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INSTITUTIONAL-ECONOMIC MODEL OF METAVERSE STANDARDIZATION

The article examines the institutional and economic foundations of the formation of standards for metaverse functioning in the context of its accelerated market growth. The theoretical provisions of the economics of standards, the theory of network effects, institutional economics and platform theory in relation to the development of digital ecosystems are analyzed. Key factors of technological fragmentation have been identified, including platform incompatibility and the formation of closed ecosystems that increase transaction costs.

Based on the analysis of market dynamics, the exponential trajectory of the global metaverse market development is determined and the formation of a new macro-level digital industry is demonstrated. The geo-economic constraints associated with the growing demand for rare earth elements and the high concentration of their extraction and processing are analyzed. The analysis demonstrates that resource dependence increases the institutional risks of scaling digital platforms in the absence of unified standards.

An institutional and economic model of metaverse standardization has been developed, which defines a cascading relationship between market momentum, technological fragmentation, geo-economic constraints, and the formation of standards. The necessity of developing a roadmap for the phased implementation of standards as a tool to reduce transaction costs, ensure interoperability and increase the sustainability of digital ecosystems is substantiated.

The results obtained can be used in shaping the policy of international standards coordination and developing strategies for the long-term development of digital platforms.

Keywords: metaverse, standardization, economics of standards, digital ecosystems, institutional regulation, platform economy, geo-economic risks, rare earth elements.

Кілт сөздер: метаверс, стандарттау, стандарттар экономикасы, цифрлық экожүйелер, институционалдық реттеу, платформалық экономика, геоэкономикалық тәуекелдер, сирек жер элементтері.

Ключевые слова: метавселенная, стандартизация, экономика стандартов, цифровые экосистемы, институциональное регулирование, платформенная экономика, геоэкономические риски, редкоземельные элементы.

Introduction. The rapid development of the metaverse is shaping a new phase of transformation in the digital economy, in which virtual environments, platform technologies, and immersive interfaces are integrated into production, financial, and social processes. The metaverse is gradually moving beyond the entertainment sphere and is positioned as an infrastructural basis for the formation of digital ecosystems that unite users, companies and governments. At the same time, the accelerated scaling of this technological environment is accompanied by increased fragmentation of platforms, the lack of unified protocols for interaction and the formation of closed ecosystems, which increases transaction costs and limits the interoperability of digital services.

The relevance of the research is determined by the need for an institutional understanding of the processes of standardization of the metaverse in the context of its accelerated growth and increasing competition between technological platforms. The scientific and analytical literature is dominated by market forecasts and applied research of individual industry scenarios, however, an insufficiently developed institutional and economic mechanism for the formation of standards capable of ensuring the long-term sustainability and compatibility of digital ecosystems remains.

The purpose of this study is to develop an institutional and economic model for the formation of standards for the functioning of the metaverse and substantiate the need for a phased implementation of the corresponding roadmap. To achieve this goal, the following tasks are being solved:

- analysis of the theoretical foundations of the economics of standards in digital ecosystems;
- assessment of market dynamics and structural factors of the metaverse development; identification of institutional and geo-economic constraints;
- formation of a conceptual standardization model and identification of key directions for its implementation.

The methodological basis of the research is the provisions of the theory of network effects, institutional economics and the theory of platforms. The study employs comparative analysis, institutional modeling, forecasting market dynamics based on open analytical sources, as well as the systematization of statistical data from international organizations and industry reports. The use of generally accepted methods of economic analysis and statistical information processing ensures the reproducibility of the results obtained and the correctness of the conclusions.

Literature review. Modern research on the metaverse is formed at the intersection of the digital economy, platform theory and analysis of new technological ecosystems. A significant part of the publications is devoted to assessing the market potential and forecasts of industry growth. In particular, analytical reports by Mordor Intelligence [1] and Bloomberg Intelligence [2] emphasize the transformational nature of the metaverse as the next global technology platform capable of integrating digital services, financial instruments, and immersive communication technologies. These sources form the quantitative basis for assessing the scale and pace of market expansion.

Methodological aspects of digital media research are being developed in works devoted to new tools for analyzing user behavior in VR/AR and metaverse contexts [3]. These studies demonstrate the increasing complexity of service models and the formation of new types of digital interaction. At the same time, a number of publications examine the possibilities and prospects for the development of the metaverse for the economy and society [4], including its impact on the structure of markets, the digital transformation of industries and the formation of new business models. Later, the research was supplemented by an analysis of the current state of technology development and their application scenarios in certain sectors, primarily in the financial industry [5], which highlights the institutional and technological limitations of scaling digital ecosystems.

In more recent works, the problems of the intersectoral application of the metaverse are expanded, value effects, regulatory challenges and risks of fragmentation of digital platforms are analyzed [6, 7]. At the same time, studies summarizing forecasts of market dynamics and offering conceptual models of the levels of functioning of the metaverse within the digital economy are presented [8]. These publications confirm the intersectoral nature of the development of the metaverse and emphasize the need for an integrated institutional approach to its standardization and regulation.

Despite the considerable volume of publications, a certain methodological gap remains in the literature. Most of the research focuses either on market forecasts, or on the applied aspects of technology implementation, or on the analysis of their socio-economic potential. The institutional and economic mechanism for the formation of standards for the functioning of the metaverse as a tool for overcoming technological fragmentation and reducing transaction costs has not been sufficiently developed. There is no holistic model integrating market dynamics, platform competition, and the need for international coordination of standards.

These contradictions and unresolved issues substantiate the relevance of this study aimed at developing an institutional and economic model for standardization of the metaverse and forming a roadmap for its sustainable development in the context of accelerated scaling of digital ecosystems.

The main part. The formation of standards for the functioning of the metaverse cannot be considered outside the context of its exponential market dynamics. In recent years, the market has demonstrated one of the highest growth trajectories among digital industries, reflecting the structural transition of the global economy to immersive digital ecosystems. The scaling of virtual and augmented reality, the development of cloud infrastructure, and the expansion of software and services segments are creating a steady investment momentum that contributes to the institutionalization of the new digital industry.

The dynamics and forecast of the global metaverse market are presented in Table 1.

Table – 1

Dynamics and forecast of the global metaverse market (2021-2040), USD million*

Year	Market volume, million USD	Data type
2021	53,610.2	Actual
2023	82,020.6	Actual
2024	105,396.5	Actual
2030	936,574.7	Forecast (CAGR 43.9%)
2040	35,660 000	Projection (author's extrapolation)

*compiled by the authors based on the source [9]; the year 2040 is calculated by the authors based on maintaining the average annual growth rate at 43.9%.

The analysis of the data presented in Table 1 indicates a sharp acceleration of market expansion. If in 2021 the market volume was 53,610.2 million US dollars, by 2024 it had almost doubled, reaching 105,396.5 million US dollars. The forecast for 2030 (US\$ 936,574.7 million) is based on an average annual growth rate of 43.9%, reflecting the exponential phase of the industry's development.

Scenario extrapolation, while maintaining the current dynamics, demonstrates a potential volume of about 35.66 trillion US dollars by 2040. Even taking into account the possible adjustment of growth rates, the data point to the formation of a new macro-industry on a global scale. In the context of such dynamics, network effects intensify, market concentration rises, and barriers to entry increase.

The economic importance of the metaverse goes beyond the digital entertainment sector, transforming into an infrastructural element of the digital economy. Consequently, the lack of unified standards in the context of rapid scaling can lead to the consolidation of fragmented platform structures and the formation of an oligopolistic market architecture. However, the growth of digital infrastructure is accompanied by increased material dependence on critical resources, primarily rare earths, necessary for the production of VR/AR devices, semiconductor components and sensor systems. In this regard, the analysis of the resource base is of key importance for understanding the sustainability of the metaverse as a global technological ecosystem. Data on the forecast demand for rare earths are presented in Table 2.

Table – 2

Forecast of demand for rare earth elements (APS), thousand tons

Indicator	2021	2023	2030	2040
Demand for clean technologies	11	16	46	64
Other uses	67	76	87	105
Total demand	78	93	134	169
Secondary supplies and reuse	22	25	36	48
Primary supply requirements	57	67	98	121
The share of the three largest countries in production, %	81%	85%	81%	81%
The share of the three largest countries in processing, %	98%	98%	92%	93%

*compiled from the source [10]

The data presented in Table 2 reflect the forecast of global demand for rare earths under the Announced Pledges Scenario (APS) developed by the International Energy Agency. This scenario models the dynamics of demand, provided that countries implement their announced energy and climate commitments, which makes it relevant for analyzing long-term technological transformation.

According to the data presented, the total demand for rare earths is increasing from 78 thousand tons in 2021 to 169 thousand tons by 2040, which means a more than twofold increase over two decades. The most significant dynamics is observed in the clean technology segment: the growth from 11 thousand tons in 2021 to 64 thousand tons in 2040 indicates a structural reorientation of the global economy towards digital and low-carbon solutions.

Special attention should be paid to the indicator of primary supply requirements, which increases from 57 thousand tons to 121 thousand tons. Despite the growth of secondary supplies and reuse, dependence on the extraction of primary raw materials remains. This indicates the limited possibilities of fully compensating for the growing demand due to the circular economy.

A key institutional factor is the high concentration of extraction and processing of rare earths. The share of the three largest countries in production is 81-85%, and in processing it reaches 98%. This global

supply structure creates a systemic vulnerability of technological industries, including the metaverse, to external shocks, trade restrictions, and geopolitical risks. In the context of the development of the metaverse, this dependence acquires strategic importance.

The hardware infrastructure of the metaverse — VR/AR headsets, sensor systems, chips, tactile devices - directly depends on the supply of rare earth elements and high—tech components. Consequently, the exponential growth of the digital market (Table 1) is accompanied by a proportional increase in commodity dependence.

From an institutional and economic point of view, this means the following:

- The growing scale of the metaverse increases the burden on concentrated supply chains.
- The concentration of production increases transaction-related and strategic risks.
- The lack of uniform technical standards exacerbates fragmentation, as different platforms use incompatible hardware solutions.

Fragmentation increases production costs, reduces scalability, and limits the competitive environment. Thus, the problem of standardization goes beyond software compatibility and becomes an element of geo-economic sustainability of digital infrastructure.

With the simultaneous growth of the metaverse market and increasing demand for critical resources, an institutional challenge is emerging: a coordination mechanism is needed that can reduce technological fragmentation, reduce hardware redundancy, and ensure the interoperability of digital ecosystems. This logic is systematically reflected in Figure 1.

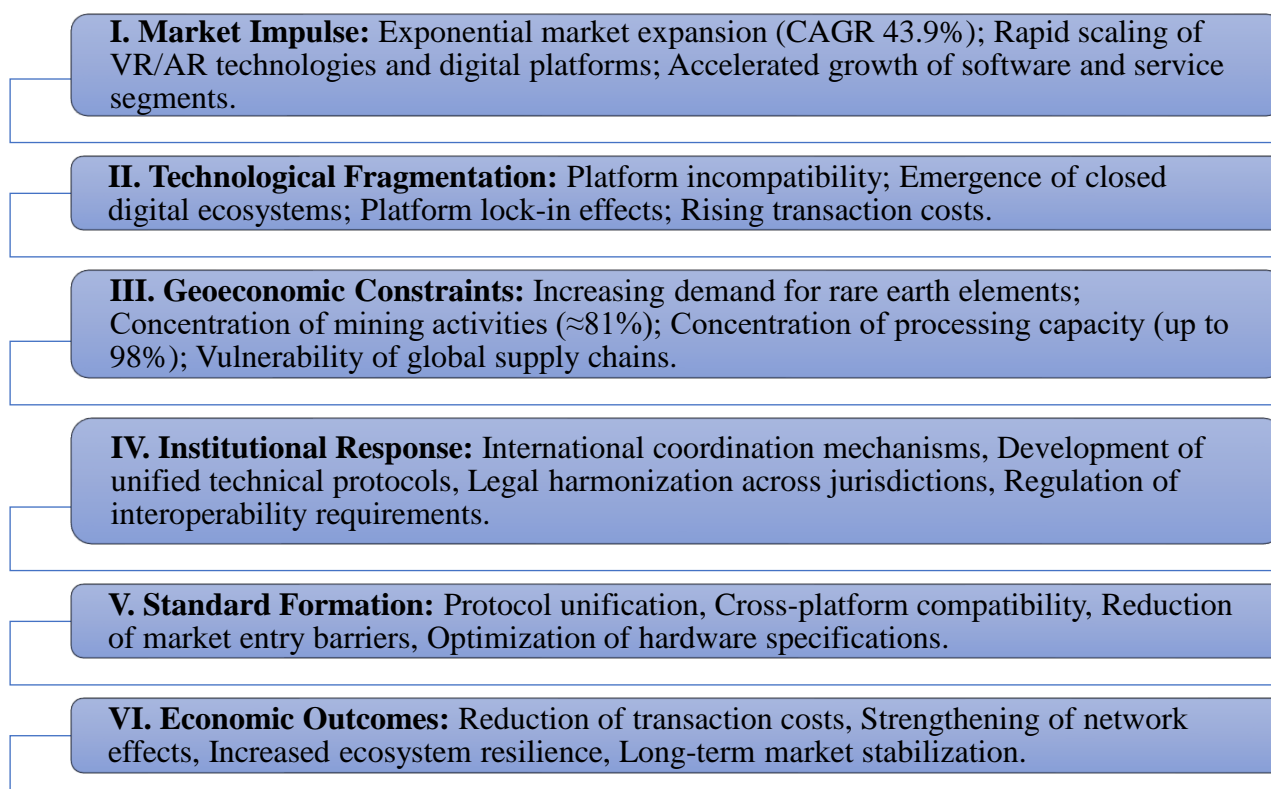


Figure – 1. **Institutional-Economic Model of Metaverse Standardization***

** Developed by the authors.*

The model shown in Figure 1 demonstrates the cascading relationship between market momentum, technological fragmentation, geo-economic constraints, and institutional response. The exponential growth of the market initiates the scaling of digital platforms, which leads to the formation of closed ecosystems and platform lock-in effects. At the same time, dependence on concentrated commodity supply chains is increasing. An institutional response in the form of international coordination, the development of technical protocols and the harmonization of legal norms is becoming a prerequisite for the formation of sustainable standards.

It is standardization that allows:

- to unify the protocols of interaction,

- ensure platform compatibility,
- reduce transaction costs,
- reduce barriers to market entry,
- optimize hardware requirements.

The economic effect of standardization is manifested in strengthening network effects, enhancing the stability of digital ecosystems and long-term market stabilization. Thus, Figure 1 integrates the quantitative results of Tables 1 and 2 into a single institutional and economic framework, demonstrating the need to develop a roadmap for standards for the functioning of the metaverse.

Conclusion. Within the framework of the conducted research, the necessity of forming an institutionally agreed system of standards for the functioning of the metaverse in the context of its exponential market growth is substantiated. Based on a quantitative analysis of the dynamics of the global metaverse market, the emergence of a new macro-level industry of tens of trillions of US dollars in the long term has been revealed. It has been established that the accelerated scaling of digital platforms is accompanied by increased network effects, increased market concentration, and the consolidation of closed ecosystems.

The analysis of the resource base showed the structural dependence of the development of the metaverse on the supply of rare earth elements and a high concentration of extraction and processing of critically important materials. It has been revealed that the lack of uniform technical and institutional standards in the context of commodity concentration increases transaction costs, increases strategic risks and limits the scalability of the digital ecosystem.

The scientific novelty of the research lies in the integration of network effects theory, institutional economics, and standards economics with a geo-economic analysis of the resource dependence of digital platforms. The developed Institutional-Economic Model of Metaverse Standardization makes it possible to systematically link market momentum, technological fragmentation, geo-economic constraints and institutional response into a single cascading structure of standards formation.

The practical significance of the results lies in the possibility of using the proposed model in the development of international technical protocols, the formation of an interoperability policy for digital platforms, as well as in the preparation of national strategies for digital sovereignty and regulation of critical supply chains. The results can be applied by government authorities, international standardization organizations, as well as corporate market participants in shaping strategies for the long-term development of the metaverse.

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МЕТАВЕРСТІ СТАНДАРТТАУДЫҢ ИНСТИТУЦИОНАЛДЫҚ-ЭКОНОМИКАЛЫҚ МОДЕЛІ

Андатпа

Мақалада метаверстің жеделдетілген нарықтық өсу жағдайында оның жұмыс істеу стандарттарын қалыптастырудың институционалдық-экономикалық негіздері қарастырылған. Сандық экожүйелердің дамуына қатысты стандарттар экономикасының, желілік эффекттер теориясының, институционалдық экономиканың және платформалық теорияның теориялық ережелері талданады. Технологиялық фрагментацияның негізгі факторлары анықталды, соның ішінде платформалардың үйлесімсіздігі және транзакциялық шығындарды арттыратын жабық экожүйелердің қалыптасуы.

Нарықтық динамиканы талдау негізінде метаверстің жаһандық нарығын дамытудың экспоненциалды траекториясы анықталды және цифрлық экономиканың жаңа макроиндустриясының қалыптасуы көрсетілді. Сирек жер элементтеріне сұраныстың өсуіне және оларды өндіру мен өндеудің жоғары концентрациясына байланысты геэкономикалық шектеулер талданды. Ресурстарға тәуелділік бірыңғай стандарттар болмаған жағдайда цифрлық платформаларды масштабтаудың институционалдық тәуекелдерін күшейтетіні анықталды.

Метаверсті стандарттаудың институционалдық-экономикалық моделі жасалды, онда нарықтық импульс, технологиялық фрагментация, геэкономикалық шектеулер мен стандарттардың қалыптасуы арасындағы каскадтық байланыс анықталды. Транзакциялық шығындарды азайту, интероперабельділікті қамтамасыз ету және цифрлық экожүйелердің тұрақтылығын арттыру құралы ретінде стандарттарды кезең-кезеңімен енгізудің жол картасын әзірлеу қажеттілігі негізделген.

Алынған нәтижелер стандарттарды халықаралық үйлестіру саясатын қалыптастыруда және цифрлық платформаларды ұзақ мерзімді дамыту стратегияларын әзірлеуде пайдаланылуы мүмкін.

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ИНСТИТУЦИОНАЛЬНО-ЭКОНОМИЧЕСКАЯ МОДЕЛЬ СТАНДАРТИЗАЦИИ МЕТАВСЕЛЕННОЙ

Аннотация

В статье рассмотрены институционально-экономические основы формирования стандартов функционирования метавселенной в условиях её ускоренного рыночного роста. Проанализированы теоретические положения экономики стандартов, теории сетевых эффектов, институциональной экономики и платформенной теории применительно к развитию цифровых экосистем. Выявлены ключевые факторы технологической фрагментации, включая несовместимость платформ и формирование закрытых экосистем, повышающих транзакционные издержки.

На основе анализа рыночной динамики определена экспоненциальная траектория развития глобального рынка метавселенной и показано формирование новой макроиндустрии цифровой экономики. Проанализированы геэкономические ограничения, связанные с ростом спроса на редкоземельные элементы и высокой концентрацией их добычи и переработки. Выявлено, что ресурсная зависимость усиливает институциональные риски масштабирования цифровых платформ в условиях отсутствия унифицированных стандартов.

Разработана институционально-экономическая модель стандартизации метавселенной, в которой определена каскадная взаимосвязь между рыночным импульсом, технологической фрагментацией, геэкономическими ограничениями и формированием стандартов. Обоснована необходимость разработки дорожной карты поэтапного внедрения стандартов как инструмента снижения транзакционных издержек, обеспечения интероперабельности и повышения устойчивости цифровых экосистем.

Полученные результаты могут быть использованы при формировании политики международной координации стандартов и разработке стратегий долгосрочного развития цифровых платформ.

