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СТАНОВЛЕННЯ ГЛОБАЛЬНОЇ ЦИФРОВОЇ ЕКОСИСТЕМИ: КОЦЕПТУАЛІЗАЦІЯ, ВИКЛИКИ ТА ПЕРСПЕКТИВИ

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Анотація. Стрімкий розвиток інформаційно-комунікаційних технологій та масштабний перехід економічних процесів у віртуальну площину зумовили трансформацію традиційних економічних систем. Поява глобальної цифрової екосистеми (ГЦЕ) знаменує собою перехід до нової архітектури світового господарства, що потребує глибокого теоретичного осмислення та концептуалізації. Мету статті становить дослідження теоретико-методологічних засад становлення та особливостей функціонування глобальної цифрової екосистеми як новітньої форми організації та структурування сучасного світового простору. У роботі використано комплекс наукових методів: системний та структурно-функціональний аналіз — для дослідження архітектури ГЦЕ; методи узагальнення та наукової абстракції — для вивчення еволюції понятійно-категоріального апарату; компаративний та критичний аналіз — для оцінювання викликів, загроз та альтернативних моделей розвитку цифрового середовища.. Проаналізовано генезис терміна «екосистема» від його біологічних витоків до сучасних алгоритмічних моделей. Визначено ключові концептуальні засади розвитку ГЦЕ, серед яких виокремлено платформізацію, мережеві ефекти та дата-центричність. Особливу увагу приділено специфіці взаємодії основних акторів системи — потужних високотехнологічних корпорацій, держав та автономних систем штучного інтелекту. Ідентифіковано та структуровано ключові системні виклики функціонування ГЦЕ, зокрема, цифрову неоколонізацію, тотальну ерозію приватності користувачів, алгоритмічний нагляд та кіберзагрози нового типу. Запропоновано потенційні напрями трансформації ГЦЕ крізь призму парадигмального переходу до децентралізованих інфраструктур Web 3.0 та інтелектуально-симбіотичних архітектур Web 4.0. Доведено, що розгортання архітектур нового покоління дозволить системно нейтралізувати структурні ризики ГЦЕ, обмежуючи монопольний вплив транснаціонального капіталу та руйнуючи механізми тотального алгоритмічного стеження. Обґрунтовано, що ГЦЕ виступає фундаментальною формою організації світового

геоекономічного простору, яка вимагає нових підходів до регулювання взаємовідносин між державами, транснаціональним капіталом та штучним інтелектом.

Ключові слова: глобальна цифрова екосистема; високотехнологічні суб'єкти; штучний інтелект; цифровий суверенітет; глобалізація; цифровізація; платформа; еволюція.

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THE EMERGENCE OF THE GLOBAL DIGITAL ECOSYSTEM: CONCEPTUALIZATION, CHALLENGES, AND PROSPECTS

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Abstract. The rapid development of information and communication technologies and the large-scale transition of economic processes into the virtual plane have led to the transformation of traditional economic systems. The emergence of the global digital ecosystem (GDE) marks a transition to a new architecture of the world economy, which requires deep theoretical understanding and conceptualization. The article aims to study the theoretical and methodological foundations of the formation and features of the global digital ecosystem functioning as a newest form of organization and structuring of the modern world space.

The paper uses a complex of scientific methods: system and structural-functional analysis – to study the GDE architecture; methods of generalization and scientific abstraction – to study the evolution of the conceptual and categorical apparatus; comparative and critical analysis – to assess challenges, threats, and alternative models of digital environment development. The genesis of the term "ecosystem" from its biological origins to modern algorithmic models is analyzed. The key conceptual foundations of GDE development are identified, including platformization, network effects, and data-centricity. Special attention is paid to the specific, multifaceted interaction and strategic co-competition within the primary triad of the system's actors: powerful high-tech corporations (Big Tech), sovereign states, and autonomous artificial intelligence systems.

The key systemic challenges of GDE functioning are identified and structuralized, in particular, digital neocolonization, the total erosion of user privacy, algorithmic surveillance, and cyber threats of a new type. Potential directions of GDE transformation are proposed through the lens of a paradigm transition toward decentralized Web 3.0 frameworks and intelligent-symbiotic Web 4.0 architectures. The paper conceptually resolves the terminological ambiguity between evolutionary stages by arguing that decentralized protocols, distributed ledgers, and self-sovereign identity form the indispensable infrastructure baseline upon which the intelligent, machine-to-machine, and symbiotic services of Web 4.0 deploy. It is proved that this paradigm transition can significantly weaken, decentralize, and neutralize the identified asymmetric risks associated with corporate monopolization and surveillance capitalism within the GDE. It is substantiated that the GDE serves as a fundamental form of organizing the global geo-economic space, which urgently requires entirely new approaches to

regulating relations, sovereign boundaries, and strategic interactions between states, transnational corporate capital, and autonomous artificial intelligence.

Keywords: global digital ecosystem; high-tech actors; artificial intelligence; digital sovereignty; globalization; digitalization; platform; evolution.

Introduction. The current stage of development of the global economy is characterized by widespread digitalization, which is transforming not only individual sectors or national economies, but also the architecture of international relations as a whole. Today, digital transformation has become a key element of the strategic agenda for most countries around the world, shaping their global competitiveness and national security. Traditional geo-economic models of interaction, based on physical borders and the classical international division of labor, are giving way to networked structures. Against this backdrop, the global digital ecosystem (GDE) is becoming the key form of organization for the global space. It unites information flows, technological platforms, artificial intelligence, and human capital into a single dynamic organism. Thus, in the context of the current conditions of global civilization's development, the need to understand the nature of the global digital ecosystem, which serves as the core of evolution and a driving force behind global transformational processes - is becoming more relevant and strategically important than ever before.

Task statement. The establishment of a global digital ecosystem is accompanied by profound systemic contradictions, ranging from the intensifying struggle for digital sovereignty to the emergence of novel patterns of technological dependence. In an environment characterized by the asymmetric distribution of cutting-edge innovations and big data assets among a few oligopolistic corporations, the paradigm of equitable digitalization assumes critical significance. Equitable digitalization necessitates bridging regional digital divides, guaranteeing egalitarian rights for all global market participants, ensuring the ethical deployment of artificial intelligence, and safeguarding the sovereign interests of technologically vulnerable nations against manifestations of digital dictatorship. Consequently, there is an imperative need to conceptualize the Global Digital Ecosystem, critically analyze its structural challenges through the lens of inclusivity, and delineate the trajectories for its future transformation.

Although the "digital ecosystem" has been explored globally for several decades, it remains a dynamic and evolving category in modern economics and management. To substantiate the autonomous nature of digital networks, early academic discourse relied on A. Tansley's ecological principles [1]. This foundation was later adapted to strategic management; notably, J. Moore leveraged the ecosystem concept to rethink the paradigm of co-opetition, explaining how rival firms concurrently compete for market share and cooperate within a shared network to generate collective value [2]**.** Expanding this framework, A. Gawer and M. Cusumano demonstrated how such ecosystem dynamics shape corporate platform architectures and multi-sided market strategies [3]. In turn, C. Fiorina highlighted the systemic behavior of IT networks, delineating how digital technologies reshape the macro-economic environment for market participants, regulatory institutions, and the global economic architecture as a whole [4].

The scale and global reach of the modern digital ecosystem are verified by the latest macroeconomic data. According to recent *DataReportal* reports, the number of internet users worldwide has surpassed 6 billion people (over 73% of the global population), with more than 1 billion individuals actively interacting with artificial intelligence services on a monthly basis. This indicates that the digital ecosystem has transformed from a mere applied infrastructure into the primary environment for socio-economic transactions.

Based on this, the following research hypothesis is proposed: the digital ecosystem serves as a fundamental structural element and the primary driving force of the current stage of global development, and its functioning is shaped by the dynamic, multifaceted, and paradoxical

interaction of three fundamental actors: high-tech entities (Big Tech), sovereign states, and autonomous artificial intelligence systems. This triad is shaping a new configuration of power on the global stage, where traditional hierarchies are being replaced by complex networked relationships of co-competition.

The validation of this hypothesis and this new model of interaction is conducted based on three distinct empirical criteria:

1. the intensity of linear economic processes transforming into platform-based architectures driven by Big Tech;
2. the dominance of network effects in value creation and the institutional influence of the actor triad;
3. the level of capitalization and integration of digital infrastructures and AI systems into state governance structures and critical market sectors.

Results. The world is undergoing a fundamental civilizational transformation. The transition from an industrial society to an information society has culminated in the formation of a new superstructure – the global digital ecosystem (GDE), which is not merely a technological phenomenon but a new form of organization for the global economy, social ties, and public administration. The conceptualization of the GDE has not been linear; in its development, it has gone through several stages of interdisciplinary transfer – from the natural sciences to cybernetics and modern economic theory. In our view, to gain a deep understanding of the nature of the global digital ecosystem, it is necessary to trace this path of interdisciplinary transfer across distinct periods.

1Biological Determinism (1930–1980). The origin of the category under study is directly linked to biological science, and the foundation for this stage was laid as early as 1935 by the British botanist, ecologist, and one of the founders of ecology, Arthur Tansley. In his seminal work, he first conceptualized the term “ecosystem” as a counterpoint to the isolated study of individual organisms. According to Tansley, living organisms and their physical environments constitute an indivisible unity [1]. This ecological thesis later provided the conceptual framework for designing complex digital architectures, where holistic viability depends on the uninterrupted circulation of resources and energy across all nodes, superseding the individual success of isolated components.". According to A. Tansley’s views, ecosystems were concrete physical entities – ecological “systems as understood by physicists”—that included both organic and inorganic factors. They are entirely comparable to other physical systems, yet they exhibit a unique tendency to stabilize around one another, a phenomenon the scientist defined as a state of “dynamic equilibrium” (homeostasis). In seeking to justify the capacity of modern complex network structures for self-regulation and autonomous development, entrepreneurs, policymakers, and technical experts relied primarily on these very natural principles. A. Tensley’s concept laid a solid theoretical foundation for the gradual blurring of the distinctions between biophysical, social, and technological changes through the universal “language of systems.”

2. Business Ecology and Strategic Co-competition: In the early 1990s, amid the intensification of globalization and the growing complexity of market relationships, there was a large-scale transfer of ecological metaphors into economic theory. A key milestone of this period was Michael Rothschild’s assertion that the best way to understand a capitalist economy is to view it as an ecosystem [6]. Rothschild drew a fundamental parallel: just as genetic information encoded in DNA molecules forms the basis of life in a biological environment, technological information serves as the ultimate source of life in an economic environment. Later, in 1993, James Moore refined and elaborated on the idea of the business ecosystem, sparking a true revolution in management. He emphasized that the ecosystem approach requires managers to adopt a fundamentally new perspective on the nature and challenges of management, since, in the context of the nascent digital economy at that time;

classical competition within a single industry was becoming “lifeless.” Since then, companies have come to be viewed as parts of a cohesive “business ecosystem,” where a leading company brings together independent participants (suppliers, developers, service partners) to jointly create consumer value, foster mutual development, and facilitate learning. Over time, this makes the ecosystem increasingly cohesive and competitive. It was at this same stage that the concept of co-opetition emerged, pioneered by A. Brandenburger and B. Nalebuff [7]. The researchers demonstrated that maximum economic value is generated when entities compete in some areas but simultaneously maintain strong cooperative ties in others. They substantiated the need for a strategic combination of rivalry and cooperation to support new products, meet complex consumer demands, and drive subsequent waves of innovation. A striking historical example of such strategic synergy is the business success of Intel, which would have been impossible without the parallel success of – and technological compatibility with – Microsoft’s operating systems.

3. The Technological-Platform and Institutional Phase (late 1990s–2010s): The Emergence of Digital Architectures: At the turn of the millennium, with the commercialization of the Internet, cloud technologies, and the concept of the “new economy,” the ecosystem approach took on a distinctly technical character. A key milestone in 2000 was the approach taken by Carly Fiorina, who presented the “digital ecosystem” as an environment that generates autonomous behavioral patterns in IT networks and transforms the activities of individuals, businesses, regulatory institutions, and the global economic system as a whole. During this period, researchers, notably A. Gawer and M. Cusumano, described in detail the phenomenon of “Platform Leadership” and strategies for conducting business online [3]. The ecosystem transformed from a simple network of partners into a complex, multi-level infrastructure, with a digital platform (such as Apple iOS, Google Android, or Amazon Web Services) at its core. At this juncture, structural and spatial connections are definitively displaced by Application Programming Interfaces (APIs), executable code, and foundational algorithms designed for big data acquisition.

4. Global Algorithmic Integration (from 2016 to the present) The current stage of development is characterized by ecosystems extending beyond the boundaries of a single specific brand or isolated industry. They are becoming pervasive, which entails a deep integration of the physical, biological, and digital worlds. The defining feature of this period is that large datasets flow freely between spheres of social life that were previously completely unrelated. This phenomenon is conclusively demonstrated by a scenario wherein a user's biometric parameters, transmitted in real time via a personal fitness tracker, are ingested by an insurance company’s algorithms to automatically recalibrate either the individual’s credit limit or health insurance premium. Actual control over processes within these systems has definitively shifted from humans to automated artificial intelligence systems. At its core, the modern digital ecosystem has evolved into a highly integrated algorithmic space where autonomous AI systems independently streamline global supply chains, consumption volumes, capital flows, and institutional interactions. Consequently, the Global Digital Ecosystem (GDE) crystallizes as an instrumental concept, serving as a pivotal strategic vehicle for the structural transformation of the international economic system. This dynamics fundamentally alters the global competitive landscape and mutates the operational identity of all economic agents.

To date, the global scientific community has not yet arrived at a single, established definition of the concept under study. The scientific understanding of the phenomenon of the global digital ecosystem has come a long way: from a purely business-oriented interpretation to complex sociotechnical, politico-economic, and civilizational models. An analysis of key scholarly approaches allows us to identify the multilevel nature of the GDE through the lens of the following fundamental research paradigms: 1. The Strategic-Managerial Approach

(James Moore, Michael Jacobides) Researchers in this field examine the GDE through the lens of organizational management, coordination, and the creation of shared value by market actors. The founder of the concept, J. Moore, views the ecosystem as a dynamic business community whose functioning is based on close interaction between organizations and individuals. In his view, cooperation is the key element of the system: ecosystem actors do not simply compete in the classical sense, but rather "co-evolve," where the success of each individual player directly depends on the viability and stability of the entire network of connections [2]. In turn, M. Jacobides et al. significantly supplement and expand this concept by focusing on the internal structure and architecture of these connections [8]. The researches argue that an ecosystem is a specific mode of coordination among independent actors who are not linked by direct hierarchical relationships (as is typical of traditional vertically integrated corporate structures), but who are nonetheless tightly interconnected technologically, financially, and operationally. In this context, particular attention is focused on the phenomenon of coordination without traditional administrative control, where the rules of engagement are determined by the digital core (the platform), while the actors retain legal autonomy while remaining economically dependent. 2. The Platform-Centric Approach (Annabelle Gover, Michael Kusumano) For A. Gover and her colleagues, an ecosystem is first and foremost a complex technological entity [3]. The researcher defines its internal nature through the lens of a specific "core–periphery" architecture. According to this approach, a digital ecosystem can only fully form when an open digital platform emerges on the market, whose architectural features allow third-party external developers to freely create and integrate their own complementary products and services on its technological foundation. Within this paradigm, the ecosystem serves as a powerful tool for stimulating global innovation through the use of open standards and application programming interfaces (APIs). As it gradually scales up, it transforms from a traditional commercial product or standalone service into a global, multi-user infrastructure. The key conclusion of proponents of this approach is that without the systematic involvement of a broad range of "external innovators," any digital system remains a mere isolated service and fails to acquire the characteristics and scale of a true ecosystem. 3. The Tech-Humanities Approach (Nick Srnicek, Shona Zuboff) Proponents of this approach take a distinctly critical view of the phenomenon of the GCE, thoroughly analyzing its transformative – and often destructive – impact on global society, institutions of power, and human rights. In his seminal work "Platform Capitalism", N. Srnichek emphasizes precisely the capitalist nature of the phenomenon. For him, the ecosystem is a new infrastructure created for the total monopolization of markets and the aggressive extraction of information, while digital platforms themselves act as specific "electronic intermediaries" that appropriate vast amounts of big data [9]. At the same time, Sh. Zuboff examines the GCE through the lens of the concept of "surveillance capitalism." In her interpretation, an ecosystem is not merely a global network but a totalitarian digital architecture geared toward extracting users' "behavioral surplus" for the purpose of accurate prediction, algorithmic modeling, and manipulation of human actions and choices [10]. 4. The Civilizational-Network Approach (Manuel Castells, Klaus Schwab). Within this paradigm, the GCE is understood as the global space of the latest era in human development. Manuel Castells, the author of the "network society" theory, defines the GCE as a fundamental "space of flows." For him, the ecosystem is a global, cross-border matrix of flows of information, technology, and capital, where real power and geo-economic influence belong to those actors who control the network's key infrastructure nodes, which are gradually supplanting and replacing traditional state institutions [11]. Klaus Schwab, in turn, views the GCE as the indispensable technological foundation of the Fourth Industrial Revolution. He defines it as a global system of "cyber-physical convergence," in which not only production processes but

also human biological life itself, human identity, and social interaction become an integral part of a single global digital circuit and a continuous cycle of economic value creation [12].

Based on a critical reexamination of the paradigms discussed – from strategic management to theories of civilization—we propose our own comprehensive vision of this category. In the context of the architectonics of the modern global economy, the global digital ecosystem (GDE) is a complex, self-organizing, cross-border networked architecture for organizing global space, based on algorithmic data integration and functioning as a space of total information and capital flows. Its distinctive features are that it:

Operates through non-hierarchical coordination of legally independent actors around a technological core (digital platforms) via open application programming interfaces (APIs);

- serves as an instrument of innovative development that is transforming into a pervasive, life-sustaining infrastructure;
- implements the latest models of capital accumulation through the monetization of information datasets and user behavior patterns, shaping new contours of platform-based regulation;
- it blurs traditional boundaries, revealing a new “algorithmic geography” of power, where traditional state institutions are forced to compete and interact with high-tech transnational entities and autonomous artificial intelligence agents.

Experts emphasize that three conceptual drivers contribute to the emergence and exponential growth of the GCE:

- Platformization. Platforms serve as an architectural framework, shifting value creation outward. Their main asset is not a product, but a specific set of rules (APIs) combined with infrastructure that allows millions of strangers to trust one another as they interact.
- Network effects. According to Metcalfe’s Law, the value of an ecosystem grows in proportion to the number of participants: more users attract more content creators, which, in turn, attracts new users. This effect leads to the formation of natural digital monopolies.
- Data-centricity and algorithmic management. Data in the GCE serves as both an asset and a driver. Continuous data collection allows AI to refine recommendations, which increases user loyalty. Governance is carried out through code (“Code is Law”). Algorithms determine what people will see in their news feeds, at what price they will purchase certain goods, and what types of social connections they form.

The theoretical analysis of the global digital ecosystem's essence, its historical evolutionary stages, and its key growth factors indicates that at the current stage, it has transformed into a complex, non-linear environment. To understand the architecture of this modern phase, an objective necessity arises to transition from a theoretical description of evolutionary waves to a practical analysis of how the stated triad of actors (Big Tech, sovereign states, and autonomous AI) interacts within the networked co-competition model. Let us examine the key aspects and strategic models of these paired relational configurations that define the new power structure on the global stage.

High-tech corporations (Big Tech) vs. sovereign states. This is the main source of geoeconomic tension and strategic rivalry within the GCE. Transnational tech giants (such as Alphabet, Microsoft, Meta, Apple, Amazon, as well as their Asian counterparts Tencent and Alibaba) possess colossal infrastructural power, which often far exceeds the financial, organizational, and regulatory capacity of most countries in the world. The conflict between them centers on control over extraterritorial “digital territories” and citizens’ private data. Corporations seek to maximize the autonomy of their platforms, effectively assuming the functions of quasi-states: they establish their own rules for internal censorship, create closed payment and financial ecosystems, and implement global digital identity systems. While sovereign states remained largely passive observers of these expansive processes for a long time, they are now actively seeking to reclaim their agency and regulatory control on the

global stage. Three key strategic models for restoring state agency have clearly emerged on the global stage: The Regulatory Pressure Model (European Union): Through the implementation of strict legal mechanisms – including the General Data Protection Regulation (GDPR), the Digital Markets Act (DMA), and the Digital Services Act (DSA) – the European Union systematically curtails the monopolistic power of Big Tech. Within this model, the state (or a supranational entity) acts as a strict legal arbiter that protects citizens' fundamental rights and privacy against the exploitative practices of corporate capital.

The "State as a Digital Platform" Model (the Ukrainian Case): With its unique "Diya" project, Ukraine has successfully transformed itself into an effective and flexible platform operator, establishing itself as a global leader in building a comprehensive state ecosystem. In this case, the state itself is transforming into a specific "technology giant" that offers citizens seamless high-tech services and competes directly with private ecosystems in terms of interface quality, speed, and usability. This approach creates an unprecedented level of digital interaction between the government and society, offering a new historical form of social contract: citizens receive maximum convenience in daily life and rapid service delivery in exchange for full digital transparency vis-à-vis state institutions.

The Digital Dirigisme Model (China): This strategy is based on the complete subordination of private technology capital to national geopolitical goals. In the PRC, the state and national tech giants function as a single, monolithic digital entity. The ecosystem here serves not only as a marketplace but also as an indispensable tool for geopolitical, ideological, and social control (as vividly illustrated by the social credit system). China is focusing on achieving a strategic technological lead: the country already holds about 40% of global patents in the field of 6G networks, which ensures its long-term infrastructure leadership in the physical and architectural layers of the future global digital ecosystem. At the same time, despite obvious sources of tension, a deep symbiotic partnership persists between governments and corporations: governments are forced to delegate to Big Tech the tasks of supporting national critical infrastructure, cloud-based registry storage, and cyber defense, while private corporations critically need state legal and judicial institutions to legitimize and protect their property rights.

Sovereign States vs. Artificial Intelligence (AI). Interaction in this area is shaped by states' efforts to integrate AI into their national development strategies (the digital agenda) while simultaneously mitigating the risks of its excessive autonomy. AI is becoming the primary tool for geopolitical dominance (the so-called "AI arms race"). The conflict arises from the fact that generative models and large language models are capable of eroding state institutions through the automated generation of disinformation, algorithmic bias, and the threat of mass unemployment in traditional sectors. Governments are forced to adopt unprecedented regulatory measures (such as the EU AI Act) in an effort to bring algorithms under the purview of national legal systems and the concept of ethical technology use.

High-Tech Corporations vs. Artificial Intelligence. In this context, a symbiotic partnership predominates, which, at the same time, is gradually transforming into a new form of dependency. Corporations are the primary architects, owners, and beneficiaries of AI technologies. They use autonomous AI agents as a tool for internal algorithmic management to optimize platforms, retain user attention, and monetize data sets. However, as AI models become more complex, a technological conflict arises: algorithms are becoming increasingly opaque even to their creators (the "black box" problem).

The analysis of the outlined strategic models and contradictions within the actor triad shows that the foundation of modern leadership in the global digital ecosystem is control over its physical and architectural layers. A vivid example of this is China's strategy, which focuses on achieving global technological advancement: the country has already accumulated and holds about 40% of global patents in the field of 6G networks. According to analytical reports

by the *Cybercreative Institute (2025–2026)* and the International Telecommunication Union *(ITU, 2026)*, such a high level of intellectual property concentration in next-generation telecommunications ensures the PRC's long-term dominance in the infrastructural layer of the future intelligent web. This forces other sovereign states and transnational corporations to accelerate their own technological developments to preserve digital sovereignty and competitiveness in the global market.

The strategic models of relations formulated above, the infrastructural dominance via 6G patents, as well as the specific dynamics of conflicts and symbioses within the actor triad, are fully reflected in the actual statistical indicators of the last three years (2024–2026). The obtained empirical data allow for the verification of the proposed complex hypothesis across all three defined criteria.

First, the documented massive replacement of linear value chains by platform-based structures is verified by UNCTAD reports, showing that over 65% of cross-border digital transactions are currently controlled by leading ecosystems [5]. Furthermore, research by McKinsey & Company [13] and Gartner [14] indicates that more than 70% of new supply chain integrations rely on cloud architectures, and 85% of large enterprises have shifted to "Platform-as-a-Product" strategies, enabling them to reduce transaction costs by up to 30%.

Second, the scale of network effects directly drives the colossal infrastructural and financial power of Big Tech, enabling them to operate on par with sovereign states. A stark illustration of this trend is the capitalization dynamics of ecosystem companies during the 2025–2026 period: the market valuation of Apple and Nvidia confidently surpassed the historic USD 4.5–5 trillion threshold, while Alphabet (Google), Microsoft, and Amazon consistently hold within the USD 2.5 – 4.2 trillion range [15]. Closed-loop ecosystem cycles and cross-platform data monetization shape a new architecture of the global market.

Third, the described processes of state and Big Tech integration (including the cases of digital dirigisme and GovTech platforms like Ukraine's "Diya") are fully supported by investment scales. According to IDC reports, global spending on AI and sovereign clouds reached USD 310 billion in 2026, with the public sector driving major investments [16]. Gartner research shows that over 60% of governments worldwide have integrated autonomous AI into public services [14], and according to the World Bank GovTech Maturity Index, more than 80 nations are deploying national AI strategies in deep partnership with Big Tech (Microsoft, AWS, Google Cloud) [17].

These statistics empirically confirm that the conflicts, patent leadership, and symbioses identified in our analysis are not merely a theoretical construct, but the functioning institutional foundation of the current global transformation stage, where traditional state hierarchies are de facto replaced by networked relationships of co-competition.

At the same time the process of forming the GCE as a new form of global organization is accompanied by the emergence of a number of systemic challenges that threaten the stability of international relations and distort the principles of fair digitalization. For the purposes of our study, we define fair digitalization as a model of technological and institutional development of the global environment based on the principles of inclusivity, ethics, equal access to the benefits of technology, and unconditional respect for the sovereignty of all participants in the global arena. This concept is not a purely abstract category but unfolds through three key dimensions:

The economic-spatial dimension: involves bridging the global digital divide, whereby peripheral countries gain a real opportunity to develop their own high-tech entities, rather than merely serving as consumers of ready-made foreign algorithms.

Humanitarian-ethical dimension: ensures the protection of fundamental human rights in cyberspace, primarily the right to privacy, protection against algorithmic manipulation, and the subordination of artificial intelligence systems to universal ethical standards.

The political-regulatory dimension: ensures the preservation of states' digital sovereignty and the ability of nations to independently determine their digital agenda without coercive dictates or covert pressure from transnational monopoly platforms.

However, the current architecture of the Global Tech Ecosystem (GTE) is developing in direct contradiction to these principles, generating a series of critical distortions: *Digital neocolonization*. This phenomenon is linked to the formation of a stark asymmetry in the global distribution of technological benefits and capital. A small group of countries (primarily the United States and China), which control the core of the GCE (Big Tech, cutting-edge AI centers, and microchip manufacturing facilities), are carrying out technological and informational expansion into peripheral countries. Less developed states are turning into mere "digital colonies"– raw material appendages that supply primary behavioral data to global platforms for free and are forced to purchase ready-made algorithmic solutions. This perpetuates economic backwardness and makes independent technological development by the periphery impossible. *Erosion of privacy*. The latest models of capital accumulation, based on the total monetization of information databases, have turned people's private lives into a commercial resource. Constant algorithmic monitoring of user behavior patterns leads to the de facto disappearance of the classic institution of privacy. Citizens find themselves trapped inside digital "echo chambers" and information bubbles, where their choices – from everyday purchases to political voting – become the subject of covert algorithmic manipulation. .*New Types of Cyber Threats.* Modern GCE architecture is characterized by a high level of vulnerability due to the increasing complexity of systems. The emergence of autonomous AI agents has given rise to a new generation of threats: ranging from automated cyberattacks on critical infrastructure – capable of adapting in real time – to the creation of industrial-scale deepfakes that undermine financial markets and institutional trust in society. The Struggle for Digital Sovereignty and the "Splinternet" Phenomenon. States' efforts to regain control over their own information-economic sphere in response to the risks of neocolonization and monopolization by Big Tech have become the main driving forces behind the deglobalization of cyberspace. This process has been termed "Splinternet" in academic literature – the phenomenon of the fragmentation of what was once a unified, open, and universally accessible global network into isolated, heavily regulated, and ideologically marked national or regional digital zones.

The systemic challenges that have been identified–ranging from the monopolization of markets by Big Tech corporations to the fragmentation of the internet due to the "Splinternet" phenomenon – point to a profound crisis in the current architecture of the Global Digital Economy (which operates according to Web 2.0 standards). The centralized nature of data and algorithm management makes it impossible to build a fair digital space. In this context, the transition to decentralized technologies and Web3 standards becomes the only viable path for transforming the GCE. Web3 (or the decentralized digital ecosystem) represents a new stage in the evolution of the global digital space, where distributed ledger technologies (blockchain), smart contracts, decentralized autonomous organizations (DAOs), and self-sovereign identity (SSI) are used instead of centralized servers operated by transnational giants.

The implementation of Web3 standards serves as the primary tool for mitigating global digital risks and restoring the balance of power in the global arena through the following mechanisms: mitigating digital neocolonialism through the decentralization of infrastructure. Web3 technologies are dismantling the monopoly of the "core–periphery" architecture. Instead of relying on cloud storage providers like Amazon (AWS) or Google Cloud, peripheral countries gain the ability to integrate into decentralized data processing and storage networks. This allows local high-tech entities to compete on equal footing, as access to infrastructure and code becomes open and independent of the political will or sanctions of any

individual state or Big Tech actor. Protecting privacy and regaining control over data. Web3 standards are transforming the model of ownership of information sets. The concept of sovereign identity (SSI) stipulates that the user (whether a citizen or a business) is the absolute and sole owner of their personal data and digital behavioral patterns. Transnational platforms lose the ability to extract "behavioral surplus" for free. Data monetization occurs exclusively with the user's consent via smart contracts, which eliminates the foundation for "surveillance capitalism" and algorithmic manipulation. Ensuring flexible digital sovereignty for nations. For sovereign states, Web3 offers an alternative to the Splinternet. Instead of erecting closed digital borders ("Golden Shield") or waging cyberwarfare, states can create sovereign digital instruments (such as central bank digital currencies – CBDCs) based on transparent blockchain protocols. This allows them to protect their financial systems and national security from the extraterritorial dictates of Big Tech, while remaining integrated into the global flow of capital and information. Implementing the principles of equitable digitalization. Web3 ensures inclusivity by creating open financial and social protocols (DeFi, DAO), where the rules of the game are hard-coded and immutable for all participants, regardless of their geographic location. Within Web3, artificial intelligence is integrated as an accountable actor whose activities are governed by transparent cryptographic protocols, making its covert monopolization by tech giants impossible.

A profound insight into the transformation vectors of the GDE requires a historical analysis of the World Wide Web's architectural models, given that each evolutionary stage established a distinct paradigm for allocating capital, data, and power globally:

1. The Web 1.0 Era (1990s – early 2000s): "Read-Only" or Static Internet

The inaugural generation of the World Wide Web was characterized by a decentralized yet structurally static framework. The network comprised predominantly static web pages administered by individual enthusiasts or corporate entities, positioned users strictly as passive consumers of information. The economic paradigm of this evolutionary stage centered on hosting services and the nascent development of corporate websites. Network power remained fragmented due to technical limitations that prevented the centralized aggregation of large-scale datasets.

2. The Web 2.0 Era (mid-2000s – present): "Read-Write" or Platform Capitalism

The emergence of social networking and cloud computing transformed users into active content creators. Architecturally, however, this transition triggered a radical centralization of infrastructure. The proliferation of millions of independent websites was effectively superseded by a few global monopolists (BigTech) that established enclosed platform ecosystems. The Web 2.0 economic model relies on the asymmetric extraction of user behavioral data for subsequent monetization via advertisers or the training of proprietary artificial intelligence algorithms. Consequently, Web 2.0 architecture has generated systematic challenges, including digital neocolonization, the erosion of privacy, and network fragmentation through the Splinternet.

3. The Web 3.0 Era: "Read-Write-Own" or the Era of Decentralized Sovereignty

Web 3.0 introduces a fundamental paradigm shift by returning to the decentralized origins of the Internet via an advanced infrastructural layer. This architecture is underpinned by distributed ledger technologies (blockchain), smart contracts, decentralized autonomous organizations (DAOs), and Self-Sovereign Identity (SSI). This framework enables users and sovereign states to directly control their digital assets and identities without relying on intermediary electronic platforms.

- *Tokenization of Economic Relations***:** Value and intellectual property are converted into digital tokens, operationalizing an ownership economy where value added is automatically allocated through smart contracts.

- *The "Proof of Sovereignty" Concept:* The integration of cryptographic protocols and zero-knowledge proofs (ZKPs) allows users or state entities to verify their status or financial solvency in the global space without disclosing primary data. This structural shift fundamentally dismantles the mechanisms of surveillance capitalism.

Currently, the global digital ecosystem is undergoing a transitional phase, frequently conceptualized as Web 2.5. Rather than a complete displacement of Web 2.0 architectures, this period is characterized by a hybrid coexistence: digital platforms retain centralized control over core physical infrastructure, while selectively integrating decentralized Web 3.0 protocols. Complete systemic migration toward Web 3.0 remains constrained by technological scalability barriers, complex user experience (UX) barriers, and fragmented regulatory frameworks enacted by sovereign states.

Despite existing infrastructural and regulatory barriers, Web 3.0 paradigms have already established resilient, practical niches across several critical domains of the global digital economy:

- *The Financial Sector***:** Decentralized ledger frameworks increasingly underpin cross-border settlement systems via stablecoins and the architecture of Central Bank Digital Currencies (CBDCs).
- *Digital Identity and Privacy Protocols***:** Self-Sovereign Identity (SSI) frameworks and Zero-Knowledge Proofs (ZKPs) are actively deployed in sovereign and enterprise environments, enabling secure authentication without compromising primary personal data.
- *The Creator Economy***:** The tokenization of intellectual property and digital assets circumvents traditional web-platform intermediaries (e.g., streaming and content hosting services), enabling authors to monetize content via direct, peer-to-peer economic models."

Looking ahead, the evolutionary trajectory points toward Web 4.0 (emerging in the mid-2020s and projected to mature through the 2030s)**,** often termed the Symbiotic or Intelligent Web. Academically, this paradigm represents a convergence of decentralized Web 3.0 ledgers with omnipresent artificial intelligence, advanced Internet of Things (IoT) ecosystems, and brain-computer interfaces. In this model, the role of data evolves from being merely owned (as in Web 3.0) to being autonomously interpreted and executed by ubiquitous AI agents. This shift alters the distribution of global power, transitioning it from traditional digital platforms to the algorithmic nodes that coordinate autonomous, machine-to-machine resource distribution. This emerging paradigm introduces a new architectural and conceptual layer to the global digital ecosystem, which can be disaggregated into the following structural dimensions:

- Algorithmic Symbiosis and Machine-to-Machine (M2M) Autonomy: In Web 4.0, economic interactions shift from human-centric models to autonomous, predictive transactions managed by interconnected AI agents. These ubiquitous agents independently optimize global supply chains and distribute resources, operating on the infrastructural layer established by decentralized Web 3.0 ledgers.
- The "Cognitive Sovereignty" Paradigm: As brain-computer interfaces and spatial computing systems integrate into the ecosystem, the traditional perimeter of personal data expands to include cognitive and neuro-data. Consequently, the concept of digital sovereignty evolves into safeguarding cognitive privacy against advanced algorithmic manipulation and decentralized neural-profiling.
- The Geoeconomic Architecture of Algorithmic Nodes: Global power dynamics shift away from centralized web platforms toward the physical and structural infrastructure that hosts advanced AI models and decentralized 6G telecommunication nodes. Control over these algorithmic nodes becomes the primary arena of strategic rivalry among sovereign states and high-tech corporations, transforming the nature of geopolitical dominance.

To synthesize the analytical breakdown of the World Wide Web's evolution and its direct impact on global power dynamics, the key characteristics of each technological era are systematically compared in Table 1.

Table 1

Evolutionary Paradigm of World Wide Web Architectures and Governance Models

Web Era & Timeline	Architectural Core	Capital & Data Allocation Model	Power & Sovereignty Distribution
Web 1.0 *(1990s – early 2000s)* "Read-Only" / Static Internet	Decentralized protocols; static HTML web pages hosted on independent servers	Infrastructure-centric; monetization via web hosting services and corporate websites	Highly fragmented; minimal data aggregation limits structural monopoly
Web 2.0 *(mid-2000s – present)* "Read-Write"/ Platform Capitalism	Radical infrastructural centralization; proprietary clouds and application programming interfaces (APIs)	Asymmetric extraction and monetization of user behavioral data; platform monopolies (BigTech)	Centralized institutional power; risks of digital neocolonization and network fragmentation (Splinternet)
Web 2.5 *(Transitional Phase)* Hybrid Ecosystem	Hybrid framework; centralized infrastructure layered with selective decentralized protocols	Asymmetrical data monetization coupled with nascent decentralized asset flows	Contested governance; traditional digital platforms versus emerging decentralized governance networks
Web 3.0 *(Emerging / Actively Developing)* "Read-Write-Own"/ Decentralized Internet	Distributed Ledger Technologies (DLT/Blockchain); smart contracts; tokenized protocols	Ownership Economy; automated tokenization of value and IP; elimination of intermediaries	Distributed sovereignty; user-controlled data and identities via Self-Sovereign Identity (SSI)
Web 4.0 *(Mid-2020s – projected 2030s)* "Symbiotic" / Intelligent Internet	Convergence of blockchain, omnipresent AI agents, IoT ecosystems, and neural interfaces	Algorithmic and autonomous orchestration of value; machine-to-machine resource distribution	Decentralized symbiotic power; automated execution of rights and governance by ubiquitous AI systems

Source: Compiled by the authors.

Beyond institutional and structural risks, the formation of the GDE is accompanied by an accelerating burden on the biosphere, creating a fundamental contradiction between the pace of digitalization and sustainable global development goals. The energetic cost of artificial intelligence (AI) and big data architecture is a critical concern, as the rapid expansion of machine learning and cloud computing demands an exponential scalability of data center capacity. According to International Energy Agency (IEA) projections, global electricity consumption by data centers is anticipated to double by the end of 2026 compared to 2022 levels, exceeding 1,000 TWh – a figure equivalent to the annual energy consumption

of Japan. Furthermore, despite strategic declarations by multinational technology corporations regarding imminent carbon neutrality, empirical emission metrics continue to escalate. For instance, Microsoft reported a 29% increase in its greenhouse gas emissions since 2020, a surge directly attributed to the construction of specialized AI infrastructure. On a micro-level, a single query processed by ChatGPT consumes approximately ten times more electricity than a conventional Google search query.

An equally critical yet heavily under-researched factor is the intensive consumption of freshwater required for cooling server architecture. Empirical estimates indicate that training the GPT-4 model necessitated roughly 15 to 20 million liters of water. On a global scale, the aggregate freshwater withdrawal demand for digital ecosystems is projected to reach 6.6 billion cubic meters by 2027, severely exacerbating localized water scarcity in regions hosting major data center clusters. Simultaneously, the physical layer of the GDE intensifies crises surrounding electronic waste (e-waste) and rare-earth element depletion. The hardware underpinning digital ecosystems relies heavily on finite materials – such as lithium, cobalt, and neodymium – while the rapid obsolescence of digital devices generates over 60 million metric tons of e-waste annually, of which a mere 20% undergoes formalized recycling.

Concurrently, these environmental externalities precipitate a novel paradigm of global geopolitical and economic inequality. Developed economies successfully cultivate “clean”, service-oriented digital ecosystems, whereas the ecological costs of raw material extraction and e-waste disposal are disproportionately offloaded onto developing nations. This dynamics manifests a systemic paradox: the GDE, conceptually designed to optimize planetary resource allocation, operates as a primary driver of environmental destabilization. Consequently, the future structural legitimacy of the GDE hinges on its capacity to transition toward "green coding" frameworks and circular economy paradigms. Without a radical algorithmic optimization of AI energy consumption and mitigation of digital water deficits, the continued expansion of the global digital ecosystem risks entering an irreversible ecological bottleneck, conflicting directly with the biophysical boundaries of human survival.

Conclusions. Based on a comprehensive theoretical and methodological analysis, this study substantiates a conceptual shift in understanding the nature of the global digital ecosystem (GDE), which has evolved from a descriptive biological metaphor into the dominant socio-technical superstructure of the modern world order. It is established that the contemporary socio-economic, political, and legal environment is undergoing total algorithmization, wherein traditional institutional hierarchies are increasingly superseded by network protocols and interaction interfaces.

The study demonstrates that the imperative deployment of artificial intelligence systems and predictive analytics as key instruments for GDE coordination determines the emergence of “algorithmocracy”. This phenomenon modifies decision-making mechanisms and necessitates the implementation of updated criteria for transparency and legal accountability among digitalization actors. Furthermore, a causal link between platformization, network effects, and data-centricity is found to initiate the genesis of “natural digital monopolies”. The scaling of these structures leads to an unprecedented concentration of capital within a limited circle of global high-tech entities whose market capitalization and resource potential blur traditional interstate borders, exceeding the GDP of most sovereign nations. Such asymmetry of market power determines the monopolistic imposition of endogenous technological standards and extrapolates the risks of “digital neocolonization” to countries lacking a developed national technology stack.

An examination of the architecture of "surveillance capitalism" reveals a critical accumulation of ethical and security distortions, signaling the exhaustion of this model and the degradation of its constructive component. Consequently, the study argues the objective

inevitability of a paradigmatic transition toward intelligent-symbiotic Web 4.0 architectures**,** immersive metaverses, and the institutional capacity of DAOs powered by Web3 protocols.

Within this evolutionary shift, a clear distinction must be made between the infrastructure layer and the functional superstructure. Decentralization, which serves as the core technological baseline of Web 3.0, is not neutralized on the next developmental wave. Instead, distributed networks, smart contracts, and self-sovereign identity form the indispensable infrastructure baseline upon which the intelligent and symbiotic services of Web 4.0 deploy.

Ultimately, it is concluded that the transformation of the GDE into a resilient system of common good and its inclusive development depend entirely on the international community's capacity to harmonize technological progress with the mechanisms of ethical AI governance, digital sovereignty, and personal data protection.

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