*2 value indicates a more economical and effective public social security system, as a smaller share of expenditure (as a percentage of GDP) supports the well-being of a larger proportion of the population.

As noted earlier, ratio analysis is frequently employed in studies of social expenditure efficiency, as it provides straightforward and interpretable assessments of the relationship between socioeconomic outcomes and the financial resources allocated to achieve them. For the state, an efficient system (economical in expenditure and effective in increasing the share of the "non-poor" population) is characterized by the lowest possible *K*2 value.

Formulas for *K*1 and *K*2 are based on ratio analysis approach of Timofeev and Tumanyants [3], where efficiency is evaluated as the ratio of costs to social outcomes. The introduction of *K*3 extends this approach by incorporating the factor EffCoverSP, enhancing the objectivity of the assessment and contributing to the methodological novelty of this study, formula (3).

$$\begin{cases} K3 = \dfrac{K2}{EffCoverSP} = \dfrac{TotGovSSS2GDP}{PUPovLM50 * EffCoverSP} = \\ = \dfrac{TotGovSSS}{TotGovBSp} * \dfrac{TotGovBSp}{GDP} * \dfrac{Pop}{PUPovLM50} * \dfrac{1}{EffCoverSP}; \\ K3 \rightarrow min \end{cases} \quad (3)$$

where: *GDP* — Gross Domestic Product, in monetary units; *TotGovSSS* — Public expenditure on social security, in monetary units; *TotGovBSp* — total public expenditure, in monetary units; *Pop* — total population, in persons; *EffCoverSP* — effective coverage of the population by social protection programs, measured on a scale from 0 to 1 (as per ILO standards).[4]

The proposed factor model enables the decomposition of the *K*3 coefficient into several interrelated components, providing significantly more informative insights for comparative cross-country analysis of FIMSS efficiency. Each factor in this model carries distinct economic significance, facilitating a transition from simple ratio analysis to comprehensive factor analysis based on widely used and interpretable coefficients (*Appendix 1*).

The *K*3 coefficient reflects how effectively budgetary resources allocated to social security achieve socioeconomic outcomes — namely, a high standard of living for the majority of the population (the share of the "non-poor" population) while accounting for the coverage of social protection programs.

[4] The EffCoverSP indicator, developed by the International Labour Organization (ILO) and measured in relative units on a scale from 0 to 1, represents the proportion of the population covered by at least one social protection program (e.g., pensions, unemployment benefits, health insurance, maternity payments, etc.). A value of 0 indicates no coverage whatsoever, while 1 signifies universal coverage of the entire population by at least one program.

A lower *K*3 value indicates a more efficient FIMSS, as the state achieves substantial social outcomes (a high share of the "non-poor" population and broad program coverage) with moderate budgetary expenditures on social security.

Conversely, a high *K*3 value may indicate FIMSS inefficiency, such as excessive expenditures, low program coverage, or insufficient poverty reduction.

It should be emphasized that expenditure minimization is considered in the context of optimization, not complete replacement with private financing.

Thus, *K*3 integrates the results of ratio analysis (coefficients *K*1 and *K*2) and supplements them with a control factor — the effective coverage indicator (EffCoverSP). This makes *K*3 more objective, as it accounts not only for monetary poverty indicators but also for the accessibility of social programs, aligning with ILO standards and the UN Sustainable Development Goals (SDGs). The decomposition of *K*3 into interrelated factors (expenditures, GDP, population, and program coverage) enables cross-country analysis and identification of key drivers of FIMSS efficiency.

In this study, *K*3 is used for ranking countries and analyzing the dynamics of FIMSS efficiency, as well as a dependent variable in regression analysis employing gradient boosting to identify nonlinear relationships with exogenous factors (e.g., public debt, urbanization, and fertility rates).

The XGBoost algorithm was selected due to its ability to handle nonlinear relationships and missing data, which is particularly relevant for analyzing OECD countries [20, 21]. The XGBoost model, in its basic form, can be described as shown in Formula (4).

$$F(x) = F_0(x) + \sum_{m=1}^{M} \gamma_m h_m(x), \qquad (4)$$

where: $F(x)$ — the predictive model, minimizing the error between predicted values $F(x_i)$ and actual values (from the test data subset), constructed through m = 1,2,..., M iterations of parameter calculations, where decision trees are added, and residuals (gradients of the loss function based on model predictions) are computed to guide improvements in the model's predictive power in subsequent gradient descent iterations; x_i — the vector of features, exogenous independent variables used to further explain the causality of the calculated FIMSS efficiency indicators; γ_m — the step size for minimizing the loss function; $h_m(x)$ — the decision tree.

The advantage of this method lies in its additional capability for graphical data representation and the construction of Partial Dependence Plots (PDP-plots). These plots facilitate factor analysis of efficiency based on a set of independent variables and demonstrate the nonlinearity of the relationship between the dependent variable and explanatory variables.

3.2. Research database

The study utilizes data from open sources, including the OECD,[5] the World Bank,[6] IMF,[7] the World Inequality Database (WID),[8] the ILO,[9] Rosstat, and the Ministry of Finance of Russia.[10]

The indicator of effective coverage by social security programs, sourced from the ILO database, serves as a control variable in the proposed approach for assessing FIMSS efficiency. For the purposes of this study, it is assumed that the value of this indicator remains constant across all years, based on the data available from the ILO for 2021, as this is the only publicly accessible information at the time of the research.

The study covers data from 38 OECD countries, Russia, and China over the period 2005–2022. The ratio and factor analyses of efficiency include data from Russia and China, whereas the regression analysis is limited to a smaller sample of 26 countries (excluding Russia and China) due to data scarcity and a high number of missing values, even within the OECD database.

OECD countries provide standardized and reliable data on public expenditure, social security, demographic indicators, and other variables (through OECD, ILO, and World Bank (WB) databases), ensuring high-quality and comparable information for cross-country analysis. The inclu-

[5] OECD database. URL: https://stats.oecd.org/Index.aspx?datasetcode=SOCX_REF# (accessed on 30.12.2024).

[6] WorldBank database. URL: https://data.worldbank.org/indicator (accessed on 30–12–2024).

[7] IMF database. URL: https://data.imf.org/?sk=a0867067-d23c-4ebc-ad23-d3b015045405 (accessed on 30.12.2024).

[8] WID database. URL: https://wid.world/data/ (accessed on 30.12.2024).

[9] ILOSTAT. URL: https://www.ilo.org/data-and-statistics (accessed on 30.12.2024).

[10] Ministry of Finance. URL: https://minfin.gov.ru/ru/perfomance/budget/policy/osnov (accessed on 30.12.2024).

sion of Russia and China accounts for the diversity of economic structures and expands the sample, potentially making the results more generalizable.

Challenges in forming the research database for gradient boosting modeling necessitated the use of the *K*3 coefficient as the dependent variable, calculated not for a specific year but as a five-year moving average over the period 2005–2022. This approach reduced the number of missing values and smoothed the results.

In the regression analysis using gradient boosting, additional exogenous factors were incorporated. Income inequality, urbanization, and fertility rates are considered external challenges to which FIMSS must respond. The efficiency of FIMSS is measured by the system's ability to minimize poverty and ensure program coverage under the influence of these factors.

Descriptive statistics of the research database are presented in *Appendix 2*.

4. Results and discussion

4.1. Ratio and factor analysis

The calculation of efficiency coefficients and their dynamic assessment were conducted considering the limitations of the research database. The most comprehensive data from recent reporting periods in the compiled database were available starting from 2019 and earlier. Consequently, the primary efficiency indicators were calculated for 2019 rather than later periods. To analyze efficiency dynamics, the average values of factors for each country over the last five years were also calculated (see *Table*). The right-hand side of *Table* presents the assessment of efficiency dynamics. Descriptive statistics for each factor across the full sample of countries for the period 2005–2021 are provided in rows 41–46.

Indicators in columns 2–11, consistent with the logic of the efficiency assessment model, should be minimized. The values of the control coefficients for effective coverage in columns 6 and 11 are identical, as only 2021 data are available in open sources, leading to the assumption that these indicators are conditionally constant. In future studies, these indicators should be applied dynamically if the ILO provides such data.

Columns 12–15 show changes in factors that should be minimized, comparing the current year to the five-year moving average. A decrease in the indicator reflects an increase in FIMSS efficiency. Descriptive statistics, calculated for the period 2005–2022, also allow for assessing efficiency relative to global averages (Russia is highly efficient). Instead of ranking, a heatmap construction method is applied. In the heatmap, the highest coefficient value is highlighted in red, and the lowest in green, as the *K*3 efficiency coefficient, per the proposed approach, should be minimized.

Significant progress in reducing poverty has been observed in Ireland and Portugal, leading to increased FIMSS efficiency in these countries. In contrast, Russia's share of the poor population, according to the applied approach, has increased. Nevertheless, the efficiency indicator decreased due to a reduction in the share of public social security expenditure within the budget structure, coupled with an increase[11] in total budgetary expenditure as a percentage of GDP. As the indexation rate of social policy expenditures slightly lags behind the growth rate of total public expenditure, Russia's FIMSS remains relatively efficient in the context of cross-country comparisons.

In Russia, the control factor for effective population coverage by social programs (1/coverage coefficient) stays at low levels. This indicates that, during the study period, Russia's social security system performs relatively well (relative to budgetary expenditures and the socioeconomic outcomes of other countries).

Low *K*3 value suggests a potentially more efficient FIMSS in Russia, as a smaller share of social expenditure (as a percentage of GDP) supports a high proportion of the "non-poor" population (PUPovLM50). However, a reduction in *K*3 driven by an increase in non-social budgetary items, such as defense spending in 2022–2025, without improvements in social outcomes (e.g., increases in PUPovLM50 or program coverage, EffCoverSP) should be considered a negative factor affecting FIMSS efficiency.

The unprecedented reduction in poverty in Russia, alongside a decline in the share of social expenditure in GDP, should be interpreted cau-

[11] According to Rosstat data, the primary poverty level indicator based on the subsistence minimum is significantly lower and shows a declining trend by the end of the study period. We utilized Rosstat's median income statistics to ensure the comparability of our analysis. Even under these conservative parameters, Russia demonstrates remarkable competitiveness in the K3 indicator, performing comparably to EU nations that have long served as benchmarks for our socio-economic policy.

Table

Ratio and factor analysis of FIMSS efficiency

№	Country	2019 Data					5-Year Average (2015–2019)					Efficiency Dynamics			
		K3	F1	F2	F3	F4	K3	F1	F2	F3	F4	K3	F1	F2	F3
	1	2	3	4	5	6	7	8	9	10	11	12=3/8–1	13=4/9–1	14=5/10–1	15=6/11–1
1	Australia	–	0.459	0.360	–	1.000	–	0.466	0.362	–	1.000	–	–1.65%	–0.41%	–
2	Austria	–	0.586	0.486	–	1.014	0.333	0.582	0.495	1.140	1.014	–	0.53%	–1.82%	–
3	Belgium	0.298	0.517	0.519	1.111	1.000	0.298	0.513	0.526	1.105	1.000	0.02%	0.85%	–1.42%	0.60%
4	Canada	0.211	0.516	0.375	1.088	1.002	0.210	0.525	0.368	1.089	1.002	0.32%	–1.55%	1.83%	–0.05%
5	Chile	–	–	–	1.130	1.425	–	–	0.254	1.141	1.425	–	–	–	–0.98%
6	Colombia	–	–	–		1.905	–	–	–	1.195	1.905	–	–	–	–
7	Costa Rica	–	–	0.320	1.248	1.724	–	–	0.303	1.259	1.724	–	–	5.49%	–0.80%
8	Czech Republic	0.239	0.489	0.410	1.059	1.126	0.240	0.496	0.404	1.062	1.126	–0.14%	–1.33%	1.45%	–0.28%
9	Denmark	0.359	0.605	0.497	1.070	1.117	0.367	0.598	0.516	1.065	1.117	–2.03%	1.17%	–3.66%	0.47%
10	Estonia	0.222	0.476	0.391	1.175	1.016	0.220	0.463	0.393	1.187	1.016	1.23%	2.73%	–0.46%	–1.01%
11	Finland	0.333	0.585	0.533	1.068	1.000	0.340	0.585	0.545	1.067	1.000	–1.92%	0.03%	–2.11%	0.15%
12	France	–	0.574	0.553	–	1.000	–	0.573	0.562	–	1.000	–	0.21%	–1.50%	–
13	Germany	0.303	0.598	0.450	1.122	1.005	0.298	0.599	0.443	1.115	1.005	1.78%	–0.27%	1.40%	0.65%
14	Greece	0.451	0.535	0.477	1.130	1.563	0.460	0.515	0.497	1.151	1.563	–1.87%	3.83%	–3.91%	–1.83%
15	Hungary	0.220	0.374	0.460	1.101	1.160	0.233	0.390	0.472	1.092	1.160	–5.72%	–4.12%	–2.50%	0.86%
16	Iceland	–	0.430	0.437	–	1.235	0.236	0.408	0.445	1.057	1.235	–	5.32%	–1.61%	–
17	Ireland	0.163	0.555	0.243	1.088	1.110	0.175	0.542	0.266	1.095	1.110	–7.02%	2.31%	–8.59%	–0.64%
18	Israel	0.356	0.418	0.387	1.209	1.821	0.352	0.414	0.383	1.218	1.821	1.12%	1.01%	0.80%	–0.69%
19	Italy	0.393	0.575	0.485	1.157	1.220	0.394	0.567	0.490	1.162	1.220	–0.16%	1.36%	–1.10%	–0.42%
20	Japan	–	0.618	0.385	–	1.020	0.283	0.616	0.382	1.186	1.020	–	0.37%	0.76%	–
21	Korea	–	–	–	1.195	1.294	–	–	0.311	1.206	1.294	–	–	–	–0.94%
22	Latvia	0.200	0.425	0.381	1.193	1.036	0.194	0.406	0.384	1.200	1.036	3.31%	4.67%	–0.81%	–0.53%
23	Lithuania	0.235	0.532	0.347	1.182	1.079	0.225	0.509	0.343	1.195	1.079	4.73%	4.45%	1.31%	–1.07%
24	Luxembourg	0.273	0.546	0.430	1.117	1.042	0.266	0.547	0.413	1.126	1.042	2.90%	–0.24%	3.98%	–0.81%

Table (continued)

№	Country	2019 Data					5-Year Average (2015–2019)					Efficiency Dynamics			
		K3	F1	F2	F3	F4	K3	F1	F2	F3	F4	K3	F1	F2	F3
	1	2	3	4	5	6	7	8	9	10	11	12=3/8–1	13=4/9–1	14=5/10–1	15=6/11–1
25	Mexico	–	–	–	–	1.603	–	–	–	1.194	1.603	–	–	–	–
26	Netherlands	0.259	0.551	0.421	1.087	1.026	0.264	0.551	0.431	1.086	1.026	–2.12%	–0.04%	–2.20%	0.11%
27	New Zealand	0.193	0.479	0.350	1.148	1.000	0.197	0.481	0.353	1.160	1.000	–2.34%	–0.46%	–0.84%	–1.04%
28	Norway	0.321	0.551	0.511	1.092	1.044	0.318	0.560	0.500	1.091	1.044	0.80%	–1.49%	2.20%	0.11%
29	Poland	0.281	0.516	0.419	1.104	1.178	0.276	0.508	0.416	1.112	1.178	1.67%	1.62%	0.75%	–0.71%
30	Portugal	0.290	0.550	0.424	1.119	1.109	0.298	0.532	0.448	1.128	1.109	–2.71%	3.48%	–5.27%	–0.84%
31	Slovakia	0.236	0.494	0.405	1.085	1.086	0.245	0.500	0.416	1.087	1.086	–3.95%	–1.39%	–2.47%	–0.18%
32	Slovenia	0.249	0.534	0.431	1.080	1.000	0.260	0.528	0.451	1.090	1.000	–4.15%	1.12%	–4.38%	–0.91%
33	Spain	0.339	0.561	0.416	1.172	1.236	0.334	0.551	0.417	1.175	1.236	1.51%	1.99%	–0.24%	–0.26%
34	Sweden	0.286	0.529	0.491	1.100	1.000	0.294	0.541	0.495	1.098	1.000	–2.88%	–2.38%	–0.66%	0.15%
35	Switzerland	0.176	0.461	0.320	1.110	1.079	0.178	0.461	0.322	1.109	1.079	–0.64%	0.04%	–0.77%	0.08%
36	Turkey	0.238	0.464	0.348	1.176	1.253	0.224	0.454	0.336	1.180	1.253	6.26%	2.35%	3.45%	–0.31%
37	United Kingdom	0.273	0.549	0.408	1.142	1.070	0.275	0.551	0.413	1.131	1.070	–0.62%	–0.37%	–1.15%	0.91%
38	United States	0.273	0.446	0.382	1.220	1.314	0.271	0.446	0.381	1.215	1.314	0.70%	0.06%	0.28%	0.36%
39	Russia	0.207	0.404	0.378	1.222	1.110	0.210	0.417	0.372	1.222	1.110	–1.55%	–3.19%	1.52%	0.00%
40	China	–	0.351	0.315	–	1.412	–	0.335	0.310	–	1.412	–	4.86%	1.90%	–
Descriptive Statistics for 2005–2022 Period															
41	Minimum	0.146	0.108	0.189	1.047	1.000	0.146	0.184	0.210	1.052	1.000	–7.02%	–4.12%	–8.59%	–1.83%
42	1st Quartile	0.227	0.452	0.369	1.092	1.015	0.232	0.453	0.372	1.092	1.015	–2.12%	–0.42%	–1.89%	–0.82%
43	Median	0.274	0.506	0.426	1.125	1.086	0.275	0.503	0.421	1.132	1.086	–0.16%	0.37%	–0.71%	–0.29%
44	Mean	0.279	0.493	0.423	1.135	1.186	0.279	0.491	0.422	1.141	1.186	–0.47%	0.74%	–0.58%	–0.31%
45	3rd Quartile	0.313	0.547	0.488	1.171	1.236	0.312	0.546	0.490	1.186	1.236	1.23%	2.15%	1.33%	0.12%
46	Maximum	0.525	0.619	0.649	1.404	1.905	0.479	0.616	0.578	1.404	1.905	6.26%	5.32%	5.49%	0.91%

Source: Compiled based on the research materials.

Notes: Hyphen symbol (–) in a cell without numbers signifies that the data are not available. Descriptive statistics were calculated for the period 2005–2022. However, the moving average values of *K*3 are presented only for the period 2015–2022, as this five-year period has the most complete data availability in the research database.

tiously as a factor of improved FIMSS efficiency. This reduction is driven by the lagging indexation of the absolute poverty threshold amidst faster growth in prices and labor incomes, rather than the quality and accessibility of social security programs.

4.2. Regression analysis of efficiency coefficients using gradient boosting

For the construction of gradient boosting models, the research database was randomly split into two subsets: 85% of the data were used for model training, and the remaining 15% for testing. The modeling results and the model with the best performance characteristics are presented in *Appendix 3*.

Partial dependence plots (PDP) for FIMSS efficiency are presented in *Fig. 2*, ordered by the decreasing significance of explanatory factors.

The results indicate that higher budgetary expenditures, including defense spending, are associated with lower FIMSS efficiency. Similar findings are reported in studies by Astapov et al. [28] and Smykova et al. [29], which note that certain budgetary expenditures have low fiscal multipliers and act as a burden on the economy. Thus, excessively high social policy expenditures should be avoided, and principles of efficiency, targeting, and means-testing should be adhered to. A significant negative impact on efficiency occurs in the range of 35–42% of GDP, corresponding to a 0.04 percentage point increase in the efficiency coefficient. A further 0.02 percentage point reduction in efficiency occurs in the range of 46–48% of GDP.

Although the construction of *K*3 implies a negative relationship between FIMSS efficiency and budgetary expenditures for its financing, XGBoost identified threshold values of budgetary expenditures (35–42% of GDP) where FIMSS efficiency declines sharply, confirming earlier empirical findings by Afonso et al. (2010) [2].

The impact of defense spending is considerably lower than that of total expenditures, yet its increase negatively affects FIMSS efficiency. Similar results are shown in studies by Arzhenovsky [30] and Kudrin and Knobel [31], which explain that the growth of the "non-productive economy" can accelerate inflation and slow economic growth, creating challenges for effective management of social security finances. A 0.003 percentage point increase in the FIMSS efficiency coefficient occurs in the range of 1.3–1.6% of GDP, after which additional increases in defense spending have minimal impact on FIMSS efficiency per the *K*3 coefficient.

Among the factors, public debt has the most significant negative impact on FIMSS efficiency. Interestingly, in the range of 0–50% of GDP, rising public debt enhances FIMSS efficiency, but beyond this threshold, each additional percentage point of public debt reduces efficiency. A sharp decline in FIMSS efficiency (by 0.075 percentage points) occurs in the range of 130–140% of GDP. Rising borrowing costs and the crowding-out effect create challenges for economic growth, threatening social stability and FIMSS efficiency in the long term, particularly during periods of high inflation and rising interest rates [32].

Pre-tax income inequality exhibits a nonlinear relationship with FIMSS efficiency. The most efficient FIMSS systems are associated with a Gini index range of 0.37–0.43. An increase in the Gini index beyond this range to 0.48 is associated with a 0.006 percentage point reduction in FIMSS efficiency. However, further increases in income inequality do not significantly affect FIMSS efficiency.

The impact of wealth inequality differs from that of income inequality. An increase in this indicator leads to a reduction (increase) in the FIMSS efficiency coefficient. Changes in the wealth Gini index within the range of 0.66–0.76 do not significantly affect FIMSS efficiency.

A decline in the birth rate to 9 newborns per 1,000 population reduces FIMSS efficiency by approximately 0.006 percentage points. Similarly, a total fertility rate below 1.55 leads to a gradual reduction in FIMSS efficiency. The most efficient FIMSS systems are observed in countries with a total fertility rate of 1.55–1.7. A decline in the share of the young population below 14.5% and the exacerbation of population aging reduce FIMSS efficiency by 0.025 percentage points.

Optimal FIMSS efficiency with respect to urbanization is achieved by targeting an urban population share of 63–74% of the total population. An increase in urbanization reduces FIMSS efficiency more significantly than a decrease below this range. Urbanization within this range ensures the optimal concentration of economic activity, enabling cities to provide high-quality social

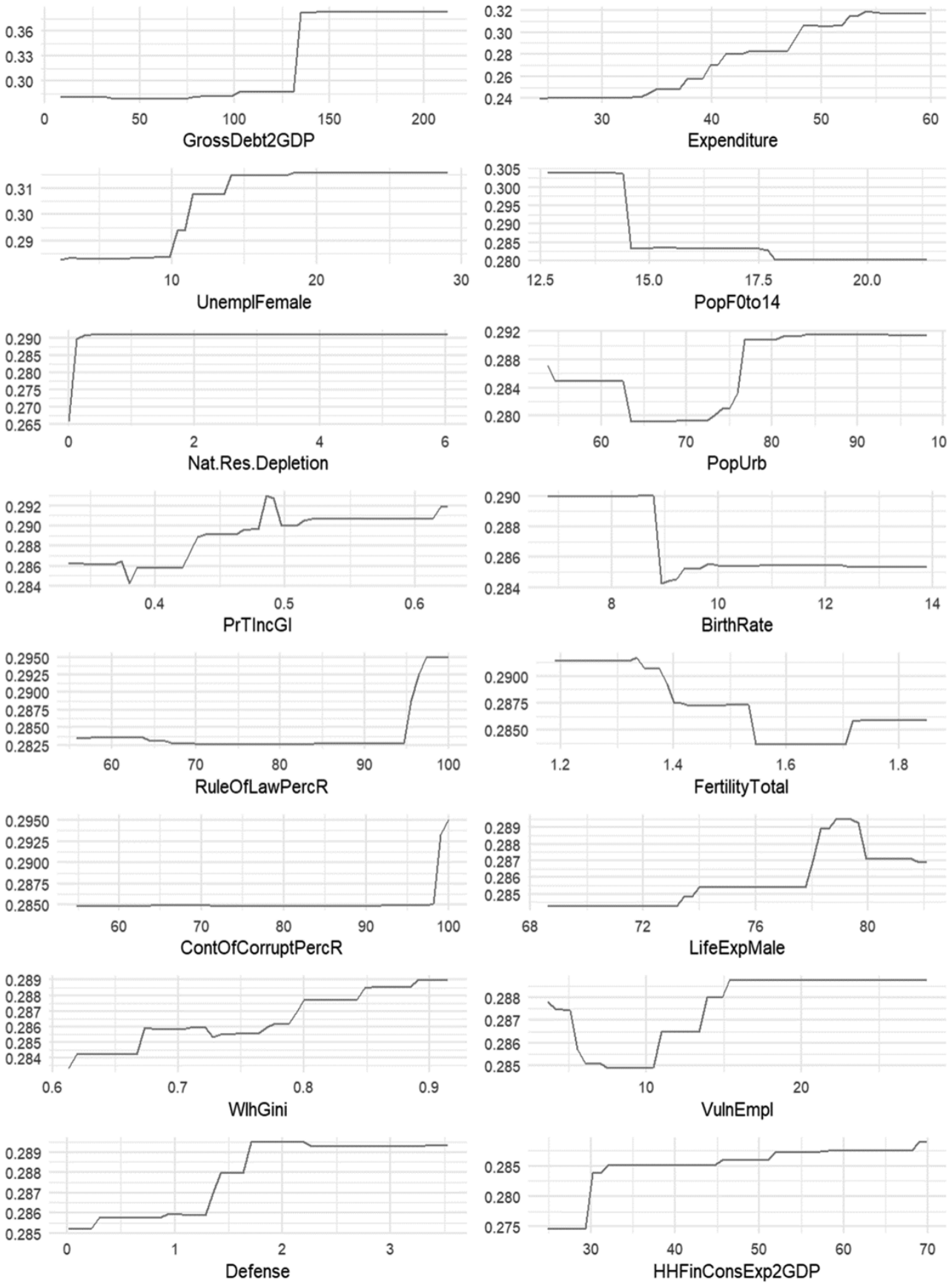

Fig. 2. **Partial dependence plots for FIMSS efficiency**

Source: Compiled by the author based on the research materials.

services (healthcare, education) and economic opportunities due to scale and density.

5. Research limitations and directions for future research

The limitations of the approach in this study stem from challenges in forming the research database and the fact that the factor model does not account for the impact of non-state FIMSS on the *K*3 efficiency coefficient.

Limitations of the data, such as the use of a five-year moving average for the *K*3 coefficient and the reduction of the sample to 26 countries for regression analysis due to data unavailability, constrain the scope of the study. These limitations can be addressed in future research by expanding the sample or integrating additional data sources.

It should also be noted that the study does not include private-sector healthcare or pension systems, which are well-developed in certain countries, such as the United States. This exclusion is due to limitations in the research database and may be addressed in future studies.

6. Conclusion

Contemporary challenges facing social security systems underscore the importance of developing a comprehensive approach for analyzing the efficiency of Financial and Investment Models of Social Security. Within the framework of this study, a novel comprehensive approach for assessing FIMSS efficiency was developed and tested, integrating ratio analysis, factor analysis, and the gradient boosting method.

The study successfully confirmed hypothesis H1, which posits that FIMSS efficiency is determined by the ability of public social protection systems to minimize poverty and ensure coverage by social security programs while maintaining moderate levels of budgetary expenditure and public debt. The ratio and factor analyses demonstrated that countries with low *K*3 values achieve high economy and effectiveness through optimized expenditure and an increased share of the "non-poor" population. The XGBoost model confirmed the nonlinear influence of contextual factors: optimal levels of income inequality (Gini index of 0.37–0.43), urbanization (63–74%), and fertility rates (1.55–1.7) are associated with minimal *K*3 values, consistent with the hypothesis. Public debt contributes to FIMSS efficiency when it remains below 50% of GDP, but its increase beyond 130% significantly reduces efficiency indicators.

The findings can be applied to reform FIMSS to enhance their resilience amid global challenges, such as demographic decline, the climate crisis, and technological transformation. Future research prospects include further development of the proposed approach for analyzing other areas of public policy and its integration with big data to improve the accuracy of forecasts and the granularity of analysis.

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APPENDICES

Appendix

Characteristics of the general economic meaning of components in the factor model described in formula (3)

	***K*3**	***F*1**	***F*2**	***F*3**	***F*4**
Factor	$\frac{TotGovSSS2GDP}{PUPovLM50} =$	$\frac{TotGovSSS}{TotGovBSp}$ *	$\frac{TotGovBSp}{GDP}$ *	$\frac{Pop}{PUPovLM50}$ *	$\frac{1}{EffCoverSP}$
Title	State-type FIMSS efficiency ratio	Social security and healthcare expenditures as a share of budget spending	Government expenditures as a percentage of GDP	Ratio of total population to population above poverty line	Adjustment coefficient for population coverage by social protection programs

Appendix 1 (continued)

Factor	***K*3** $\frac{TotGovSSS2GDP}{PUPovLM50} =$	***F*1** $\frac{TotGovSSS}{TotGovBSp^{*}}$	***F*2** $\frac{TotGovBSp}{GDP^{*}}$	***F*3** $\frac{Pop}{PUPovLM50}^{*}$	***F*4** $\frac{1}{EffCoverSP}$
Economic Meaning	The specific level of budget expenditures on social security and healthcare as a percentage of GDP spent per 1% of population above the poverty line. Rationale for Indicator Selection Social security and healthcare expenditures primarily target low-income citizens while being funded by middle- and high-income citizens. When evaluating expenditure efficiency — which according to the Russian Budget Code represents both effectiveness (poverty reduction or growth of non-poor population) and economy (means-tested targeted assistance ensuring expenditure minimization) — we can compare "resources spent" (input) with "outcomes achieved" (one of socioeconomic development indicators). Here, we could use either the poor population share or non-poor population share in the denominator. However, using the poor population share would distort the efficiency indicator's meaning, as it would require reducing the numerator to obtain a lower denominator value, creating interpretation challenges. Therefore, I propose using specifically the "non-poor population" share in the denominator. This allows unambiguous coefficient interpretation: lower values indicate better performance, achieved either through reduced funding for the same non-poor population or through faster growth of non-poor population relative to funding increases	The share of social security and healthcare expenditures in total budget system spending. Reflects the budget's social orientation level	Budget system expenditures as percentage of GDP. Reflects: The budget system's economic scale; Current fiscal pressure level; Government involvement in public goods provision	Values closer to 1 indicate smaller poor population share (defined based on income below 50% of median per capita income). Can also be expressed as [1/(1-poor population share)]	Adjusts state-type FIMSO efficiency for population coverage by at least one social protection program. Enables monitoring justification for reducing government expenditures in this area. The inverse value is used because efficiency is evaluated from the perspective of minimization

Appendix 1 (continued)

Factor	***K*3**	***F*1**	***F*2**	***F*3**	***F*4**
	$\frac{TotGovSSS2GDP}{PUPovLM50} =$	$\frac{TotGovSSS}{TotGovBSp^{*}}$	$\frac{TotGovBSp}{GDP^{*}}$	$\frac{Pop}{PUPovLM50}^{*}$	$\frac{1}{EffCoverSP}$
Areas for Optimization to Enhance Efficiency	The coefficient is optimized toward lower values. Given the inverse relationship between social security expenditures and economic growth, it is advisable to reduce the numerator while maintaining or increasing the denominator. This indicator can be interpreted as the "cost of decent living" for the population, primarily linked to social security and secondarily to healthcare. Since the analysis employs a poverty metric based on median income (rather than the conventional Russian poverty line), an important consideration arises: This poverty assessment framework does not imply the elimination of poverty, as a segment of the population will always have incomes below a defined threshold (e.g., 40%, 50%, or 60% of the median). Thus, poverty is approached here as a regulated process — focused on control and minimization rather than eradication. This differs fundamentally from the subsistence minimum (ПМ), which can be administratively set (e.g., yielding 4–5% poverty in Moscow but 10%+ in other Russian regions). In this context, the indicator represents the economic cost — in terms of budget expenditures — required to ensure that a given share of the population maintains incomes above the poverty threshold	Reducing this indicator could free up fiscal resources for redirecting budget allocations toward infrastructure and economic investments	A reduction in the government's economic footprint may lead to lower tax burdens and create greater opportunities for accelerating technological progress and economic growth. Moreover, when economic growth outpaces the expansion of public spending, this dynamic serves as a fundamental driver for enhancing FIMSO efficiency	This coefficient will exceed 1, but the government should implement measures to gradually reduce it toward 1 and maintain it at modest levels, which would indicate effective poverty control.	The adjustment coefficient increases the K3 coefficient to account for underdeveloped social protection programs and low population coverage. Within this approach, higher values of the indicator correspond to lower FIMSO efficiency

Source: Compiled by the author from research materials.

Appendix 2

Descriptive statistics of the research dataset

Indicator Name		Min	Median	Average	Max	Max/ min
Full Name	**Abbrev.**					
Year	**Year**	**2015**	**2018**	**2018**	**2021**	**–**
Social expenditure efficiency indicator for social security and healthcare, 5-year moving average	K3_5YAv	0.17	0.28	0.29	0.48	2.80
Social security and healthcare expenditures as share of budget spending, 5-year moving average	F1_5YAv	0.37	0.52	0.51	0.60	1.64
Government expenditures as percentage of GDP, 5-year moving average	F2_5YAv	0.25	0.45	0.45	0.56	2.21
Ratio of total population to population above poverty line, 5-year moving average	F3_5YAv	1.05	1.11	1.12	1.22	1.16
Adjustment coefficient, 5-year moving average (ILO basis)	F4_5YAv	1.00	1.08	1.11	1.56	1.56
Pre-tax Gini index (WID basis)	PrTIncGI	0.33	0.45	0.45	0.63	1.88
Post-tax Gini index (WID basis)	PostTIncGI	0.24	0.35	0.36	0.63	2.62
Wealth Gini index (WID basis)	WlhGini	0.61	0.74	0.75	0.91	1.49
Total budget system expenditures as% of GDP (IMF basis)	Expenditure	24.28	44.94	44.89	59.62	2.46
Defense expenditures as % of GDP (IMF basis)	Defense	0.02	1.12	1.25	3.53	213.38
Healthcare expenditures as % of GDP (IMF basis)	Health	2.10	6.98	6.70	10.44	4.97
Education expenditures as % of GDP (IMF basis)	Expenditure_on_ education	2.93	5.04	5.16	8.12	2.77
Social security expenditures as% of GDP (IMF basis)	Social_protection	7.49	16.88	16.68	25.50	3.40
Household final consumption expenditures as % of GDP (IMF basis)	HHFinConsExp2GDP	23.65	52.06	52.44	69.88	2.95
Population aged 0–14 (% of total) (WB basis)	PopF0to14	12.65	15.62	15.96	21.36	1.69
Population aged 15–64 (% of total) (WB basis)	PopF15to64	61.68	65.14	65.28	70.45	1.14
Population aged 65+ (% of total) (WB basis)	PopF65	13.12	19.05	18.75	23.68	1.81
Urban population (% of total) (WB basis)	PopUrb	53.73	75.71	75.73	98.12	1.83
Agricultural land (% of land area) (WB basis)	AgricultLandShare	2.69	44.36	40.56	72.42	26.88
Total fertility rate (children per woman) (WB basis)	FertilityTotal	1.19	1.57	1.56	1.85	1.55
Life expectancy at birth, total (years) (WB basis)	LifeExpTotal	73.28	81.31	80.36	83.90	1.14
Life expectancy at birth, female (years) (WB basis)	LifeExpFemale	78.00	83.70	83.15	86.70	1.11

Appendix 2 (continued)

Indicator Name		Min	Median	Average	Max	Max/ min
Full Name	**Abbrev.**					
Year	**Year**	**2015**	**2018**	**2018**	**2021**	**–**
Life expectancy at birth, male (years) (WB basis)	LifeExpMale	68.60	78.90	77.70	82.10	1.20
Birth rate (per 1,000 people) (WB basis)	BirthRate	6.80	10.10	10.05	13.90	2.04
Total dependency ratio (% of working-age population) (WB basis)	AgeDependRatTol	41.94	53.50	53.28	62.13	1.48
Old-age dependency ratio (% of working-age population) (WB basis)	AgeDependRatOld	20.02	29.25	28.81	37.19	1.86
Youth dependency ratio (% of working-age population) (WB basis)	AgeDependRatYoung	19.87	23.59	24.47	32.60	1.64
Unemployment rate, total (% of labor force) (WB basis)	UnemplTotal	2.02	5.97	6.93	24.98	12.37
Unemployment rate, female (% of female labor force) (WB basis)	UnemplFemale	2.39	5.71	7.16	29.03	12.16
Unemployment rate, male (% of male labor force) (WB basis)	UnemplMale	1.73	5.79	6.75	21.74	12.60
Vulnerable employment (% of total employment) (WB basis)	VulnEmpl	3.64	9.70	10.12	28.08	7.71
CO_2 emissions (metric tons per capita) (WB basis)	CO2Emis	3.24	6.19	6.86	16.03	4.94
Renewable energy consumption (% of total) (WB basis)	RenewEnergCons	5.62	18.69	26.31	82.79	14.73
Natural resource depletion (% of GDP) (WB basis)	Nat.Res.Depletion	0.00	0.08	0.28	6.05	–
Forest area (% of land area) (WB basis)	ForestArea	0.48	33.65	34.68	73.74	153.49
Government debt (% of GDP) (WB, OECD basis)	GrossDebt2GDP	8.20	64.64	70.97	212.39	25.89
Control of Corruption Index (score 0–100)	ContOfCorruptPercR	54.81	89.90	83.74	100.00	1.82
Government Effectiveness Index (score 0–100)	GovEffPercR	59.62	87.74	86.01	99.52	1.67
Political Stability Index (score 0–100)	PolStabilPercR	38.57	74.76	74.32	99.53	2.58
Regulatory Quality Index (score 0–100)	RegQualPercR	60.58	90.14	86.79	99.52	1.64
Rule of Law Index (score 0–100)	RuleOfLawPercR	55.77	88.94	86.08	100.00	1.79
Voice and Accountability Index (score 0–100)	VoicePercR	57.97	89.86	86.86	100.00	1.72
Log of land area per capita (for land resource availability analysis)	LogLandArPerCap	0.28	0.97	1.08	2.48	8.76

Source: Compiled by the author from research data.

Appendix 3

Description of XGBoost model variations and optimal model parameters (best-performing model highlighted in gray shading, R^2 = 0.99135)

eta	max_depth	nrounds	RMSE	Rsquared	MAE	RMSESD	RsquaredSD	MAESD
0.1	2	50	0.022484	0.900105	0.015949	0.001700	0.019115	0.000689
0.3	2	50	0.020780	0.906189	0.014195	0.001215	0.029219	0.001640
0.1	4	50	0.020536	0.907934	0.013685	0.002696	0.033642	0.001895
0.3	4	50	0.021034	0.903364	0.013904	0.001771	0.004682	0.000756
0.1	2	100	0.020857	0.909325	0.014433	0.001958	0.019927	0.000817
0.3	2	100	0.020427	0.908986	0.013820	0.001163	0.028252	0.001392
0.1	4	100	0.019856	0.913201	0.013020	0.002481	0.029539	0.001229
0.3	4	100	0.021034	0.903364	0.013904	0.001771	0.004682	0.000756
0.1	2	200	0.020487	0.911290	0.013936	0.001942	0.022071	0.000833
0.3	2	200	0.020382	0.909402	0.013777	0.001135	0.028151	0.001352
0.1	4	200	0.019821	0.913510	0.012991	0.002481	0.029762	0.001237
0.3	4	200	0.021034	0.903364	0.013904	0.001771	0.004682	0.000756
0.1	2	300	0.020331	0.912339	0.013710	0.001897	0.022301	0.000797
0.3	2	300	0.020382	0.909402	0.013777	0.001135	0.028151	0.001352
0.1	4	300	0.019821	0.913510	0.012991	0.002481	0.029762	0.001237
0.3	4	300	0.021034	0.903364	0.013904	0.001771	0.004682	0.000756
0.1	2	400	0.020287	0.912666	0.013685	0.001859	0.022487	0.000765
0.3	2	400	0.020382	0.909402	0.013777	0.001135	0.028151	0.001352
0.1	4	400	0.019821	0.913510	0.012991	0.002481	0.029762	0.001237
0.3	4	400	0.021034	0.903364	0.013904	0.001771	0.004682	0.000756
0.1	2	500	0.020287	0.912666	0.013685	0.001859	0.022486	0.000765
0.3	2	500	0.020382	0.909402	0.013777	0.001135	0.028151	0.001352
0.1	4	500	0.019821	0.913510	0.012991	0.002481	0.029762	0.001237
0.3	4	500	0.021034	0.903364	0.013904	0.001771	0.004682	0.000756
0.1	2	600	0.020287	0.912666	0.013685	0.001859	0.022486	0.000765
0.3	2	600	0.020382	0.909402	0.013777	0.001135	0.028151	0.001352
0.1	4	600	0.019821	0.913510	0.012991	0.002481	0.029762	0.001237
0.3	4	600	0.021034	0.903364	0.013904	0.001771	0.004682	0.000756
0.1	2	1000	0.020287	0.912666	0.013685	0.001859	0.022486	0.000765
0.3	2	1000	0.020382	0.909402	0.013777	0.001135	0.028151	0.001352
0.1	4	1000	0.019821	0.913510	0.012991	0.002481	0.029762	0.001237
0.3	4	1000	0.021034	0.903364	0.013904	0.001771	0.004682	0.000756

Source: Compiled from research data.

Notes: eta — Learning rate controlling each decision tree's contribution; nrounds — Number of decision trees; RMSE (Root Mean Squared Error) — Square root of the average squared errors; R^2 (Rsquared) — Coefficient of determination; MAE (Mean Absolute Error) — Average absolute difference between predicted and actual values; RMSESD (RMSE Standard Deviation) — Model stability metric showing variation across cross-validation folds; RsquaredSD — Standard deviation of R^2 across cross-validation folds; MAESD (MAE Standard Deviation) — Standard deviation of mean absolute errors.

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Typology and Characteristics of Global Cognitive, Spiritual, and Moral Shifts in the World Economic System

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ABSTRACT

The **subject** of this study is a comprehensive typology of the global cognitive, spiritual, and moral shifts currently influencing the world economic system. The **purpose** of the study is to identify and classify the prevailing transformations in both individual and collective consciousness and spiritual content that is reflected in economic behavior and growth conditions at the global level. The **relevance** of this study arises from the necessity to fully incorporate the factors under consideration into the concept of economic development. The author employs the **methods** of content analysis and inductive research to examine processes encompassing such areas as knowledge, information, responsibility and culture, as well as the method of typological classification. The **result** of the analysis is to elucidate the mechanisms through which the examined shifts manifest themselves and interact within the global economic system. The **novelty** of this typology lies in its identification of complex properties and interrelations between cognitive and moral transformations and their underlying drivers, as well as their influence on economic development. The study reveals that each type of change has progressive characteristics, but their processes are uneven across countries and communities and may face problems of ambivalence, which complicates the analysis of feedback loops and their impact on global economic dynamics. Conceptually, this research is important for advancing theories of economic growth, sustainable development, and ethical economics. The author **concluded** that the suggested typology may be applied in developing policy principles aimed at more effectively harnessing the benefits of the information and knowledge revolution, fostering mutual respect among stakeholders, and promoting sustainable economic development.

Keywords: world economic system; cognitive shifts; spiritual and moral shifts; knowledge; information; responsibility; culture; economic development; sustainable development; economic growth; system approach

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ОРИГИНАЛЬНАЯ СТАТЬЯ

Типология и характеристики глобальных когнитивных, духовных и нравственных сдвигов в мировой экономической системе

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АННОТАЦИЯ

Предметом данного исследования является комплексная типология глобальных когнитивных, духовных и моральных сдвигов, в настоящее время влияющих на мировую экономическую систему. **Цель** исследования состоит в выявлении и классификации преобладающих трансформаций в индивидуальном и коллективном сознании, в системе моральных принципов, отражающихся в экономическом поведении

и условиях роста на глобальном уровне. **Актуальность** данного исследования обусловлена необходимостью полноценного включения рассматриваемых факторов в концепцию экономического развития. Автор использует **методы** контент-анализа, индуктивного исследования процессов, охватывающих такие области, как знания, информация, ответственность и культура, и метод типологизации. **Результат** проведенного анализа состоит в прояснении механизмов проявления изучаемых сдвигов и их взаимодействия в рамках глобальной экономической системы. **Новизна** подхода заключается в выявлении сложных свойств и взаимосвязей между когнитивными и моральными трансформациями и их основополагающими факторами, а также их влиянием на экономическое развитие. Исследование показывает, что каждый тип изменений обладает прогрессивными характеристиками, однако процессы их протекания неравномерны в разрезе стран и сообществ и могут сталкиваться с проблемами двойственного понимания, что усложняет анализ обратных связей и их влияния на глобальную экономическую динамику. С концептуальной точки зрения данное исследование важно для развития теорий экономического роста, устойчивого развития и этической экономики. Авторы делают **вывод**, что предложенная типология может быть применена при разработке принципов политики, направленных на более эффективное использование преимуществ информационной и интеллектуальной революции, укрепление взаимного уважения между заинтересованными сторонами и содействие устойчивому экономическому развитию.

Ключевые слова: мировая экономическая система; когнитивные сдвиги; духовно-нравственные сдвиги; знания; информация; ответственность; культура; экономическое развитие; устойчивое развитие; экономический рост; системный подход

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Introduction

The rapid pace of economic, technological, socio-political, and demographic processes, along with the profound transformations in economic life observed over the past 250 years, has been accompanied by significant changes affecting the cognitive, spiritual, and moral characteristics of individuals and communities. The dissolution of certain economic relations and the emergence of others, urbanization, shifts in political regimes, increased educational attainment, the growing importance of knowledge, the communication technology revolution, the critical transformation of the information environment, ecological challenges, and other phenomena and processes have substantially contributed to the foundation for these changes. In turn, these alterations in cognitive, spiritual and moral characteristics — often manifesting as shifts — are transmitted into the global economic system, influencing its parameters. Such shifts demand conscious reflection from policymakers, organizations, and citizens, beginning with an understanding of their significance and culminating in the adaptation of strategies. This dynamic underpins the academic interest in the topic and motivates the present study.

The aim of this study is to develop a comprehensive typology and delineate the key characteristics of current global cognitive, spiritual, and moral shifts within the world economic system. This paper is essential for a more detailed understanding of the systemic transformations that are altering economic paradigms, stakeholder behaviors, and policy frameworks. Additionally, it seeks to assess the potential impact of these deep-seated changes on economic growth and development trajectories.

In this study, the global economic system is conceptualized as a complexly organized network of actors interconnected through economic relations that generate transactions and flows extending beyond the confines of national markets. This comprehensive structure, which facilitates the production, distribution, and consumption of goods and services on a global scale, is traditionally understood as being influenced by institutional factors and technological advancements. However, as we aim to demonstrate in this article, its organization and outcomes — particularly the rate of economic growth — are also responsive to factors defined by the triad of cognitive, spiritual, and moral principles. The observed shifts highlight the necessity of examining processes associated with such entities as knowledge, information, self-awareness, responsibility, and culture.

Methodologically, our analysis is grounded in the theory of socio-cultural foundations of economic development and complex systems theory. In addition, we use and develop concepts related

to economic growth theory by expanding the understanding of its non-economic determinants.

The theory of complex systems offers a robust framework for transcending traditional reductionist economic models [1], illustrating that cognitive and spiritual and moral principles are not mere externalities but rather fundamental, endogenous factors that shape economic development. Several studies indicate that cognitive principles — such as how agents perceive and adopt new ideas — and moral principles — such as the criteria used for selection, including efficiency or sustainability — serve as the primary mechanisms of selection in the evolutionary processes that drive economic change [2].

Among the central themes in economic literature concerning the aspect under consideration is the role of knowledge. The conventional understanding among economists is that knowledge progress generates innovations, contributes to productivity improvements, and drives economic growth. This perspective on knowledge is extensively discussed in both theoretical and empirical literature, including works by P. Romer [3], G. Grossman and E. Helpman [4], P. Aghion and P. Howitt [5], and N. Hausman [6], among others. This prevailing perception of the significance of knowledge has led to the development of the research field known as the "knowledge economy" [7–9].

In recent years, the concept of "knowledge" and its perceived significance have undergone several fundamental changes. Knowledge models have been expanded to incorporate the growing influence of interdisciplinary connections and the increasing transfer of methodological tools and approaches across different fields of knowledge and scientific disciplines [10]. Significant challenges have emerged in adapting educational approaches to address the complexity of knowledge, the rapid pace of its renewal, its informational density, and related factors. Therefore, if a cognitive shift is defined as a substantial change in human cognitive activity, as evidenced by alterations in perception, modes of thinking, and behavior, then the rapid transformations in knowledge models indeed underscore the occurrence of such a shift that has transpired over the past few decades.

A significant shift in the evaluation of knowledge's role involves the recognition that knowledge embodied in intangible assets is becoming more important than physical capital. Thus, at the end of the first quarter of 2025, the goodwill and intangible assets of NVIDIA, the largest corporation in the information technology sector of the S&P 500, amounted to $ 6.267 billion.[1] This is only slightly lower than the net tangible assets of GE Aerospace, the largest company in the industrial sector, which totaled $ 6.547 billion.[2] It should be pointed out that it is the Info Tech that brought about the most radical innovations, which enable the identification of a cognitive shift characterized by a transition to a new level of interaction with the world.

With respect to intangible assets and their significance for the global economy, it is essential to emphasize that they are increasingly becoming a critical factor in profit generation for corporations and subject to international competition. A recent study indicates that companies with substantial intangible assets have derived greater benefits from globalization, capitalizing on the trade of goods and services protected by patents and trademarks [11].

The related issue concerning knowledge management pertains to the fundamental object of ownership, control, and utilization: information and data. The global economic system has undergone a profound transformation — from an era characterized by limited and fragmented access to information to one defined by the production, dissemination, and utilization of colossal volumes of data in real time [12].[3] This shift from data scarcity to abundance has significantly altered decision-making processes within economic agents, enhancing the precision of market analysis, risk assessment, and forecasting. The rise of targeted advertising, digital marketing, adaptive consumer engagement models, and data-driven innovations serves as evidence of a fundamental shift in the manner in which consumers perceive and understand the world.

The increasing value attributed to data has intensified debates over ownership rights, especially

[1] URL: https://macrotrends.net/stocks/charts/NVDA/nvidia/goodwill-intangible-assets-total (accessed on 27.08.2025).

[2] URL: https://finance.yahoo.com/quote/GE/balance-sheet/ (accessed on 27.08.2025).

[3] The contemporary consumer acquires data from a diverse array of sources and simultaneously serves as a target for advertising. On average, adults spend over three hours per day on social media platforms and even more time with streaming services.

concerning personal data, including individual preferences, habits, and characteristics [13]. Similar concerns apply to data within the industrial sector [14]. The resolution of disputes regarding data ownership, usage rights, and boundaries has gained critical importance for many businesses. Individuals are often hesitant to relinquish their rights not only to personal data but also to information regarding their preferences, patterns, and habits. Concurrently, governments demand access to data held by companies for purposes related to national security, law enforcement, and regulatory compliance. The outcomes of these debates will have global implications, as they impact all stakeholders and transcend national boundaries.

A profound shift in global consciousness, which influences economic dynamics through institutional and technological channels, is occurring in connection with the advancement of the green agenda. Indeed, beginning with the 1972 Stockholm Conference on the Environment, the green agenda has increasingly permeated the minds of policymakers, business leaders, and broad segments of society — expressing their will as consumers, savers, private investors, community members, and more [15–17]. Simultaneously, the increasing focus on sustainable development and environmental protection can be associated with shifts in spiritual beliefs, resulting in the formation of a moral imperative to safeguard the planet. This transformation has given rise to phenomena such as green business, sustainable practices, and ethical consumerism. A growing number of companies and banks adopt sustainable practices in response to changing preferences of both private [18] and institutional [19] investors. This movement significantly impacts the international production system and global capital markets.[4] Similarly, in consumer markets, individuals are increasingly favoring environmentally friendly products [20], which in turn influences the structure of supply chains and corporate strategies.

Overall, it is evident that in recent decades, continuous processes have been unfolding that impact the cognitive and moral components of societies. These processes are becoming significant factors shaping the global economic system and influencing prospects for economic growth. In the subsequent section of this article, we propose a typology of these processes, along with a more detailed discussion of the changes (shifts) they induce, particularly regarding their implications for the global economy and growth trajectories.

Global cognitive, spiritual, and moral shifts' typology

A comprehensive understanding of the ongoing cognitive changes that are significant at the scale of the global economy, as well as a further analysis of these changes — including their potential impact on economic growth — requires the development of criteria for their classification and differentiation. Establishing such criteria enables the typologization of the observed changes. The most general categories of change are proposed to be classified as cognitive and spiritual-moral transformations. Subcategories or specific types within the cognitive changes include those affecting knowledge, information, cultural components, and attitudes. Regarding spiritual-moral changes, the examined transformations are categorized into value orientations, social responsibility, and ethics. This approach is summarized in *Table*.

Global cognitive, spiritual, and moral shifts and economic growth prospective

Following the structure of this typology, we will examine how global cognitive and spiritual-moral shifts can influence the characteristics of the global economic system, as well as the dynamics of both the world economy and national economies. The manifestations of this influence are evident in changes to individuals' mindsets, the strategic behaviors of economic agents, and the channels and mechanisms of interaction, as well as in the emergence of new business models. The cumulative effect of these processes is reflected in variations in labor productivity and the rates of economic growth.

[4] According to the Bank for International Settlements (BIS), the global green bond market is projected to reach a size of USD 2.9 trillion by 2025. This projection indicates that the market has experienced an annual growth rate of at least 50% over the past decade. See: Demski J., Dong Y., McGuire P, Mojon B. Growth of the green bond market and greenhouse gas emissions. BIS Quarterly Review. 2025. URL: https://www.bis.org/publ/qtrpdf/r_qt2503d.htm (accessed on 29.08.2025). The volume of assets under management of sustainable funds grew during these same years, according to Statista, at a rate of 36%, reaching the same size of $ 2.9 trillion by the beginning of 2024. URL: https://www.statista.com/statistics/1549922/market-value-sustainable-funds-worldwide/ (accessed on 03.09.2025).

Table

The global cognitive, spiritual, and moral shifts in the world economic system: typology and characteristics

Category	Type	Impact on the global economic system
Cognitive changes	Rethinking the modern role of knowledge	The transition from traditional models of knowledge to integrative approaches that embrace interdisciplinary connections and factors; the increasing role of technology and data that create new approaches to teaching and understanding the world
	Innovative thinking and creativity	Increasing the value of creativity and innovation as key factors for economic growth; shifting public policy towards supporting start-ups and entrepreneurship, innovative development
	Changing the information paradigm	Embodies a transformative approach to understanding information and interacting with it, driven by technological advances that are changing both individual cognition and collective knowledge structures. Information is becoming a valuable commodity. Large volumes of data characterizing consumer behavior, characteristics of production processes, etc., are transformed into a high-value asset. Changing the ways information is received, processed, produced, distributed, as well as the increasing the value of data, are critical to growth prospects
	Globalization of culture	The spread of cultural elements around the world through technology and media has a dual impact on individuals and communities (including ethnic groups). On the one hand, the globalization of culture enriches and fills the individual, promotes a spirit of tolerance and mutual understanding. On the other hand, this phenomenon can threaten local traditions, cause rejection and resistance
	Splitting the attitudes: from developing global consciousness to following local narratives	The trend towards globalization, formed in the second half of the 20th century, created an image of the interconnectedness of countries and regions, heightened awareness of global problems and shared responsibility. This same trend focused the emphasis of social development on universal values (human rights, social justice), strengthened the tendencies to build a model of a social state, and contributed to the formation of a sustainable development economy. The global financial and economic crisis of 2007–2009 undermined this trend, forming tendencies towards fragmentation based on the priority of national and local interests driven by local narratives
	Changing the economic security paradigm	The global economic crises of 2007–2009 and 2020, the anti-Russian sanctions of 2014 and 2022, the tariff war of 2025, and other events have led to a change in the view of national economic security, causing changes in the world economic system, including deglobalization, geoeconomic fragmentation, the formation of payment and settlement systems alternative to the dollar, etc.

Table (continued)

Category	Type	Impact on the global economic system
Changes related to spiritual and moral properties	Changes in consumer value orientation	The transition from a consumerist approach to a lifestyle that is consciously based on ethical and moral principles, environmental orientation; growing interest in spirituality, culture and self-awareness. This transition is driven by technological factors (the spread of the Internet and social networks), increased transparency of life, a broad cultural shift towards increased consumer awareness, social responsibility, and a collective desire for meaningful participation in the world. It fuels the demand for an economy based on transparency, consumer-centered interests that promote a healthy lifestyle, and other principles
	Rethinking traditional values	The impact of globalization on traditional values of different cultures, causing both the synthesis of different cultural practices and their conflicts; the search for a new balance between tradition and modern challenges such as technology and socialization
	Social and environmental responsibility of business	The changing role of business in society, moving from purely economic to social and environmental objectives; an emphasis on corporate social responsibility and sustainability criteria influencing business strategies and decision-making
	Environmental ethics	Recognition of the need for environmentally sustainable use of resources as a value important for future generations; the development of environmental protection movements and sustainable development policies, which affects the rate and structure of output growth

Source: Developed by the author.

The first type of cognitive change to be examined is the reevaluation of the significance of knowledge. Building upon the approach proposed by Thomas Kuhn [21], knowledge should be viewed not only as the "fuel" for scientific development, where progress occurs through the gradual accumulation and refinement of understanding. Instead, scientific progress also results from abrupt paradigm shifts, where existing knowledge is replaced by new, revolutionary insights. Recently, largely due to changes in the informational environment, both evolutionary and revolutionary advancements in knowledge have increasingly emerged through interdisciplinary interactions and mutual cross-fertilization [22]. This process has become one of the most important sources of innovation. This innovation-driven growth process generates substantial structural changes, including the rapid expansion of intangible assets, the increasing prominence of companies centered on the creation and utilization of such assets, and the swift integration of information-oriented and data-oriented technologies into an ever-growing array of products and solutions.

A prominent trend of the contemporary era is the rapid integration of artificial intelligence (AI) technologies and solutions across a vast array of human activities. AI promises to further enhance the integrative nature and flow of knowledge, thereby accelerating innovation. It is predicted that the average rate of economic growth resulting from the implementation of AI will increase significantly, rising from the current range of 2–3 to 20–30 percent [23]. This forecast is based on the premise that the ultimate source of economic growth is the generation of ideas that are subsequently transformed into scientific and technological knowledge. However, emerging trends — particularly those centered around the development of AI technologies — partially conflict with older trends, notably the increasing prominence of the creative class. In our view, it is reasonable to expect that the creative class, whose significance has grown steadily since the publication of Richard Florida's seminal work over twenty years ago [24], will undergo substantial adaptation to this new environment, simultaneously perceiving artificial intelligence as both a competitor and an assistant.

A focus on creativity and innovation as key drivers of growth and development fosters the emergence of new technologies and business models. In *Table*, this characteristic is identified as "*innovative thinking and creativity*." Countries that excel in this area benefit from the creation of new jobs, a structural shift in their economies toward more productive sectors and successful companies, and enhanced competitiveness of their goods and services in international markets [25]. At the same time, comparative analyses of investment dynamics in research and development, as well as the number of registered patents, indicate that the global gap in technological development and its potential across countries is not only persisting but widening. For example, over the past decade, the average score of the Global Innovation Index for the top 20 countries increased by 2.79 points, whereas the average score for the 20 lowest-ranking countries declined by 22.6 points.[5]

At the same time, the perspective on knowledge, innovative thinking, and creativity — highlighting cognitive shifts that are generally regarded as unequivocally positive for economic growth prospects — takes on a more nuanced character when scholars develop the concept of cognitive capitalism. Within this framework, particular emphasis is placed on the transition of knowledge from being viewed as a private good to being recognized as a public good. This transition drives the process of knowledge appropriation by companies through institutions that protect intellectual property rights, such as patent laws, among others. However, the flip side of this process involves the alienation of workers from the knowledge generated through their efforts, as well as the concentration of intellectual property assets within large corporations — potentially leading to a form of global monopolization of knowledge [26]. Such dynamics can hinder the development of small and medium-sized enterprises and impede the economic growth of countries that lag behind in creating and securing intellectual property rights in the form of patents and industrial designs. These phenomena lead to inefficient resource allocation and hinder innovation activity, ultimately contributing to slower productivity growth and overall economic expansion. To some extent, the pressures exerted by the United States — initially in 2018 and subsequently in 2025 — targeting China and several other countries, reflect an effort to assert dominance through control over intellectual property rights. The set of demands from the United States includes strengthening legal protections for American patents, trademarks, and copyrights in China, as well as increased oversight of industrial espionage and technology theft. According to the definition provided in reference [26], this pressure can be characterized as "a legal monopoly over some items of knowledge, which extends well beyond national boundaries."

A no less intense conflict exists in the realm of control over information flows and accumulated data. As illustrated in *Table*, this conflict is rooted in *a shift within the informational paradigm*. This shift represents a cognitive phenomenon characterized by a fundamental change in how individuals and societies process, understand, and utilize information. It has been driven by technological advancements, particularly the widespread adoption of the internet and digital communication technologies, which have transformed traditional methods of acquiring and disseminating information and knowledge.

Historically, information was often transmitted through linear, hierarchical structures such as books, formal education, and expert judgments conveyed by authoritative figures. The advent of the information age and the widespread availability of the Internet have fundamentally disrupted this paradigm, resulting in the democratization of knowledge. Today, anyone with internet access can obtain information and accumulate knowledge. Moreover, the systematization and expansion of knowledge have become the result of the activities of a much broader social group than in the past. Consequently, individuals experience a cognitive reassessment in several key areas. First, as information has become instantly accessible through search engines, social media platforms, and AI chatbots, there has been a reassessment of priorities regarding attention allocation and information processing. Second, the virtually infinite volume of available information leads to cognitive overload, which adversely affects critical thinking and decision-making processes. Third, there is a noticeable shift toward collaborative knowledge creation, diminishing the value traditionally placed on individual advancement of

[5] Our calculation is based on the data published on the Global Innovation website. URL: https://www.globalinnovationindex.org/Home (accessed on 03.04.2025).

knowledge. Crowdsourcing and social platforms provide diverse perspectives, fostering a deeper understanding of complex issues. This shift reflects a change in cognitive dynamics from passive reception to active engagement and participation. Fourth, transformations in the ways information is presented, stored, and managed generate a demand for new skill sets.

Currently, one of the central challenges influencing the competitiveness of nations is digital literacy, which encompasses, among other aspects, the ability to navigate, evaluate, and synthesize vast amounts of information from diverse sources. Overall, the aforementioned points indicate that the shift in the informational paradigm stimulates the development of higher-order thinking skills, thereby enhancing adaptability and creativity in the application of knowledge. The speed of information production, transmission, and exchange is increasing, along with greater flexibility in its processing and utilization. These processes constitute a significant factor contributing to productivity growth and long-term economic development. At the same time, one cannot help but see the limits of such growth, stemming from consumer conservatism or cognitive problems inherent in older individuals.

To complement the foregoing, it is important to assert that the shift in the information paradigm should be characterized as a qualitative leap that fundamentally elevates the role of information in successful business operations. The integration of decision-making approaches based on deep and comprehensive information analysis has significantly enhanced the operational efficiency of companies across both the real and financial sectors of the economy [27, 28]. The emergence of big data analytics and real-time information flows has enabled more informed strategic decisions, fostering competitive advantages and stimulating innovation across various industries [29], thereby laying the foundation for increased productivity and sustained economic growth.

A profound and significant cognitive shift, identified in *Table* as *the development of global consciousness*, should be examined in conjunction with the prevailing trends of adherence to local narratives. The phenomenon of global consciousness, reinforced by a growing awareness of interdependence, has become increasingly evident over recent decades through heightened recognition of global challenges such as climate change, migration, poverty and inequality, and the pursuit of financial stability. This awareness is reflected in the numerous international initiatives and agreements aimed at collectively addressing these pressing global issues.

The link between the development of global consciousness and prospects for economic growth can be observed through various mechanisms and channels. A significant portion of emerging initiatives and agreements based on this consciousness aim to enhance the resilience of economies against challenges and crises — particularly through the formulation of coordinated measures focused on achieving financial stability.[6] Additionally, these efforts seek to attain long-term sustainability of global socio-economic development, primarily within the context of environmental agendas,[7] as well as to address social issues such as poverty and inequality [30]. Research indicates that the success of such policies can substantially contribute to economic growth [31, 32].

It is important to acknowledge the complexity inherent in the relationship between the shifts associated with the development of global consciousness and those related to spiritual and moral values. This complexity arises from a fundamental contradiction. Although spiritual and moral values are often perceived as universal, they are in fact shaped by societies bounded by specific territorial and historical contexts and are transmitted primarily within local groups. Consequently, spiritual and moral values are not monolithic or universally applicable; rather, they likely contain embedded codes that facilitate intercultural, intercivilizational, and interethnic dialogue. However, the inclusion of these codes may be hindered by conditions in which countries and communities prefer to pursue strategies focused on their own (often short-term) interests. This very shift has been observed in the period following the 2007–2009 financial and economic crisis, as well as during the collapse triggered by the COVID-19

[6] Basel III: international regulatory framework for banks. Basel Committee on Banking Supervision (BCBS). December 2010. URL: https://www.bis.org/bcbs/basel3.htm (accessed on 04.05.2025); Financial Stability Board (FSB) Recommendations. URL: https://www.fsb.org/ (accessed on 04.05.2025).

[7] Paris Agreement. United Nations Framework Convention on Climate Change (UNFCCC). December 12, 2015. URL: https://unfccc.int/sites/default/files/english_paris_agreement.pdf (accessed on 05.05.2025).

pandemic. These events exposed the vulnerabilities of the world's largest economies and revealed the unwillingness of the wealthiest nations to assume responsibility for the global state of affairs and the order they had previously established [33].

The typological series illustrating cognitive changes concludes in *Table* with a shift in attitudes toward *economic security*. It becomes evident that many of the prevailing notions about the patterns of formation and functioning of the global economic system, established in the 20th century, as well as compelling arguments in favor of cultural globalization, the synthesis of cultural practices, and consensus on sustainable "green" growth, are losing their primacy, priority, and unquestionable justification in the context of escalating inter-state competition. The economic miracle of China has not merely resulted in the emergence of a formidable competitor to the United States; it has also marked a pivotal threshold beyond which the most significant geopolitical reconfiguration since World War II is underway. As it has become evident, policies aimed at leveraging comparative advantages — such as promoting trade and financial liberalization, deepening international division of labor, and fostering global specialization — relying heavily on the technological leadership of Western developed countries and their economic dominance, have led to a distribution of physical, human, and intellectual capital that fails to realize its full potential. Instead, this distribution reveals vulnerabilities in a state that deviates from the optimal conditions of globalization, exposing systemic fragilities rather than fostering resilience. As a result, liberal thinking is now being openly or implicitly replaced by an alternative paradigm across the globe. In the lexicon of policymakers, experts, and researchers, key terms such as "reindustrialization", "industrial policy", "national interests", "import substitution", "tariff restrictions", "technological sovereignty", and others have become prominent. These concepts, which we collectively categorize under the broad umbrella of economic security, reflect a shift in strategic priorities and policy orientations in response to evolving geopolitical and economic challenges.

This trend is expected to lead to a deterioration of economic conditions and a slowdown in the pace of economic growth. Taking into account the direct effects of the new trade restrictions announced by the United States in spring 2025, as well as their indirect effects through external trade linkages, increased uncertainty, and deteriorating market sentiment, the IMF revised its global economic growth forecast downward to 2.8 percent for 2025 (compared to 3.3 percent in 2024). This reduction, relative to the World Economic Outlook forecast issued prior to the implementation of tariff measures, amounts to a decrease of 0.5 percentage points for 2025 and 0.3 percentage points for 2026.[8]

Next, we turn to the types of changes affecting the contemporary global economic system that reflect the spiritual and moral characteristics of individuals and communities.

It is important to begin by noting that a particular interpretation and perception of spiritual and moral values can contribute to improved economic development and more dynamic growth. Specifically, this occurs through increased attention to the quality and accessibility of education and healthcare, as well as other channels that foster the growth of human capital [34]. An equally important point, as defined by A.A. Auzan, is that "value orientations shape the demand for institutions" [35, p. 17]. The potential of many countries in these areas remains far from fully realized. Its fulfillment would enhance the quality of life, improve institutional effectiveness, and stimulate economic development.

When examining the level of international and intercultural relations, it is important to emphasize the role of spiritual and moral foundations alongside the rejection of policies that impose values originating from a single culture. Persistent contradictions and conflicts underscore the significance of spiritual ideas grounded in mutual understanding and respect for diverse cultures, which can facilitate more peaceful interactions among countries and peoples. Such a foundation promotes the expansion of international trade, capital flows, and technology transfer, ultimately contributing to more sustainable growth. An important area of research in this field is intercultural religious literacy. As articulated by C. Seiple and D.R. Hoover, this approach entails "a comprehensive approach to understanding and conducting the kind of engagement that distin-

[8] International Monetary Fund. World Economic Outlook, April 2025; Chapter 1. Global prospects and policies. URL: https://www.imf.org/en/Publications/WEO/Issues/2025/04/22/world-economic-outlook-april-2025 (accessed on 10.05.2025).

guishes robust, covenantal pluralism from merely indifferent "tolerance" of diversity" [36, p. 1].

Significant cognitive shifts related to those discussed above pertain to the corporate sector and are identified in *Table* as *the social and environmental responsibility of businesses*. The recognition by businesses of the importance of their social and environmental impact, coupled with strong public demand for increased corporate accountability in these areas, has recently led to a transformation in how companies approach corporate social responsibility [37, 38] and sustainable development [39]. This shift is reflected in the integration of sustainability principles into business strategies, enhanced transparency and accountability to society, and a growing emphasis on reputation management and the cultivation of long-term relationships with customers, shareholders, and the broader community.

Finally, we characterize the changes encompassed by our typology under the term "*environmental ethics*". Rising living standards and the emergence of a middle class in many countries have driven shifts in consumer values and preferences. There is a noticeable transformation in the hierarchy of consumer values, with consumption increasingly becoming a conscious and deliberate aspect of daily life [40]. Contemporary consumers express concern for their own health and the well-being of their loved ones through their behavior. Their preferences often include demands for manufacturers to engage in environmentally responsible practices and to adhere to principles of social responsibility.

The evolving demands and criteria of consumers elicit responses from businesses and governments. Ultimately, these dynamics lead to changes in industry structures, as well as in the range of products and services available to end consumers. However, it is important to recognize that these phenomena unfold differently across various countries. To some extent, they have contributed to the relocation of "dirty" industries to less economically developed nations, which, in particular, influences the observed disparities in the ratio of green GDP to total GDP among different countries.

Discussion

The aim of this paper was to systematize the existing ideas and opinions regarding the cognitive, spiritual, and moral shifts significant for the world economic system and to elaborate a typology of these changes. Furthermore, as we explore the key characteristics of these shifts, our objective has been to project their potential impact on parameters of economic growth. In this section, the results obtained are discussed within the context of the existing theoretical frameworks, practical challenges, and determining directions for future research.

The developed typology classifies the shifts into two domains: cognitive and spiritual and moral. Our approach advances the methodology of a systems perspective on the dynamics of human development, particularly following the framework proposed by Ronald Inglehart and Christian Welzel [41, 42]. The detailed typology we have developed underscores the multi-layered nature of the processes encompassed by the concept of cognitive and spiritual and moral shifts that impact the global economy, thereby revealing the multiplicity of their consequences.

The cognitive dimension reflects a fundamental reconfiguration of collective knowledge and perception, driven by technological advancements and the proliferation of information flows. The spiritual-moral dimension embodies a shift toward purposeful values that highlight interconnectedness and holistic well-being, complemented by the emergence of evolving normative standards emphasizing responsibility, equity, and sustainability.

The interdependence between these domains, as exemplified by the pursuit of Environmental, Social, and Governance (ESG) principles, underscores the relevance of systems theory, which posits that social changes constitute a complex adaptive process characterized by feedback loops and emergent properties [43]. The co-evolution of cognitive and spiritual-moral shifts suggests that transformations in one domain catalyze and reinforce changes in the other, thereby creating a dynamic process of systemic evolution.

For example, increased awareness of environmental issues (a cognitive shift) fosters moral demands for justice and responsibility, which in turn inspire spiritual quests for purpose and interconnectedness [44]. This interrelation aligns with the concept of the "moral economy," wherein economic activity is increasingly guided by ethical and spiritual considerations [45]. The co-evolutionary process accelerates systemic change, as

each domain amplifies the influence of the others, leading to a more sustainable and adaptive global economic system.

Digital technologies and globalization act as accelerators of these shifts. The rapid dissemination of ideas and values across borders fosters a shared global consciousness, increasing the demand for moral and spiritual values [46, 47]. In the past two decades, the emergence of social platforms has played a particularly significant role. Interactions among users on these platforms generate transformations in the norms governing such interactions and lead to rapid shifts in perceptions regarding specific events, processes, and individuals. The extensive reach of consumers within social networks is revolutionizing traditional approaches to corporate economic behavior [48].

At the same time, a large number of economic players whose businesses either do not benefit from such changes or who are not ready to compete with more successful rivals are becoming opposed to these innovations [48]. We will add that the process of building Chinese walls in terms of the possibilities of disseminating certain social networks in some countries, which has been observed most recently, is actually slowing down the effect of disseminating ideas and values across borders, transforming social networks into a tool for manipulating consciousness.

The comprehensive analysis of specific types of global cognitive, spiritual, and moral shifts presented in this study reveals characteristics typical of complex systems [49] as applied to the contemporary global economic system. Among these characteristics are emergent properties, adaptation, the presence of catalytic elements and growth constraints, nonlinear dynamics, and others. We identify overlapping spheres of influence of the examined changes as they interact with the global economic system. Notably, some of the changes discussed in the analysis have clear positive and possible hidden negative effects in terms of their impact on economic growth prospects.

To some extent, our findings relate to the concept of the "moral economy" [45, 50]. At the same time, it is important to note that the implementation of the principles of the moral economy or sustainable development, where observed, predominantly occurs due to the specific roles that certain countries occupy within the international division of labor, as well as their possession of various strategic competitive advantages. Unfortunately, the question of how to address the interests of countries that have not succeeded in such development remains unresolved.

Overall, a thorough and in-depth analysis of cognitive, spiritual, and moral shifts helps policymakers, business leaders, and citizens make important conclusions, although these insights are not always easily converted into practical recommendations. This can be considered a limitation of the analysis carried out. The most straightforward conclusions might be as follows: policymakers should promote the creation of an environment conducive to sustainable innovation, social entrepreneurship, and ethical standards by implementing regulatory reforms and incentives [51]; businesses are encouraged to adopt purpose-driven strategies, engage actively with stakeholders, and ensure transparency in their operations, aligning corporate objectives with societal values [52]; and citizens are encouraged to embrace behaviors based on environmental stewardship, healthy lifestyles, empathy, and tolerance.

The findings also highlight the importance of educational reforms aimed at fostering awareness and competencies aligned with these shifts, such as systems thinking, ethical reasoning, and sustainability literacy [53]. Implementing such initiatives can accelerate the transition toward a more sustainable and equitable global economy, equipping individuals with the skills necessary to navigate and contribute to systemic change effectively.

The presence of both positive and negative effects resulting from various observed shifts, for example, in the realms of information, cultural globalization, in the field of the implementation of the climate agenda [54], and the conflicting trends of global consciousness and the promotion of local narratives, brings about, as mentioned above, certain limitations regarding the formulation of policy recommendations. From the perspective of developing the methodological approach implemented in this study, it is important to consider the promising prospects of cross-cultural analysis, utilizing data from search queries and user reactions to information as tools for conducting empirical investigations into the depth and consequences of the studied shifts.

Considering the impact of the studied shifts on economic growth as the ultimate goal, focused research of their influence on productivity appears to be a promising direction. Such investigations

could include examining effects related to the development of innovative potential, the generation of advanced technologies, and the more equitable distribution of intellectual property rights (as a potential solution to the challenges of cognitive capitalism), among other aspects.

Conclusion

The conducted study has highlighted the evident significance of cognitive, spiritual, and moral shifts for the global economic system. At the same time, it revealed the multidirectional nature of the influence exerted by some of these shifts, which is determined, among other factors, by the differentiation in countries' economic development and conflicting economic and political interests. The typology of the examined shifts proposed in this paper may facilitate a more focused and balanced analysis of their consequences and various manifestations across different sectors and domains. These include the knowledge accumulation domain, the information sphere, the cultural sphere, the value systems, ethical norms, and others.

The conducted analysis has identified specific characteristics of certain types of cognitive, spiritual, and moral shifts, while also examining their relationship with prospects for economic growth. This relationship is highly complex and cannot be reduced to straightforward causal links. For instance, a significant portion of the effects considered as consequences of geo-climatic risks are explicitly associated with negative implications for the economy. Often, these effects are simply direct damages inflicted by human activities on climate systems, water resources, soils, and other environmental factors, thereby diminishing the potential of productive forces. Simultaneously, the environmental movement, driven by the pursuit of sustainable development goals, has recently shaped — or transformed — a significant number of markets, aligning the entire production chain (including distribution, financing, manufacturing, and consumption) with stringent eco-standards. This shift stimulates economic growth by making it less destructive in terms of long-term consequences for humanity. However, because the "green" economy relies heavily on standards and regulations, its advancement may create uneven conditions for participants and pose risks, particularly for countries with less developed technological infrastructures to support green growth.

The examined components of cognitive and spiritual-moral shifts — such as paradigm changes in knowledge, the development of global consciousness, innovative thinking, creativity, and corporate social and environmental responsibility — are primarily manifested through actions that promote human capital accumulation, enhance productivity, and consequently support economic growth. However, among these and other components of cognitive, spiritual, and moral shifts, there are also elements whose consequences for the economy may be characterized as negative. Alongside the paradigm shift in knowledge, there has been a wave of new approaches to education and knowledge generation. Unfortunately, this often leads to the dismantling of traditional methods and systems, replacing them with new ones that are sometimes less effective. Beneficiaries of this process tend to be segments of the bureaucracy that promote reform agendas, while the system as a whole becomes burdened with additional costs and fails to deliver the anticipated outcomes of these reforms. A particularly significant divide emerges concerning the issue of personal data control. Large corporations that have established extensive ecosystems are accumulating increasing amounts of unique data related to consumers and their preferences. Their pursuit of unrestricted rights to utilize this information increasingly conflicts with consumers' desire to retain control over their personal data. This ongoing contradiction is likely to hinder the growth of various consumer sectors in the near future until a mutually acceptable compromise is reached, satisfying the interests of both parties.

Finally, it is important to note that the examined shifts within the global economic system are, to some extent, interrelated. For instance, geo-climatic shifts — characterized in the context of anthropogenic impacts on climate change — drive a significant portion of cognitive shifts, particularly those reflected in the growth of global consciousness. At the same time, these shifts underpin various socio-economic consequences affecting the global economic system, such as migration flows, territorial degradation, and increased poverty. Another example of the interdependence among global shifts is the connection between changes in the knowledge paradigm and the rising importance of innovative thinking and creativity. Similarly, the contemporary role of corporate so-

cial and environmental responsibility is influenced by climate change, evolving consumer preferences, and societal demands regarding product quality and the ecological footprint of manufacturers. All of these factors are interconnected within a complex web of mutual relationships and influences, which are reflected in trends related to corporate strategic behavior, the stance of governments, and the agendas of interstate relations. Consequently, they exert an impact on economic growth across various levels — from intra-firm and microeconomic scales to the international arena.

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An Interest Rate Model for Uncertain-Stochastic Financial Markets

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ABSTRACT

Over the past decades, financial markets have increasingly exhibited features of both randomness and uncertainty, creating challenges for interest rate models that rely solely on stochastic or uncertain processes. These models often fail to adequately capture the dual nature of indeterminacy, limiting their relevance in volatile and unpredictable market conditions. This study **aims** to design and assess an interest rate model for uncertain-stochastic financial markets and to derive a framework for zero-coupon bond pricing under this setting. The **methodology** applies uncertain stochastic differential equations, which integrate elements of both probability theory and uncertainty theory, thereby accommodating aleatory and epistemic forms of indeterminacy. The proposed model extends the classical short-rate frameworks by introducing two sources of indeterminacy and provides theoretical derivations for bond pricing. Numerical illustrations are included to demonstrate the application of the model to zero-coupon bond valuation and to highlight differences from conventional approaches. The **findings** indicate that interest rates and zero-coupon bond prices in uncertain stochastic financial markets can be effectively modeled through uncertain random processes, leading to improved pricing accuracy and risk management in environments characterised by incomplete information and unpredictable shocks. The key **conclusion** is that incorporating uncertain stochastic differential equations into the interest rate and zero-coupon bonds' prices modelling offers a more robust and flexible framework for uncertain stochastic markets. This study contributes to the growing body of uncertain stochastic finance by underscoring the need for hybrid models capable of guiding policymakers, investors and financial institutions in ensuring stability and resilience under future market uncertainties.

Keywords: indeterminacy; randomness; uncertainty; interest rate model; zero-coupon bond pricing; probability theory; uncertainty theory; chance theory; uncertain stochastic financial markets; uncertain random processes; uncertain stochastic differential equations

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ОРИГИНАЛЬНАЯ СТАТЬЯ

Модель процентных ставок для неопределенно-стохастических финансовых рынков

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АННОТАЦИЯ

За последние десятилетия финансовые рынки все чаще демонстрируют черты как случайности, так и неопределенности, что создает трудности для моделей процентных ставок, основанных исключительно на стохастических или неопределенных процессах. Эти модели часто неадекватно отражают двойственную природу неопределенности, что ограничивает их применимость в волатильных и непредсказуемых ры-

ночных условиях. **Целью** данного исследования является разработка и оценка модели процентной ставки для неопределенно-стохастических финансовых рынков и разработка модели ценообразования облигаций с нулевым купоном в этих условиях. **Методология** использует неопределенные стохастические дифференциальные уравнения, которые объединяют элементы как теории вероятностей, так и теории неопределенности, тем самым учитывая алеаторные и эпистемические формы неопределенности. Предлагаемая модель расширяет классические модели краткосрочных ставок, вводя два источника неопределенности и предоставляя теоретические выводы для определения цены облигаций. Приведены числовые иллюстрации для демонстрации применения модели к оценке облигаций с нулевым купоном и для выявления отличий от традиционных подходов. **Результаты** исследования показывают, что процентные ставки и цены облигаций с нулевым купоном на неопределенных стохастических финансовых рынках могут быть эффективно смоделированы с помощью неопределенных случайных процессов, что приводит к повышению точности ценообразования и управлению рисками в условиях неполной информации и непредсказуемых шоков. **Ключевой вывод** заключается в том, что включение неопределенных стохастических дифференциальных уравнений в моделирование процентных ставок и цен облигаций с нулевым купоном обеспечивает более надежную и гибкую структуру для неопределенных стохастических рынков. Данное исследование вносит **вклад** в растущий объем знаний неопределенных стохастических финансов, подчеркивая необходимость гибридных моделей, способных помочь политикам, инвесторам и финансовым учреждениям обеспечить стабильность и устойчивость в условиях будущей рыночной неопределенности.
Ключевые слова: неопределенность; случайность; неточность; модель процентной ставки; ценообразование облигаций с нулевым купоном; теория вероятностей; теория неопределенности; теория случайности; неопределенные стохастические финансовые рынки; неопределенные случайные процессы; неопределенные стохастические дифференциальные уравнения

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Introduction

Financial decisions, in practice, are executed under the condition of indeterminacy. Uncertainty and randomness are two common kinds of indeterminacy [1, 2]. Probability theory, introduced by [3], deals with randomness and uncertainty theory, developed by [4] and enhanced by [5], models human subjective uncertainty. Matenda and Chikodza postulated that the probability theory is implemented when the sample size is large to generate the probability distribution from the existing frequency [6]. On the contrary, if the size of the sample is nonexistent or too small to generate the probability distribution, the theory of uncertainty is implemented [6]. In this case, domain specialists are requested to assess their belief degrees of each event occurring [7–9]. Implementing probability theory in this situation results in counterintuitive results. Using uncertainty theory ensures that no counterintuitive results arise [10].

Stochastic processes, random variables and stochastic differential equations (SDEs) are essential in probability theory because they are implemented to deal with random phenomena that change with time [11, 12]. The Brownian motion is one of the broadly implemented stochastic processes in practice [13, 14]. SDEs are powered by stochastic processes. Applying probability theory in the finance discipline resulted in the birth of the theory of stochastic finance. Hence, stochastic processes and SDEs are essential tools in stochastic financial markets. Since the publication of the classical work of [15], SDEs have been extensively implemented in finance theory. The work [15] propounded that the price of a stock can be explained by an exponential Brownian motion and then designed option pricing formulae for the European options.

One of the most important mathematical frameworks in finance is the short-rate interest model, which describes the progression of interest rates (IRs) over time. This framework focuses on the short-term interest rate (IR), which we can simply call the short rate. It is applicable for the shortest period and is often interpreted as an instantaneous rate. Short-rate interest models have been widely used in the IR derivatives pricing, bond valuation and risk management. Traditional short rate models make use of SDEs to elucidate short-term IR progression. Quite a number of models incorporate mean reversion, which is the tendency of IRs moving towards, over time, a long-run average. These short rate models are usually developed in the context of the risk-neutral measure framework.

In 1973, [16] explained the IR by implementing stochastic processes to establish the zero-coupon bond price. The most common stochastic short rate

models have been developed by [7–10] and references thereof. A general form of the IRs term structure was examined by [17]. The author suggested a novel mean-reverting IR model powered by a Wiener process. In 1986, [18] developed [16]'s IR model, assuming a no-arbitrage principle. For more expositions on the implementation of SDEs in IR modelling, see, for instance, [19, 20]. Fundamentally, stochastic financial models are premised on the supposition that asset prices are only subject to random movements [21, 22].

Some short-rate models are computationally efficient, practical for real-world applications, incorporate mean reversion, are consistent with observed market prices, and are used in a wide range of applications that are easy to understand and apply. However, some of them allow for negative IRs, assume a single source of uncertainty, have calibration challenges, are unable to fit the entire yield curve, are over-simplified, assume constant volatility, are difficult when pricing complex derivatives and are computationally expensive.

In uncertainty theory, uncertain processes, uncertain variables, and uncertain differential equations (UDEs) are essential because they explain dynamic uncertain systems [23, 24]. The Liu process [5] is a commonly implemented uncertain process. UDEs are driven by uncertain processes. The application of uncertainty theory in the discipline of finance resulted in the emergence of the theory of uncertain finance. As a result, uncertain processes and UDEs are essential tools in stochastic financial markets. UDEs were first applied in financial models by [5]. [5] postulated that the price of a stock could be explained by an exponential Liu process. The author [5] further priced the European options for stocks premised on an uncertain stock model. Since the publication of the classical work of [5], UDEs have been widely adopted in finance theory (see, for instance, [25–27]).

UDEs have been broadly implemented to model rates of interest in uncertain financial markets [28–30]. In an uncertain environment, [31] presumed that the rate of interest is an uncertain process and applied UDEs to describe the IR and priced, in analytic form, a zero-coupon bond. [31] designed the initial uncertain IR model for uncertain markets, even though the rate of interest may be negative in this model. [32] developed the pricing formulae for IR floors and ceilings. Implementing an uncertain fractional differential equation, [33] designed an IR model. [34] generated an IR model using an uncertain exponential Ornstein-Uhlenbeck equation. Some authors, specifically [35, 36], demonstrated that UDEs could model IRs.

Most studies have modelled indeterminacy by independently using randomness or uncertainty. However, [37–40] revealed that uncertainty and randomness could concurrently materialize in a process. Similarly, [21] indicated that, in reality, financial markets frequently comprise human uncertain factors and stochastic factors. Randomness is the aleatory uncertainty, while Liu's uncertainty is the epistemic type. Recent developments in various fields have shown that it is essential to include both randomness and uncertainty when modelling indeterminacy. Hence, studies on indeterminacy have led to novel discoveries on how to describe processes with both uncertainty and randomness. [37] introduced the chance theory to deal with both randomness and uncertainty in sophisticated mathematical systems. Interestingly, [6] propounded that probability theory and uncertainty theory supplement one another.

A chance measure, a chance space, a chance distribution, an uncertain random variable, expected value, and variance were introduced by [37]. In 2015, [41] presented an uncertain random process to describe the uncertain random phenomena dynamics that change with time. Uncertain stochastic differential equations and uncertain random processes are central to the discipline of uncertain random calculus because they describe the evolution of different processes with randomness and uncertainty. The USDE is powered by a canonical Liu process and a Brownian motion [42]. USDEs are driven by US processes. The adoption of chance theory in the discipline of finance resulted in the establishment of the US finance theory. Hence, uncertain stochastic (US) processes and USDEs are imperative tools in US financial markets.

B. Liu [43] examined several aspects of uncertain random variables, which include problems in mathematical programming, risk analysis, reliability analysis, graph theory, network problems, to mention but a few. For US financial markets, [6] developed a stock model with jumps. This model was later applied in solving a US option pricing problem in the existence of uncertain jumps by [44]. Recently, [45] proposed a US optimal control model with a jump and applied it to portfolio game symmetry. [46] tackled a multi-objective optimization problem in uncertain random environments. [47] applied US systems with Markovian switching in solving a portfolio selection problem. Interestingly, until now, no study has designed an IR model for US financial markets.

In this study, we suggest that the short rates of interest are driven by USDEs in the US financial markets. In this framework, the presumption is that the IR is driven by two sources of uncertainty. Employing an uncertain differential equation, we design a US IR model and then implement that model to price a zero-coupon bond. For effective and efficiency purposes, numerical examples concerning zero-coupon bond pricing are presented.

The rest of the article is arranged as follows: Section 2 covers the preliminaries, and Section 3 examines a US short-rate model. Numerical examples are outlined in Section 4. Conclusions are given in Section 5.

Preliminaries

This section outlines crucial definitions concerning uncertainty theory, probability theory and chance theory. We presume a complete filtered uncertainty probability space $\left(\Gamma \times \Omega,\ \mathcal{L} \times \mathcal{F},\ \mathcal{M} \times P\right)$ characterised by a filtration $\left(\mathcal{L} \times \mathcal{F}_t\right)_{t\epsilon[0,T]}$, created by a standard a one-dimensional Brownian motion, $\{W_t\}_{t\epsilon[0,T]}$, and a one-dimensional Liu process, $\{\mathrm{C}_T\}_{\epsilon[0,T]}$. Basically, $\Gamma \times \Omega$ represents the universal set, $\mathcal{L} \times \mathcal{F}$ is a product σ-algebra, $\mathcal{M} \times P$ signifies a product measure and $\left(\Gamma \times \Omega, \mathcal{L} \times \mathcal{F}, \mathcal{M} \times P\right)$ denotes an uncertainty probability space.

Definition 1 Presume Ω denotes a non-empty set and $\mathcal{F}$ represents a σ-algebra over Ω. Every component A in $\mathcal{F}$ is an event. A probability measure refers to a set function $P: \mathcal{F} \to [0,1]$ which fulfills the below-stated axioms:

- **Normality:** $P\{\Omega\} = 1$ for the universal set Ω
- **Non-negativity:** $P\{A\} \geq 0$ for every event A;
- **Additivity:** For each countable series of mutually disjoint events

$$A_1, A_2, A_3, \ldots,\ P\left\{\bigcup_{i=1}^{\infty} A_i\right\} = \sum_{i=1}^{\infty} P\{A_i\}.$$

Definition 2 A random variable refers to a function ε from a probability space $(\Omega, \mathcal{F}, P)$ to a set of real numbers in a manner that for each Borel set B of real numbers, $\{\varepsilon \in B\}$ is regarded as an event.

Definition 3 Presume $(\Omega, \mathcal{F}, P)$ denotes a probability space, and T is an index set. A stochastic process refers to a measurable function $X_T(\omega)$ from $T \times (\Omega, \mathcal{F}, P)$ to the set of real numbers in a manner that at any time *t*, for every Borel set of real numbers, $\{X_t \in B\}$ is an event. Basically, a stochastic process refers to a series of random variables indexed by space or time.

Definition 4 A stochastic process W_t is regarded as a standard Brownian motion if

- $W_0 = 0$, and almost all sample paths are continuous,
- W_t *is* associated with independent and stationary increments,
- each increment $W_{s+t} - W_s$ is a normal random variable with variance *t* and an expected value 0.

Definition 5 [4] Presumed that Γ denotes a non-empty set, and $\mathcal{L}$ represents a σ-algebra over Γ. Each component $\wedge$ in $\mathcal{L}$ is regarded as an event. Basically, an uncertain measure refers to a set function $\mathcal{M}: \mathcal{L} \to [0,1]$ which fulfills the below-stated axioms:

- **Normality:** $\mathcal{M}\{\Gamma\} = 1$;
- **Monotonicity:** $\mathcal{M}\{\wedge_1\} \leq \mathcal{M}\{\wedge_2\}$ if $\wedge_1 \subset \wedge_2$;
- **Duality:** $\mathcal{M}\{\wedge_1\} + \mathcal{M}\{\wedge^c\} = 1$ for each $\wedge \in \mathcal{L}$;
- **Sub-additivity:** For each countable event series $\{\wedge_1, \wedge_2, \ldots\}$, $\mathcal{M}\left\{\bigcup_i \wedge_i\right\} \leq \sum_i \mathcal{M}\{\wedge_i\}$.

Definition 6 [4] An uncertain variable refers to a measurable function ε from an uncertainty space $(\Gamma, \mathcal{L}, \mathcal{M})$ to the set of real numbers in a manner that for every Borel set B, $\{\varepsilon \in B\}$ is regarded as an event.

Definition 7 [37] Presume that T is regarded as an index set, and $(\Gamma, \mathcal{L}, \mathcal{M})$ denotes an uncertainty space. Conceptually, an uncertain process refers to a measurable function $X_t(\gamma)$ from $T \times (\Gamma, \mathcal{L}, \mathcal{M})$ to the set of real numbers in a manner that at any time t, for each Borel set B, $\{X_t \in B\}$ is regarded as an event.

Definition 8 [5] An uncertain process C_t is a Liu process if

- $C_0 = 0$, and almost all sample paths are Lipschitz continuous,
- C_t is associated with independent and stationary increments,

• each increment $C_{s+t} - C_s$ is regarded as a normal uncertain variable characterised by variance t^2 and expected value 0, whose uncertainty distribution is described by

$$\Phi(x) = \left(1 + \exp\left(-\frac{\pi x}{\sqrt{3}t}\right)\right)^{-1}, x \in \mathcal{R}.$$

Definition 9 [37] Assume that $(\Gamma, \mathcal{L}, \mathcal{M}) \times (\Omega, \mathcal{F}, P)$ denotes a chance space, and $\Theta \in \mathcal{L} \times \mathcal{F}$ represents an uncertain random event. Hence, a chance measure $Ch\{\Theta\}$ is given by

$$Ch\{\Theta\} = \int_0^1 P\{\omega \int \Omega \mid \mathcal{M}\{\gamma \in \Gamma \mid (\gamma, \omega) \in \Theta\} \geq r\} dr.$$

A chance measure fulfills the following axioms:

- **Normality:** (Liu, 2013) $Ch(\Gamma \times \Omega) = 1,\ \mathrm{Ch}\{\varnothing\} = 0;$
- **Monotonicity:** (Liu, 2013) $Ch\{\Theta_1\} \leq Ch\{\Theta_2\}$ for each event $\Theta_1 \leq \Theta_2$;
- **Self-duality:** (Liu, 2013) $Ch\{\Theta\} + Ch\{\Theta^c\} = 1$ for each event Θ;
- **Sub-additivity:** (Hou, 2014) For each countable series of events $\Theta_1, \Theta_2 \ldots, Ch\left\{\bigcup_i^{\infty} \Theta_i\right\} = \sum_i^{\infty} Ch\{\Theta_i\};$

• **Null-additivity:** (Hou, 2014) Assume that $\Theta_1, \Theta_2 \ldots,$ denotes a series of events with $Ch\{\Theta_i\} \to 0$ as $i \to \infty$. So, for each event

$$\lim_{i \to \infty} Ch\{\Theta \cup \Theta_i\} = \lim_{i \to \infty} Ch\left\{\frac{\Theta}{\Theta_i}\right\} = Ch\{\Theta\}.$$

This implies that $Ch\{\Theta_1 \cup \Theta_2\} = Ch\{\Theta_1\} + Ch\{\Theta_2\}$ if either $Ch\{\Theta_1\} = 0$ or $Ch\{\Theta_2\} = 0;$

• **Axiom 6: Asymptotic** (Hou 2014) For each series of events $\Theta_1, \Theta_2, \ldots,$

$$\lim_{i \to \infty} Ch\{\Theta_i\} > 0, if\ \Theta_i \uparrow \Gamma \times \Omega,\ \lim_{i \to \infty} Ch\{\Theta_i\} < 1, if\ \Theta_i \downarrow \varnothing.$$

Definition 10 [37] An uncertain random variable refers to a measurable function ξ from a chance space $\{\Gamma, \mathcal{L}, \mathcal{M}\} \times \{\Omega, \mathcal{F}, P\}$ to the real numbers' set in a manner that for any Borel set B of real numbers, the set $\{\xi \in B\} = \{(\gamma, \omega) \mid \xi(\gamma, \omega) \in B\}$ is regarded as an uncertain random event in $\mathcal{L} \times \mathcal{F}$.

Definition 11 [42] (*i*) An uncertain random variable refers to a measurable function ξ from an uncertainty probability space $(\Gamma \times \Omega, \mathcal{L} \times \mathcal{F}, \mathcal{M} \times P)$ to the real numbers' set in a manner that for each Borel set B of real numbers, the set

$$\{\xi \in B\} = \{(\gamma, \omega) \in \Gamma \times \Omega \mid \xi(\gamma, \omega) \in B\} \in \mathcal{L} \times \mathcal{F}$$

is regarded as an event.

(ii) The expected value of an uncertain random variable ξ is described by

$$E[\xi] = E_p\left[E_{\mathcal{M}}[\xi]\right]$$

given that the operations on the right-hand are described well. The operators

$$\mathrm{E}_{\mathcal{M}} \text{ and } \mathrm{E}_p$$

represent the expected values in the context of the probability space and uncertainty space, respectively.

Suppose *b* and *a* are constants, $E[aC_t + bW_t] = 0$, where W_t is a standard one-dimensional Brownian motion and C_t is a Liu process. Interestingly, the uncertain random variable definitions introduced by [37] and [42] are not similar. The definition propounded by [37] indicates that an uncertain random variable is generally a function from a probability space to a set of uncertain variables [42].

Definition 12 [41] Assume that T is a completely ordered set and $(\Gamma \times \Omega, \mathcal{L} \times \mathcal{F}, \mathcal{M} \times P)$ refers to a chance space. Conceptually, an uncertain random process refers to a measurable function $X_t(\gamma, \omega)$ from $T \times \{\Gamma \times \Omega, \mathcal{L} \times \mathcal{F}, \mathcal{M} \times P\}$ to the set of real numbers in a manner that the set

$$\{X_t \in B\} = \{(\gamma,\omega) \in \Gamma \times \Omega \mid X_t(\gamma,\omega) \in B\}$$

is regarded as an uncertain random event in $\mathcal{L} \times \mathcal{F}$ for every Borel set B of real numbers at any time $t \in T$. Basically, an uncertain random process refers to a series of uncertain random variables indexed by time or space, $t \in [0, \infty)$ and is described on a chance space $\{\Gamma \times \Omega, \mathcal{L} \times \mathcal{F}, \mathcal{M} \times P\}$.

Uncertain stochastic short-rate model

This study assumes that the IR can be explained by an USDE. Hence, a US IR model to explain the dynamics of the IR is examined under this framework. An US IR model in US markets can be explained by a USDE

$$dr_t = e(t,r_t)dt + \sigma_1(t,r_t)dW_t + \sigma_2(t,r_t)dC_t,$$

where the short IR at time *t* is given by *r*, and the drift *e*, stochastic diffusion σ_1 and uncertain diffusion σ_2 are presumed to be functions of *t* and *r*. This model is an expansion of the model suggested by [6] in 1973. It is a sole factor short-term IR model that represents the evolution of the IR r_t in the presence of epistemic and aleatory uncertainty. The model lacks mean reversion, the IR is an uncertain random variable, and the model has two sources of uncertainty, that is, epistemic and aleatory uncertainty. Aleatory uncertainty is premised on the random experiment outcomes' unpredictability, while epistemic uncertainty is powered by the deficiency of adequate or precise knowledge about facts. In the following section, the model is going to be used in zero-coupon bond pricing.

Pricing a zero-coupon bond using an uncertain stochastic short rate model

[48] indicated that if $P(t,T)$ is the price of the zero-coupon bond associated with a maturity date *T*, then if today is time *t,* the maturity time can be defined as $\tau = T - t$. Also, [31] propounded that the τ-period spot IR at time *t* is described by $s(t,T)$. In addition, [48] indicated that the τ-period spot rate of interest at time *t* satisfies the equations

$$P(t,T) = \exp\left(-s(t,T)(T-t)\right),$$

and

$$s(t,T) = -\frac{\ln P(t,T)}{(T-t)}. \tag{1}$$

Further, [48] propounded that, suppose $f(t,T)$ denotes a forward IR deduced from the zero-coupon bond, then

$$P(t,T) = \exp\left(-\int_t^T f(t,T)ds\right),$$

and

$$f(t,T) = -\frac{\frac{\partial P(t,T)}{\partial T}}{P(t,T)}. \tag{2}$$

If the short IR is presumed to follow a USDE, the zero-coupon bond price $P(t,T)$ is the anticipated value of one dollar discounted by the probable short rate process's paths. [48] indicated that the local equilibrium hypothesis is that the expected immediate return is given by the short rate of the form

$$\frac{E\left[P(t+\Delta t,T)\right]}{P(t,T)} = \exp(r_t \Delta t), \text{ as } \Delta t \to 0.$$

From the local equilibrium hypothesis, the zero-coupon bond price $P(t,T)$ is described by

$$P(t,T) = E\left[\exp\left(-\int_t^T r_v dv\right)\right]. \tag{3}$$

The savings account is represented by

$$\beta(t) = \exp\left(\int_0^t r(s)ds\right).$$

Theorem 1: Suppose a short rate is described by an USDE of the form

$$dr_t = e_t dt + \sigma_1 dW_t + \sigma_2 dC_t, \tag{4}$$

where e_t is a function of t and σ_1 *and* σ_2 denote the constants, then the price of the zero-coupon bond associated with a maturity date T is given by

$$P(0,T) = \frac{1}{2}\sqrt{3}\sigma_2 T^2 \exp\left(-r_0 T\int_0^t\int_0^s e_t dtds - \sigma_1 T\rho\right)\csc\left(\frac{1}{2}\sqrt{3}\sigma_1 T^2\right). \tag{5}$$

Proof: Equation 4 is an extension of Merton's model, whose solution, r_t, is of the form

$$r_t = r_0 + \int_0^t e_s ds + \sigma_1 W_t + \sigma_2 C_t.$$

The expected value of r_t is

$$E[r_t] = E\left[r_0 + \int_0^t e_s ds + \sigma_1 W_t + \sigma_2 C_t\right] = r_0 + \int_0^t e_s ds$$

and its variance is described by

$$Var[r_t] = Var\left[r_0 + \int_0^t e_s ds + \sigma_1 W_t + \sigma_2 C_t\right] = \sigma_1^2 t + \sigma_2^2 t^2.$$

From equation 3, for $t = 0$,

$$P(0,T) = E\left[\exp\left(-\int_0^T r_s \mathrm{d}s\right)\right] = \exp\left[\int_0^\infty \mathcal{M}[\int_0^T r_s \mathrm{d}s \le -x]\right]\mathrm{d}x =$$

$$= \exp[\int_0^\infty \mathcal{M}[r_0 T + \int_0^t\int_0^s e_t dtds + \sigma_1 TW_t + \sigma_2 TC_t \le -x\,]\mathrm{d}x] =$$

$$= \exp[\int_0^\infty [\mathcal{M}[C_t \le \frac{-x - r_0 T - \int_0^T\int_0^s e_t dtds - \sigma_1 TW_t}{\sigma_2 T}]]dx] =$$

$$= \exp\left[\int_0^\infty\left[\left(1+\exp\left(-\frac{\pi\left(-x - r_0 T - \int_0^T\int_0^s e_t dtds - \sigma_1 TW_t\right)}{\sqrt{3}\sigma_2 T^2}\right)\right)^{-1}\right]dx\right].$$

Replacing W_t with its realizations ρ, we have

$$P(0,T) = \left[\int_0^\infty\left[\left(1+\exp\left(-\frac{\pi\left(-x - r_0 T - \int_0^T\int_0^s e_t dtds - \sigma_1 T\rho\right)}{\sqrt{3}\sigma_2 T^2}\right)\right)^{-1}\right]dx\right] =$$

$$= \frac{1}{2}\sqrt{3}\sigma_2 T^2 \exp\left(-r_0 T - \int_0^T\int_0^s e_t dtds - \sigma_1 T\rho\right)\csc\left(\frac{1}{2}\sqrt{3}\sigma_2 T^2\right) \tag{6}$$

Thus, the proof is concluded since equation 6 equals equation 5 which is the price of the zero-coupon bond. Replacing e_t in equation 6 with a constant e gives

$$P(0,T)=\frac{1}{2}\sqrt{3}\sigma_2 T^2\exp\left(-r_0T-\frac{1}{2}eT^2-\sigma_1T\rho\right)\csc\left(\frac{1}{2}\sqrt{3}\sigma_2T^2\right). \tag{7}$$

Applying equations 1 and 2 to equation 7, the forward IR is given by

$$\begin{gathered}S(0,T)=-\frac{\ln P(0,T)}{T}= \\ =-\frac{\ln\left(\frac{1}{2}\sqrt{3}\sigma_2T^2\right)}{T}+\frac{1}{2}eT+r_0+\sigma_1\rho-\frac{\ln\left(\csc\left(\frac{1}{2}\sqrt{3}\sigma_2T^2\right)\right)}{T},\end{gathered} \tag{8}$$

and the spot IR is described by

$$\begin{gathered}\mathrm{f}(0,T)=-\frac{\frac{\partial P(0,T)}{\partial T}}{P(0,T)}= \\ =-\frac{2}{T}+eT+r_0+\sigma_1\rho+\sqrt{3}\sigma_2T\ \csc\left(\frac{1}{2}\sqrt{3}\sigma_2T^2\right).\end{gathered} \tag{9}$$

Uncertain stochastic mean reverting short rate model

In this section, an US mean reverting short rate model is proposed. Consider a linear USDE.

Theorem 2: Let $a_{1t},a_{2t},b_{1t},b_{2t},c_{1t},c_{2t}$ be integrable uncertain random processes. The linear USDE

$$\mathrm{d}X_t=\left(a_{1t}X_t+a_{2t}\right)\mathrm{d}t+\left(b_{1t}X_t+b_{2t}\right)\mathrm{d}W_t+\left(c_{1t}X_t+c_{2t}\right)\mathrm{d}C_t \tag{10}$$

has solution

$$X_t=U_t\left(X_0+\int_0^t\frac{a_{2s}}{U_s}\mathrm{d}s+\int_0^t\frac{b_{2s}}{U_s}\mathrm{d}W_s+\int_0^t\frac{c_2s}{U_s}\mathrm{d}C_s\right) \tag{11}$$

where

$$U_t=\exp\left(\int_0^t a_{1s}\mathrm{d}s+\int_0^t b_{1s}\mathrm{d}W_s+\int_0^t c_{1s}\mathrm{d}C_s\right).$$

Proof: Let V_t and U_t be two US processes such that

$$dU_t=a_{1t}U_tdt+b_{1t}U_tdW_t+c_{1t}U_tdC_t,$$

$$\mathrm{d}V_t=\frac{a_{2t}}{U_t}\mathrm{d}t+\frac{b_{2t}}{U_t}\mathrm{d}W_t+\frac{c_{2t}}{U_t}\mathrm{d}C_t.$$

From integration by parts,

$$\mathrm{d}\left(U_tV_t\right)=V_t\mathrm{d}U_t+U_t\mathrm{d}V_t=\left(a_{1t}U_tV_t+a_{2t}\right)\mathrm{d}t\ +\left(b_{1t}U_tV_t+b_{2t}\right)\mathrm{d}W_t+\left(c_{1t}U_tV_t+c_{2t}\right)\mathrm{d}C_t.$$

An uncertain random process in equation 11 given by $X_t=U_tV_t$ is a solution to equation 10 where

$$U_t=U_o\exp\left(\int_0^t a_{1s}\mathrm{d}s+\int_0^t b_{1s}dW_s+\int_0^t c_{1s}\mathrm{d}C_s\right)$$

and

$$V_t=V_0+\int_0^t\frac{a_{2s}}{U_s}ds+\int_0^t\frac{b_{2s}}{U_s}dW_s+\int_0^t\frac{c_{2s}}{U_s}dC_s.$$

If

$$V_0=X_0\text{ and }U_0=1,$$

theorem 2's solution is obtained; thus, the proof is concluded.

An US mean reverting IR model in US markets can be described by an USDE

$$dr_t = (m - er_t)dt + \sigma_1 W_t + \sigma_2 C_t,$$

where $m, e, \sigma_1 \text{and} \sigma_2$ are constants. This model is an expansion of the model suggested by [7] in 1977. It is a sole factor short term IR model that represents the evolution of the IR r_t in the presence of aleatory and epistemic uncertainty. The model incorporates mean reversion to the dynamics of the IR process, the IR is presumed to be an uncertain random variable and the model has two sources of uncertainty, as in the previous sections. A zero-coupon bond is priced under this framework in the following section.

Pricing a zero-coupon bond using a mean reverting uncertain stochastic short rate model

Here, a zero-coupon bond pricing model is examined in the framework of a mean reverting US short rate model.

Theorem 3: Suppose the short rate is explained by an USDE

$$dr_t = (m - er_t)dt + \sigma_1 W_t + \sigma_2 C_t, \tag{12}$$

where $m, e, \sigma_1 \text{and} \sigma_2$ represent constants, the price of the zero-coupon bond associated with a maturity date T is given by

$$P(0,T) = \beta\sqrt{3}\left(\frac{\sigma_2 T}{e} - \frac{\sigma_2}{e^2} + \frac{\sigma_2}{e^2}\exp(-eT)\right) \times \exp\left(-\frac{mT}{2e} - \frac{1}{e}\left(r_0 - \frac{m}{e}\right)(1 - \exp(-eT))\right) \times$$

$$\times \csc\left(\sqrt{3}\left(\frac{\sigma_2 T}{e} - \frac{\sigma_2}{e^2} + \frac{\sigma_2}{e^2}\exp(-aT)\right)\right),$$

where

$$\beta = \exp\left(-\left[\int_0^T (\exp(-es)\, E(\int_0^T \exp(es)\, dW_s))ds\right]\right).$$

Proof: Equation 12 is the Vasicek model's extension. The process r_t includes mean reversion. Applying theorem 2 to solve equation 12, we have

$$a_{1t} = -e, a_{2t} = m, b_{1t} = 0,\ b_{2t} = \sigma_1, c_{1t} = 0,\ and\ \ c_{2t} = \sigma_2,$$

which means $U_t = \exp(-et)$. This indicates

$$r_t = U_t\left(r_0 + \int_0^t \frac{m}{U_s}ds + \int_0^t \frac{\sigma_1}{U_s}dW_s + \int_0^t \frac{\sigma_2}{U_s}dC_s\right) =$$

$$= \exp(-et)\left(r_0 + \int_0^t m\exp(es)ds + \int_0^t \sigma_1 \exp(es)dW_s + \int_0^t \sigma_2 \exp(es)dC_s\right).$$

Alternatively,

$$d(\exp(et)r_t) = \exp(et)r_t dt + \exp(et)(mdt - r_t dt + \sigma_1 dW_t + \sigma_2 dC_t) =$$

$$= \exp(-et)mdt + \exp(-et)\sigma_1 dW_t + \exp(-et)\sigma_2 dC_t.$$

That is

$$\exp(et)r_t = r_0 + m\int_0^t \exp(es)ds + \sigma_1\int_0^t \exp(es)dW_s + \sigma_2\int_0^t \exp(es)dC_s \cdot$$

This means

$$r_t = r_0 \exp(-et) + m\int_0^t \exp(es - et)ds + \sigma_1 \exp(-et)\int_0^t \exp(es)dW_s + \sigma_2 \exp(-et)\int_0^t \exp(es)dC_s =$$
$$= r_0 \exp(-et) + \frac{m}{e} - \frac{m}{e}\exp(-et) + \sigma_1 \exp(-et)\int_0^t \exp(es)dW_s + \sigma_2 \exp(-et)\int_0^t \exp(es)dC_s =$$
$$= \frac{m}{e} + \exp(-et)\left(r_0 - \frac{m}{e}\right) + \sigma_1 \exp(-et)\int_0^t \exp(es)dW_s + \sigma_2 \exp(-et)\int_0^t \exp(es)dC_s, \quad (13)$$

given that $e \neq 0$. The expected value of r_t in equation 13 above is desribed by

$$E[r_t] = \frac{m}{e} + \exp(-et)\left(r_o - \frac{m}{e}\right)$$

and the variance is described by

$$Var[r_t] = \frac{\sigma_1^2}{2}[1 - \exp(-2t)] + \frac{\sigma_2}{e} - \exp(-et)\frac{\sigma_2}{e}.$$

Applying the local equilibrium hypothesis, the following is deduced

$$P(0,T) = E\left[\exp\left(-\int_0^T r_s ds\right)\right] =$$
$$= \exp\left(-E\left[\int_0^T (\exp(-es)\int_0^T \exp(es)dW_s)ds\right] - E\left[\int_0^T (\frac{m}{e} + \exp(-es)\left(r_o - \frac{m}{e}\right) + \sigma_2 \exp(-es)\int_0^T \exp(es)dC_s)ds\right]\right).$$

That is,

$$P(0,T) = \exp\left(-E\left[\int_0^T (\exp(-es)\int_0^T \exp(es)dW_s)ds\right]\right) \times$$
$$\times \exp\left(-E\left[\int_0^T (\frac{m}{e} + \exp(-es)\left(r_o - \frac{m}{e}\right) + \sigma_2 \exp(-es)\int_0^T \exp(es)dC_s)ds\right]\right).$$

Which translates to

$$P(0,T) = \exp\left(-\left[\int_0^T (\exp(-es)E(\int_0^T \exp(es)\mathrm{d}W_s))\mathrm{d}s\right]\right) \times$$
$$\times \exp\left[\int_0^\infty \mathcal{M}[\int_0^T (\frac{m}{e} + \exp(-es)\left(r_o - \frac{m}{e}\right) + \sigma_2 \exp(-es)\int_0^T \exp(es)dC_s)ds \le -x]\right]dx.$$

Let
$\beta = \exp\left(-\left[\int_0^T (\exp(-es)E(\int_0^T \exp(es)dW_s))ds\right]\right)$.
Thus,

$$P(0,T) = \beta\sqrt{3}\left(\frac{\sigma_2 T}{e} - \frac{\sigma_2}{e^2} + \frac{\sigma_2}{e^2}\exp(-eT)\right) \times$$
$$\times \exp\left(-\frac{mT}{2e} - \frac{1}{e}\left(r_0 - \frac{m}{e}\right)(1 - \exp(-eT))\right) \times$$
$$\times \csc\left(\sqrt{3}\left(\frac{\sigma_2 T}{e} - \frac{\sigma_2}{e^2} + \frac{\sigma_2}{e^2}\exp(-eT)\right)\right). \quad (14)$$

This concludes the proof since equation 14 is similar to the price of the zero-coupon bond in theorem 3. Klebaner (2005) indicated that if

$$\int_0^T E\left(X^2(t)\right)\mathrm{d}t < \infty,$$

then we have the zero-mean property which states that

$$E\left(\int_0^T X(t)\mathrm{d}W_t\right) = 0.$$

Since

$$\int_0^T E\left(\exp(2es)\mathrm{d}s < \infty, \quad E\left(\int_0^T \exp(es)\mathrm{d}W_s\right) = 0\right.\text{.}$$

This means that by applying the zero-mean property, the zero-coupon bond price, instantaneous forward rate, and spot IR degenerate to the ones proposed by Chen (2016), that is

$$P(0,T) = \sqrt{3}\left(\frac{\sigma_2 T}{e} - \frac{\sigma_2}{e^2} + \frac{\sigma_2}{e^2}\exp(-eT)\right) \times \exp\left(-\frac{mT}{2e} - \frac{1}{e}\left(r_0 - \frac{m}{e}\right)\left(1-\exp(-eT)\right)\right) \times$$
$$\times \csc\left(\sqrt{3}\left(\frac{\sigma_2 T}{e} - \frac{\sigma_2}{e^2} + \frac{\sigma_2}{e^2}\exp(-eT)\right)\right),$$

$$S(0,T) = -\frac{\ln P(0,T)}{T} =$$

$$= -\frac{1}{T}\ln\sqrt{3}\left(\frac{\sigma_2 T}{e} - \frac{\sigma_2}{e^2} + \frac{\sigma_2}{e^2}\exp(-eT)\right) + \frac{1}{T}\left(\frac{mT}{2e} + \frac{1}{e}\left(r_0 - \frac{m}{e}\right)\left(1-\exp(-eT)\right)\right) -$$
$$-\frac{1}{T}\ln\left[\csc\left(\sqrt{3}\left(\frac{\sigma_2 T}{e} - \frac{\sigma_2}{e^2} + \frac{\sigma_2}{e^2}\exp(-eT)\right)\right)\right], \tag{15}$$

and

$$\mathrm{f}(0,T) = -\frac{\partial P(0,T)}{\partial T} / P(0,T) =$$

$$= -\left(\frac{\sigma_2}{e^2} + e\frac{\sigma_2}{e^2}\exp(-eT)\right) / \left(\frac{\sigma_2 T}{e} - \frac{\sigma_2}{e^2} + \frac{\sigma_2}{e^2}\exp(-eT)\right) =$$

$$+\left(\frac{m}{2e} - \left(r_0 - \frac{m}{e}\right)\exp(-eT)\right) + \left(\sqrt{3}\frac{\sigma_2}{e^2} - \frac{\sigma_2}{e}\exp(-eT)\right) \times$$
$$\times \csc\left(\sqrt{3}\left(\frac{\sigma_2 T}{e} - \frac{\sigma_2}{e^2} + \frac{\sigma_2}{e^2}\exp(-eT)\right)\right).$$

Remark: In the long run, the IR converges to $\frac{m}{a}$ from r_0.

Numerical example

This section presents some numerical examples of the alpha path and zero-coupon bond pricing.

Example 1

Let the initial interest rate be $r_0 = 0.08$, the instantaneous drift be $e = 0.1$, $\sigma_1 = 0.15$ and $\sigma_2 = 0.2$, $T = 10$ years and $m = 0.002$. The aim is to compute the α – path of equation 4 and equation 10 using the Euler-Maruyama method.

The α – path of equation 4 is given by

$$dr_t^{\alpha} = \left(e + \sigma_1\rho + \sigma_2\Phi_t^{-1}(\alpha)\right)dt$$

and the alpha path for its solution is

$$r_t^{\alpha} = r_0 + et + \sigma_1\rho + \sigma_2\left(\frac{\sqrt{3t}}{\pi}\ln\frac{\alpha}{1-\alpha}\right).$$

In this case, ρ represents the realisations of a standard Wiener process, α is a measure of belief and $\Phi_t^{-1}(\alpha)$ is the inverse uncertainty distribution given in definition 8 and the other parameters are as previously defined. The alpha path represents the evolution of interest rates under a specific belief degree α.

Alpha ranges from 0 to 1. These paths provide insights into the range of possible outcomes based on different levels of beliefs. In other words, α – path captures the system's behavior at this specific belief degree. These paths are real-valued functions of time t, but are not necessarily one of the sample paths [43]. Alpha paths are derived from the inverse uncertainty distribution, which provides the value of the uncertain variable for each belief degree level.

Figure 1 represents the α – path graphs for an uncertain stochastic interest rate model in equation 4. Notice how the graphs diverge from each other for different alpha values. Also, note that r_t^{α} is a linear function of time. The α – path of equation 10 is given by

$$dr_t^{\alpha} = \left(\left(m - er_t^{\alpha}\right) + \sigma_1\rho + \sigma_2\Phi_t^{-1}(\alpha)\right)dt$$

and the α – path for the solution is represented by

$$r_t^{\alpha} = r_0\exp(-et) + \left(1-\exp(-et)\right)\left(\frac{m}{e} + \frac{\sigma_1\rho}{e} + \frac{\sigma_2}{e}\left(\frac{t\sqrt{3}}{\pi}\ln\frac{\alpha}{1-\alpha}\right)\right).$$

Note that the α – path for the solution of the mean-reverting model is no longer a linear function as in the previous case. *Figure 2* displays the graphs for the α – path for equation 10.

The gradients of these graphs are reducing to zero as time progresses, indicating that they approach a minimum or a maximum value. In the next example, we price a typical zero-coupon bond using the proposed methods.

Example 2

Let $r_0 = 0.08$, the instantaneous drift $e = 0.1$, $\sigma_1 = 0.15$ and $\sigma_2 = 0.2$, $T = 4$ years and $m = 0.002$. The aim is to illustrate how the zero-coupon bond price evolves and the behavior of the instantaneous forward rate as time progresses.

After implementing the formulas in equations 7, 8, 14, and 15 into Python, the prices of the zero-coupon bond and the instantaneous forward rates over the years are obtained. The graph in *Fig. 3*, which is based on equation 7, shows the relationship between the zero-coupon bond price and the time to maturity under an uncertain stochastic short rate model. The zero-coupon bond price decreases as time to maturity increases, then it starts to increase again. The relationship is non-linear. The bond price is sensitive to changes in the short rate over time. Bond prices exhibit convexity, which can lead to non-monotonic behaviour. Also, the bond price decreases for shorter maturities due to the discounting effect and increases for long maturities due to mean reversion or declining rates.

The prices obtained from the model in *Fig. 3* are less than those on the model in *Fig. 4*. *Figure 4* shows the relationship between the zero-coupon bond price and the time to maturity under a mean reverting uncertain stochastic short rate model. It is based on equation 14.

Figure 4 produces a smoother curve than *Fig. 3*. Equation 14 is a variant of the Vasicek model with an additional Liu process. In contrast, equation 7 is an extension of Merton's model that considers the effects of the Liu process. The model in equation 14 captures the behaviour of rates to stabilise around a long term average while the model in equation 7 assumes that interest rates follow a random walk, and this model can end up producing unrealistic long term behavior, for instance, interest rates becoming extremely high or low without a limit. However, *Fig. 3 and 4* show that the prices from the two models do not differ with a greater magnitude.

Instantaneous forward rates in *Fig. 5 and 6* increase with time, then they start to decrease.

Figure 5 above shows that the instantaneous forward rates based on equation 8 are greater than those in *Fig. 6,* which is based on equation 15. Also note that the graphs based on the mean-reverting process are smoother than the ones based on Merton's model. The periods where the instantaneous forward rates are negative imply that zero-coupon bonds have negative returns. This can be caused by the central bank, which sets negative interest rates to stimulate growth in situations of deflation or stagnation.

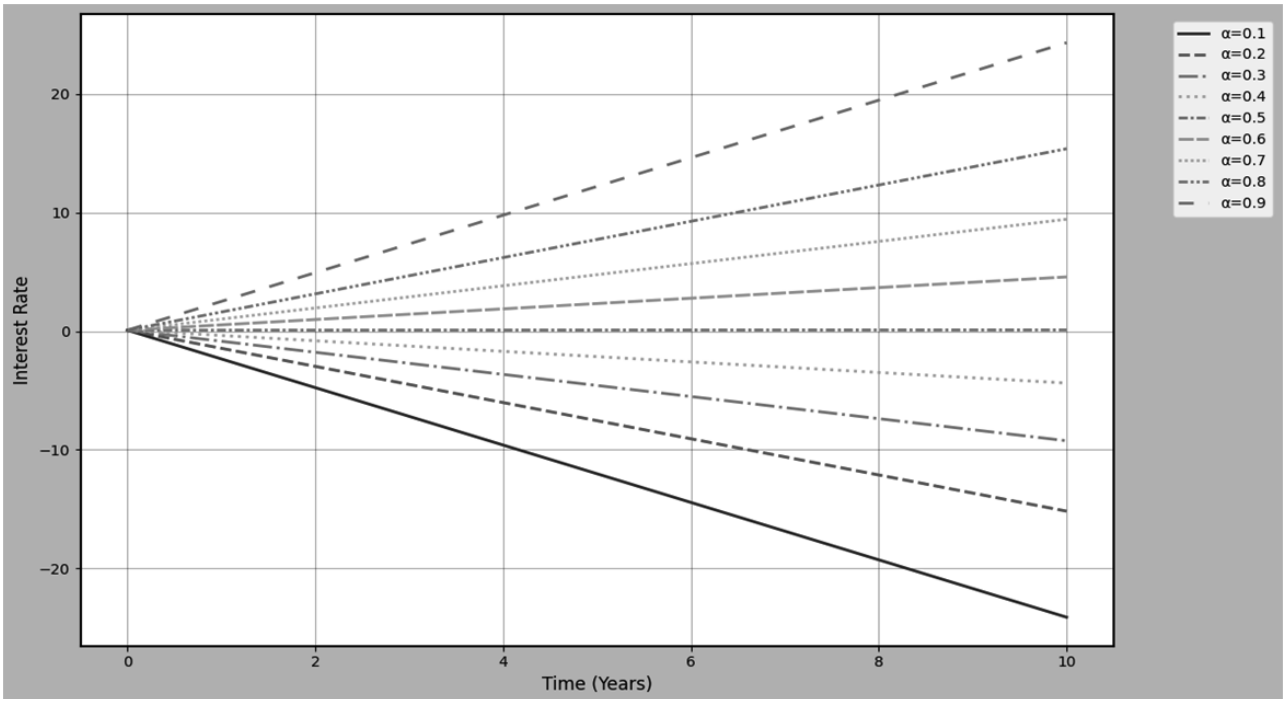

Fig. 1. **A Spectrum of** $\alpha-$ **path of** $dr_t = e_t dt + \sigma_1 dW_t + \sigma_2 dC_t$

Source: Developed by the authors.

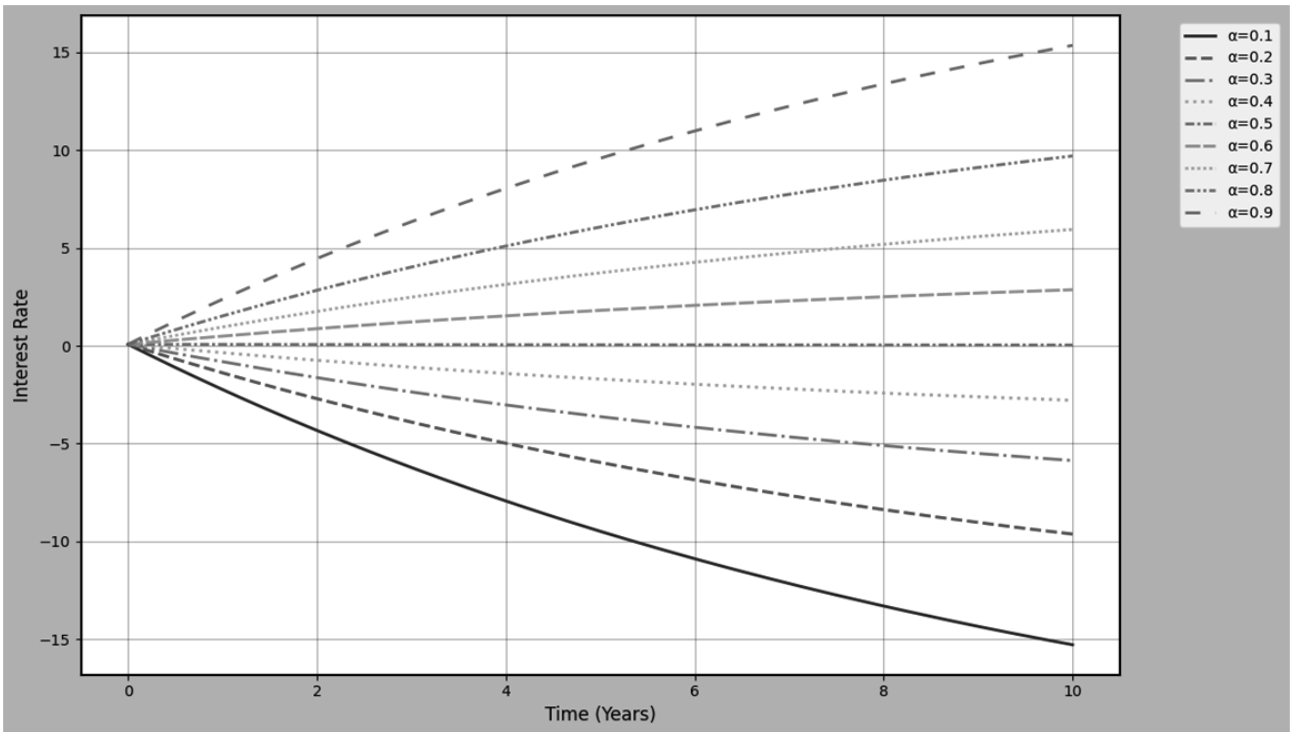

Fig. 2. **A Spectrum of** $\alpha-paths$ **of** $dr_t = \left(m - er_t\right)dt + \sigma_1 W_t + \sigma_2 C_t$

Source: Developed by the authors.

Also, this can be encountered in situations of financial stress. In addition, if markets foresee more negative interest rates, current forward rates may become negative. Apart from that, excess liquidity in the financial system can also contribute to negative instantaneous forward rates. In such situations, some investors can hold on to government bonds for their safety, while others may consider holding cash or other assets. Also, banks can struggle in making profits. These conditions are signals of weak economic growth or deflationary pressures.

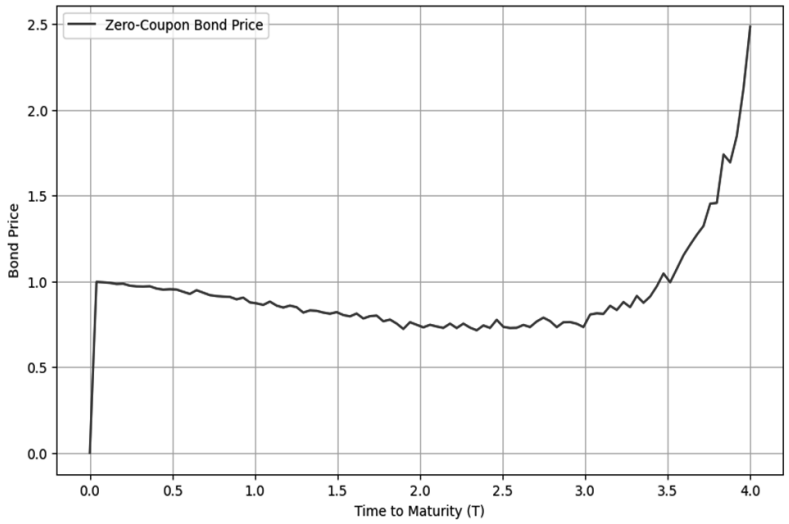

Fig. 3. **Price of zero-coupon bond against time to maturity for equation 7**

Source: Developed by the authors.

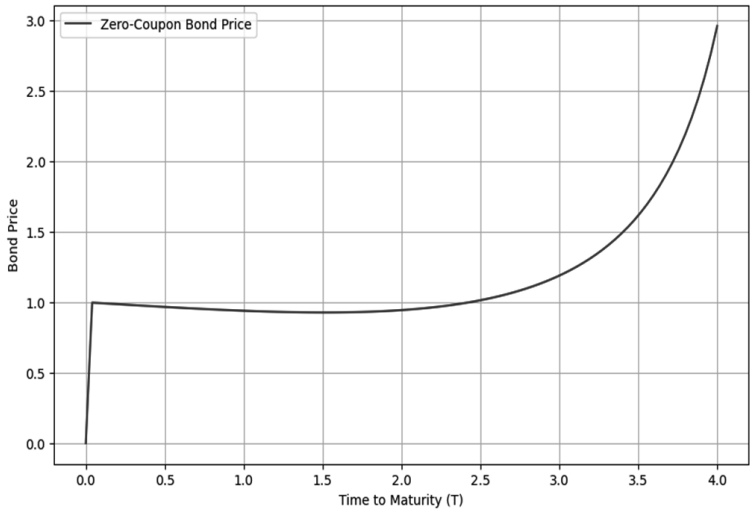

Fig. 4. **Price of zero-coupon bond against time to maturity for equation 14**

Source: Developed by the authors.

Conclusions

In this study, we suggested an interest rate model utilizing USDEs in the US financial markets. We also derived the model to compute the price of a zero-coupon bond for the interest rate model. To illustrate how to compute the price of the zero-coupon bond numerically, a practical example was presented. Modelling short-term interest rates and pricing zero-coupon bonds in the US environments represents a significant milestone in modelling financial markets under uncertainties. This approach is relevant in volatile or unpredictable market conditions. The US framework offers a flexible approach to pricing and risk management, allowing investors to combine epistemic uncertainty and exact probabilities into their models for zero-coupon bonds.

The proposed model can be applied to a wider range of emerging markets. The results obtained in this study can be extended beyond zero-coupon bond pricing to other IR derivatives. In addition, this approach can be integrated with machine learning to improve the prediction power. Also, this model can be applied in emerging markets, and policymakers and regulators can adopt this method in assessing the impact of interest rate shocks. However, the scope of this paper does not cover the use of real-world data. As part of our future work, an empirical validation will be carried out, and this will involve a rigorous comparative analysis of the developed model and established stochastic and uncertain models using real-world data in order to assess pricing accuracy and hedging effectiveness. In this process, we will estimate parameters and perform model calibration using real-world data.

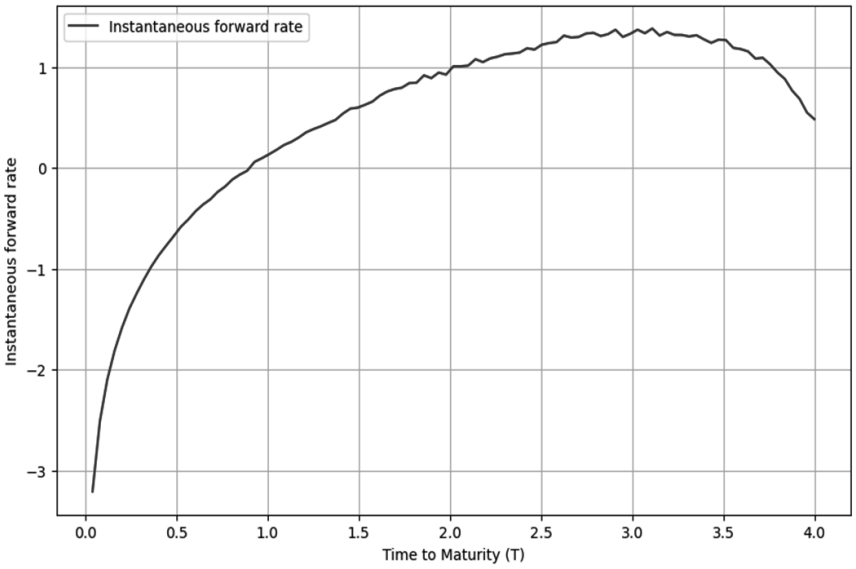

Fig. 5. **Instantaneous forward rate against time to maturity for equation 8**

Source: Developed by the authors.

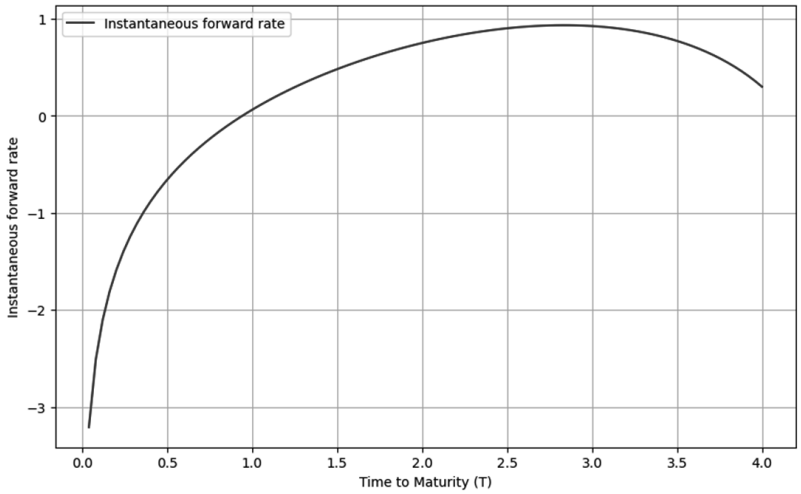

Fig. 6. **Instantaneous forward rate against time to maturity for equation 15**

Source: Developed by the authors.

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