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RESEARCH ARTICLE

The Internal Logic and Formation Mechanism of New Quality Productive Forces from the Industrial Ecosystem Perspective*

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Abstract

The industrial ecosystem covers the advanced technologies, key industries and core factors in the process of developing new quality productive forces, serving as an important perspective for investigating the development of new quality productive forces. Based on the analytical framework comprising technologies, industries and factors, this study examines the internal logic of the development of new quality productive forces. Firstly, the four industrial revolutions in history demonstrate that the industrial ecosystem has promoted a series of revolutionary technology innovations. Secondly, the industrial ecosystem promotes the formation and development of emerging industries through resource sharing, knowledge spillover, and technology diffusion. Thirdly, the industrial ecosystem achieves an innovative allocation of factors of production through the dynamic feedback loop mechanisms of data–algorithm–traffic and data–network–activity. The industrial ecosystem consists of three subsystems, including the innovation ecosystem, the business ecosystem, and the platform ecosystem. The three subsystems transcend the boundaries of innovation for new quality productive forces, broaden their application scenarios, and enhance the efficiency of factor allocation, respectively. To further advance the development of new quality productive forces, it is necessary to establish a system ensuring the coordinated development of all factors. Additionally, efforts are required to integrate the dual driving forces of technology innovation and institutional innovation, and enhance the integration of four chains, including the innovation chain, the industrial chain, the capital chain, and the talent chain.

Keywords new quality productive forces; industrial ecosystem; innovation ecosystem; data factors; integration of four chains

1 Introduction

With the acceleration of a new wave of scientific and technological revolution and industrial transformation, the development of new quality productive forces has emerged as a core mission for driving high-quality development. The third plenary session of the 20th Central

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Committee of the Communist Party of China (CPC) explicitly put forward the concept of improving the institutions and mechanisms for fostering new quality productive forces in line with local conditions, underscoring its critical role in advancing Chinese modernization. New quality productive forces essentially represent an advanced productive force formed through the interconnection and interaction of productive factors, productive structure, and productive functions. This constitutes a systemic engineering project characterized by global scope, complexity, and dynamism (Huang & Sheng, 2024). The advancement of new quality productive forces surpasses technological breakthroughs within a single industry. It necessitates coordination and integration across multiple dimensions, entities, and links to generate systematic synergy (Gao, 2024). Exploring the internal logic and formation mechanisms of new quality productive forces from a systemic perspective holds profound implications for China's economic development in the new era.

Existing studies have elucidated the role of new quality productive forces in optimizing the industrial chain from the standpoint of the industrial chain itself. Zhan and Li (2024) assert that new quality productive forces drive the modernization of the industrial chain via the high-end linkage effect, efficiency improvement effect, innovation control effect, and market competition effect. Hong and Wang (2024) highlight that the attributes of the industrial chain determine the innovative capacity of new quality productive forces, which strengthen the resilience of both the industrial chain and supply chain by facilitating supply-demand alignment and enhancing supply quality. The aforementioned studies demonstrate the proactive role of new quality productive forces in driving value enhancement within the industrial chain. Nevertheless, these studies primarily concentrate on one-dimensional optimization from the industrial chain perspective, failing to adequately capture the interplay among multidimensional factors under complex economic environments. In current studies on the industrial ecosystem, the collaboration between industrial policies and digital technology has emerged as a significant area of interest. Li and Liu (2013) adopt the industrial ecosystem as an analytical framework to examine how industrial policies support the growth of strategic emerging industries, underscoring the critical role of coordination between policies and diverse entities. Yu and Li (2021) consider the industrial ecosystem as a novel form of industrial organization and examine the critical role of digital technology in optimizing the industrial ecosystem. The aforementioned studies extend the focus from the traditional industrial chain to a more intricate industrial ecosystem, highlighting the dynamic mechanisms where multiple entities collaborate with each other. However, these studies do not thoroughly explore the formation mechanism of new quality productive forces as a central issue.

While existing studies on new quality productive forces have achieved some progress across various fields, the perspective is often confined to individual factors or specific fields. Therefore, they fail to comprehensively uncover the systemic attributes of new quality productive forces within complex economic environments and the dynamic interactions among their multidimensional factors. Compared to existing studies, the marginal contributions of this study lie in three key aspects. First, the industrial ecosystem perspective is adopted to analyze new quality productive forces. By clarifying the fundamental concepts and connotations of the industrial ecosystem, this study explores the internal logic behind the development of new quality productive forces from the industrial ecosystem perspective. Second, a framework comprising technologies, industries, and factors is established for analyzing new quality productive forces. The industrial ecosystem is divided into three subsystems, including the innovation ecosystem, the business ecosystem, and the platform ecosystem, to systematically uncover the formation mechanism of new quality productive forces within the context of the industrial ecosystem. Third, a policy pathway centered on systemic synergy, dual driving forces, and integration of four chains is proposed, offering an innovative theoretical framework and practical guidance for expediting the development of new quality productive forces and advancing high-quality economic development.

2 Connotation and Internal Correlation between Industrial Ecosystem and New Quality Productive Forces

Based on the analytical framework comprising technologies, industries and factors, the industrial ecosystem supplies technological, industrial, and factor resources to support the development of new quality productive forces, which in turn drive the iteration and evolution of the industrial ecosystem through innovations in technology, models, and business forms. The industrial ecosystem and new quality productive forces exhibit interdependence and mutual reinforcement within the economic system, establishing an intrinsic cyclical and interactive relationship.

2.1 Connotation of the Industrial Ecosystem

The concept of ecosystem initially emerged from biology (Tansley, 1935). Its profound illustration of the intricate interactions between organisms and their environment has led to widespread adoption in socio-economic domains, particularly offering a crucial analytical perspective for examining industrial development and innovation dynamics. Accelerated advancements in scientific and technological revolutions and industrial transformations have enabled industrial development to transcend the boundaries of single sectors and evolve into a complex process characterized by interactions among multiple entities. This characteristic has motivated scholars to introduce the concept of the industrial ecosystem to uncover the intricate dynamic relationships of interdependence, collaborative innovation, and symbiotic evolution between internal and external entities within industries.

In light of this, scholars have classified the industrial ecosystem into the following three categories based on differences in analytical perspectives. First, the innovation ecosystem, which centers on specific innovations or novel value propositions. The innovation ecosystem encompasses all participants delivering value innovation to end customers, establishing a robust innovation network through collaborative interactions. Lundvall (1985) initially introduces the concept of the innovation system to provide an explanation of innovative activities at national and regional levels and to elucidate how innovation propels economic development via intricate interactive mechanisms. Adner (2006) further advances the concept of the innovation ecosystem, highlighting that such an ecosystem does not rely solely on the activities of individual enterprises or research institutes. Instead, it necessitates the coordinated involvement of multiple entities, including enterprises, governments, research institutes, and educational systems. Second, the business ecosystem, which is centered on enterprises and their environment (Teece, 2007), represents a commercial community comprising interacting entities, such as enterprises, consumers, suppliers, stakeholders, governments, social organizations, and competitors. Moore (1993) is the first to introduce the biological concept of ecosystem into the business domain, emphasizing that enterprises are no longer isolated entities but rather exist within a dynamic ecosystem, co-evolving with other enterprises and organizations. The business ecosystem provides enterprises with a foundation for resource integration and optimized allocation. Additionally, it necessitates strategic flexibility to adapt to market changes, thereby enhancing competitiveness and achieving sustainable growth. Third, the platform ecosystem, which facilitates organizational activities based on platform infrastructure. This system encompasses platform providers, external contributors, and consumers, all of whom are essential for expanding the value of core platform technologies (Christensen et al., 2018). The theory of two-sided markets lays a theoretical foundation for the development of the platform ecosystem (Rochet & Tirole, 2003). Acting as intermediaries in two-sided markets, platforms maximize network effects by linking distinct user groups, such as developers and end users, while driving the overall evolution of the ecosystem. The platform ecosystem centers around the platform. It attracts external developers and partners through open technical standards and interfaces, thereby forming an efficient and collaborative innovation network (Gawer & Cusumano, 2014). The open ecosystem model offers a highly flexible and innovative environment for platform enterprises, enabling their sustained growth and fostering innovation within a competitive market.

Although the aforementioned perspectives reflect variations in research focus, they demonstrate how the ecosystem concept overlaps and integrates within socio-economic systems. Furthermore, they highlight the growing significance of ecosystem research in both socio-economic contexts and practical applications. This paper argues that the industrial ecosystem constitutes a complex network of multiple interconnected and interacting entities, encompassing advanced technologies, key industries, and core factors involved in the formation and development of new quality productive forces. The ecosystem is further divided into three critical subsystems, including the innovation ecosystem, the business ecosystem, and the platform ecosystem.

2.2 Connotation and Manifestation of New Quality Productive Forces

Chinese president Xi Jinping has provided a comprehensive explanation of the concept of new quality productive forces. He notes that they are shaped by revolutionary technological breakthroughs, innovative allocation of factors of production , and deep industrial transformation and upgrading, with the improvement of labor forces, means of labor, subjects of labor, and their optimal combination as underlying elements, and a substantial increase in total factor productivity as a core hallmark. Marked by innovation, and with high quality as the key, new productive forces are advanced productivity in essence (Xi, 2024). From the industrial ecosystem perspective, the manifestations of new quality productive forces are primarily evident at three levels, including technologies, industries and factors.

2.2.1 Revolutionary Technology Innovation

Technological progress has consistently acted as the primary driver of productivity advancement. From steam engines and electrical technology to contemporary cutting-edge technologies, such as artificial intelligence (AI), blockchain, and quantum computing, each wave of technological revolution has significantly enhanced production efficiency while promoting fundamental transformations in production methods. In the *Condition of the Working Class in England*, Engels notes that the invention of the steam engine gave rise to an industrial revolution, leading to a qualitative leap in productivity (Compilation and Translation Bureau of the CPC Central Committee, 2012). Furthermore, Marx, employing dialectics in *Capital*, underscores that technological advancements drive the development of productivity and create entirely new fields of production (Compilation and Translation Bureau of the CPC Central Committee, 2001). Currently, several major disruptive and cutting-edge technologies are continuously fostering the emergence of new industries and business forms. Examples include strategic emerging industries, such as next-generation information technology, new energy, new materials, high-end equipment, and new energy vehicles. Additionally, future industries like brain-inspired intelligence, quantum information, genetic technology, future networks, future displays, and novel energy storage solutions are thriving under the impetus of technology innovation. This progress is driving a shift in production methods toward digitalization, intelligence, and green practices. It is under the guidance of these disruptive and cutting-edge technologies that new quality productive forces transform existing production models, offer a robust technical foundation for a new wave of industrial revolution, and facilitate a significant advancement in productivity. For instance, AI enhances decision-making efficiency in production processes through deep learning and automation. Blockchain technology strengthens the security and transparency of supply chains via decentralization and immutable features. Quantum computing, with its ultra-high computing power, augments the capacity to address complex problems. The deployment of these technologies is propelling a transformative shift in production methods, ushering global production into an era of profound change.

2.2.2 Formation and Development of New Industries

New industries denote strategic emerging industries and future industries that have expanded and matured by leveraging novel technologies. These industries are marked by dynamic innovation, high technological intensity, and extensive growth prospects, playing a pivotal role in national economic and social development as well as the optimization and upgrading of industrial structures. In September 2023, President Xi Jinping (2023) emphasized the necessity of integrating technology innovation resources, guiding the advancement of strategic emerging industries and future industries, and expediting the formation of new quality productive forces. Technology innovation assumes a leading role in the development of new quality productive forces, with strategic emerging industries and future industries serving as crucial focal points within this trajectory. Strategic emerging industries and future industries are grounded in significant technological breakthroughs and substantial developmental demands. These sectors are characterized by intensive knowledge and technology utilization, minimal material resource consumption, immense growth potential, and favorable comprehensive outcomes. They signify the orientation of a new wave of scientific and technological revolution and industrial transformation, while constituting essential domains for nurturing and developing new quality productive forces. Given that strategic emerging industries and future industries typically form complex industrial ecosystems composed of multiple related sectors, the ongoing development of new quality productive forces supplies the technological support and industrial foundation necessary for the integration and interconnection of these ecosystems. As a result, this facilitates the establishment and refinement of novel industrial ecosystems. In a sense, new quality productive forces represent social productivity shaped by the clustering of strategic emerging industries and future industries (Zhao & Ji, 2024). The development of new quality productive forces facilitates interconnection and interaction among strategic emerging industries and future industries. Additionally, it empowers the industrial ecosystem, thereby driving high-quality economic development (Zhao & Ji, 2024). It is important to highlight that the development of new quality productive forces does not imply neglecting or discarding traditional industries. Traditional industries serve as the foundation for the formation of new quality productive forces. After undergoing transformation and upgrading, many traditional industries have the potential to become primary domains for nurturing new quality productive forces.

2.2.3 Extensive Utilization of New Factors

In contrast to traditional factors of production, data factors exhibit characteristics such as non-competitiveness, partial exclusivity, coexistence of increasing and diminishing returns, synergistic interaction with other factors, and the presence of both positive and negative externalities (Li, 2022). The aforementioned attributes of data establish data factors as a quintessential form of general-purpose assets, which are deployed across multiple scenarios and reused by various entities, thereby enhancing the input-output efficiency of other factors

(Jiang, 2024). According to the *Three Year Action Plan for "Data Factors X" (2024–2026)* introduced by the National Data Bureau, the breadth and depth of data factor applications have been significantly expanded, with the multiplier effect of data factors in the realm of economic development becoming increasingly evident. Currently, new quality productive forces are utilizing data as a novel production factor, continuously playing the role of amplification, superposition and multiplication of data factors. Nevertheless, the release of its data value relies on the support of algorithms and computing power. With the ongoing advancement of technologies, such as machine learning and deep learning, algorithms have emerged as core instruments for data processing and analysis, becoming pivotal factors of productivity in both the information society and intelligent society. Furthermore, new quality productive forces may be perceived as a new form of productivity epitomized by computing power (Liu et al., 2023). Serving as the foundational infrastructure for data processing and algorithmic operations, computing power has established a technological cornerstone for industry-level and region-wide industrial ecosystem collaboration. It is driving the evolution of production methods from an industrialized society toward an intelligent one. The integration of data, algorithms, and computing power has driven the transformation of productivity, facilitating an evolution from localized to global, from basic to advanced, and from standalone systems to integrated systems. This enables more efficient collaboration across all links of the industrial chain, supply chain, and value chain, thereby offering a crucial pathway for the emergence of new quality productive forces.

2.3 The Intrinsic Relationship between the Industrial Ecosystem and New Quality Productive Forces

The industrial ecosystem and new quality productive forces exhibit intricate dynamic relationships of mutual reinforcement, serving as critical components within the economic system that are highly interactive and cyclically progressive. As the foundational platform for new quality productive forces, the industrial ecosystem establishes a robust groundwork for their development by providing resource support, collaborative innovation networks, and dynamic moderating mechanisms to address environmental changes. In turn, new quality productive forces propel the iterative advancement and evolution of the industrial ecosystem through innovations in technology, models, and business forms.

The industrial ecosystem serves as a crucial support system for the development of new quality productive forces. As a complex network involving multiple entities, the industrial ecosystem creates an optimal external environment for the formation and development of new quality productive forces by integrating resources and implementing collaborative mechanisms. Firstly, the industrial ecosystem pools essential infrastructure and critical resources, with its core participants encompassing research institutes, enterprises, the capital market, and policymakers. Research institutes, as the primary drivers of innovation, assume the responsibility for technological research, development, and breakthroughs, establishing a robust technological foundation for new quality productive forces. Enterprises facilitate the transformation of these technological achievements into marketable products and services, bridging the gap between laboratory research and industrial application. The capital market ensures financial backing, while policymakers enhance the operational efficiency of the innovation chain through strategic institutional frameworks, thereby creating a conducive environment for the leapfrog development of new quality productive forces. Secondly, the collaborative innovation mechanisms within the industrial ecosystem offer indispensable support for the multi-faceted advancement of new quality productive forces. In the context of the digital economy, scientific research institutes, enterprises, and the capital market collaborate to drive the efficient integration of data, technology, and capital, continuously promoting the emergence of new industries. Additionally, through resource sharing and knowledge exchange among entities, the ecosystem accelerates the diffusion, application and transformation of technologies. Thirdly, the flexibility and openness of the industrial ecosystem provide new quality productive forces with significant adaptive capacity. In response to a rapidly changing market environment, all participants within the system are able to adapt their strategies and optimize resource allocation based on demand, thereby enhancing the sustainability and competitiveness of the overall system. Therefore, the industrial ecosystem not only strongly supports the development of new quality productive forces but also endows them with the capability to survive and thrive in complex economic environments.

New quality productive forces exert a profound influence on the formation and evolution of the industrial ecosystem. New quality productive forces have redefined the operational logic and evolutionary pathways of the industrial ecosystem through multi-dimensional innovations, including technology, models, and business forms. As the core driving force behind new quality productive forces, technology innovation directly influences the allocation and integration of resources within the industrial ecosystem by optimizing production modes, streamlining processes, and boosting productivity. This thereby expedites the development of endogenous momentum within the ecosystem. For instance, the adoption of smart manufacturing technology has rendered production processes more efficient, minimized resource wastage, and enhanced production flexibility. Enterprises are better positioned to respond to market demands with agility and precision. It elevates the productivity of individual enterprises while driving the optimization of the entire industrial chain. Moreover, it promotes the coordination and collaboration across upstream and downstream segments in the industrial chain, facilitates the establishment of a more efficient innovation chain, and supplies endogenous impetus for the sustained growth of the industrial ecosystem. Additionally, innovations in models and business forms further extend the value boundaries of new quality productive forces and enable the industrial ecosystem to expand into broader market domains based on technological advancements, thereby directly driving profound transformations in consumer markets and service models. Taking e-commerce as an example, innovative breakthroughs in models and business forms gave rise to a highly intricate industrial ecosystem encompassing payment systems, logistics, and supply chains. This reshaped traditional transaction methods, infusing the industrial ecosystem with new momentum for sustained evolution. With the acceleration of the industrialization process of new quality productive forces, the maturation rate of emerging industries increases significantly, allowing various emerging industries to achieve large-scale adoption within a short timeframe. Under the influence of new quality productive forces, the industrial ecosystem continuously enhances resource allocation efficiency and strengthens its competitive edge in the global economy through ongoing iterative progress.

3 Internal Logic of Developing New Quality Productive Forces from the Industrial Ecosystem Perspective

Based on the analytical framework of technology-industry-factor, the development of new quality productive forces is supported by the systematic functioning of the industrial ecosystem, characterized by the co-evolution of technologies, industries, and factors. Firstly, through collaborative interactions among multiple entities, the industrial ecosystem drives revolutionary technology innovation and serves as the primary impetus for the significant advancement of new quality productive forces. Secondly, mechanisms such as resource sharing, knowledge spillover, and technology diffusion enable the industrial ecosystem to offer crucial support for the emergence and growth of new industries, markedly expediting the optimization of industrial structures. Thirdly, by establishing a dynamic feedback mechanism of data–algorithm–traffic and data–network–activity, the industrial ecosystem achieves innovative allocation of factor resources, further enhances industrial flexibility and adaptability, and provides a robust foundation for the sustainable development of new quality productive forces.

3.1 Industrial Ecosystem Drives Radical Technology Innovation

Technology innovation is the core driving force for productivity development (Perez, 2007). However, the innovation does not occur in isolation. Instead, it is realized through the collaborative efforts of various entities within the industrial ecosystem. Historically, every wave of technological revolution has been underpinned by a highly interactive industrial ecosystem. Examples include the first industrial revolution powered by steam engines, the emergence of the electrical and steel industries, the extensive adoption in the automotive and oil industries, and the current information technology revolution. The industrial ecosystem of each different historical period has facilitated significant productivity advancements through collaborative innovation and institutional support, driving revolutionary technology innovation.

3.1.1 The First Industrial Revolution: Transformation of Steam Engines and Textile Industry

The First Industrial Revolution was characterized by the invention of the steam engine and the transformation of the textile industry, significantly altering production modes and advancing the initial development and evolution of the industrial ecosystem. The early industrial ecosystem facilitated the widespread adoption of new technologies through collaborative innovation networks, resource allocation, and institutional support. Textile factory owners, craftsmen, and mechanical engineers established a collaborative innovation network to promote the advancement and dissemination of textile machinery, enhancing the industry's technical standards and operational efficiency. In addition, the efficient allocation of resources emerged as a pivotal factor. The widespread adoption of steam engines relied on the judicious distribution of resources, such as coal. Especially, through the utilization of locally available materials, production expenses were reduced, which in turn facilitated the application of technology within the textile industry. In terms of institutional support, policies, such as the patent law, were implemented by the British government to safeguard the rights of innovators and stimulate additional technological inventions and commercial applications, creating an institutional framework conducive to technological expansion.

3.1.2 The Second Industrial Revolution: Development of Electrical and Steel Industries

The Second Industrial Revolution, centered on the proliferation of electrical technology and the growth of the steel industry, profoundly transformed the global manufacturing landscape and infrastructure development. During this phase, the significance of collaborative innovation, supply chain integration, and institutional support within the industrial ecosystem became increasingly evident. The invention and application of electrical technology were not achieved by a single entity. Instead, it relied on the close collaboration of multiple entities, including inventors, engineers, manufacturers, and academic institutes. This collaboration resulted in a comprehensive electrical industry ecosystem, which expedited the transition and dissemination of electrical technology from laboratories to the market. The industrial ecosystem of the steel industry comprised various links, such as mining, smelting, transportation, and processing. The seamless integration of these links substantially increased steel production, reduced manufacturing costs, and provided the essential material foundation for other industrial sectors. Large-scale infrastructure investment by the government, particularly in railways and electrical networks, provided institutional support for the widespread adoption of the steel industry and electrical technology. This further refined the structure of the industrial ecosystem and accelerated the ongoing progress of industrialization.

3.1.3 The Third Industrial Revolution: The Rise of Automotive and Oil Industries

The third industrial revolution was exemplified by the emergence of the automotive and oil industries, with the role of the industrial ecosystem being especially prominent during this period. The advancement of the automotive industry relied heavily on a complete supply chain system that encompasses multiple sectors, including steel, rubber, and glass. Henry Ford's introduction of assembly line production significantly enhanced manufacturing efficiency. Through collaboration with upstream and downstream industrial chains, a vast automotive ecosystem was gradually established. Additionally, the emergence of the oil industry provided critical energy support to the automotive industry. The processes of oil extraction, refining, transportation, and sales formed a complete oil industry ecosystem, which facilitated oil's rise as a dominant global energy source and expedited the globalization of the automotive industry. Furthermore, the growth of the oil industry spurred deep integration within sectors such as chemicals and plastics, broadening the scenarios for technology innovation applications. Throughout this process, institutional support from governments, including infrastructure development and market regulation, played a pivotal role in ensuring sustained innovation and technological expansion within the automotive and oil ecosystems, thereby establishing a robust foundation for global industrial progress.

3.1.4 Information Technology Revolution: The Digital Economy and Global Industrial Ecosystem

The Information Technology Revolution has ushered in a new era of digital transformation for the global economy, nurturing complex and diverse industrial ecosystems. The information technology industry ecosystem encompasses various entities, including hardware manufacturers, software developers, network service providers, users, and governments. These entities have established a highly collaborative innovation network through data exchange, knowledge sharing, and technology diffusion. Within this globalized industrial ecosystem, Silicon Valley serves as a quintessential example, where an innovation-driven industrial system has been developed through close collaboration among venture capital organizations, sci-tech companies, research institutes, and governments. Venture capital organizations supply substantial financial support for technology innovation, while universities and research institutes act as the originators of technology innovation. Moreover, the United States realized the rapid rise of the information technology industry through investments in network infrastructure and the implementation of open innovation policies. The European Union enacted regulations on privacy protection and data management to ensure fair competition and sustainable development within the information technology industry ecosystem, further advancing the robust growth of the global information industry.

3.2 The Industrial Ecosystem Facilitates the Formation and Development of Emerging Industries

The formation and development of new industries is not merely a simple convergence of technology innovation and market demand. It is a complex dynamic process influenced by multiple factors, reflecting a high level of systematic interaction and synergy. The industrial ecosystem facilitates the emergence and development of new industries through various mechanisms, including resource sharing, knowledge spillover, and technology diffusion.

3.2.1 Resource Sharing and Industrial Collaboration

Resource sharing and industrial collaboration are the core mechanisms through which the industrial ecosystem drives the formation and development of new industries. The mechanisms are closely associated with the transaction cost theory, which posits that the choice between firms and markets fundamentally hinges on the level of transaction costs, and transaction costs serve as a critical determinant influencing market structure and economic efficiency (Coase, 1937). Within traditional industrial systems, industry entities often encounter significant challenges in achieving deep collaboration due to information asymmetry, insufficient trust, and elevated coordination expenses. However, within the industrial ecosystem, the network collaboration mechanism stimulates rapid sharing of information flows, technological advancements, and capital movements among entities. This process substantially diminishes the costs associated with information search, decision-making, and monitoring activities. Firstly, the industrial ecosystem achieves resource sharing, mitigates information asymmetry, and lowers cooperation barriers, achieving cross-industry and cross-regional collaborative innovation. Such mechanisms expedite the development of new quality productive forces. For instance, the emergence of the digital platform economy allows enterprises to curtail redundant investments and innovation expenditures through shared information and technology. This enhances market responsiveness and improves the precision of decision-making processes. Secondly, optimizing resource allocation and enhancing collaboration among entities within the innovation network promote cross-disciplinary technological integration and significant innovation breakthroughs. New institutional economics highlights that organizational structure exerts a profound influence on economic activities (North, 1990). Within the industrial ecosystem, close collaboration and interaction among industry entities give rise to a highly synergistic networked organizational structure. This enables technology and knowledge to flow across domains, transcending traditional industry boundaries and spurring the emergence of new industries and business models.

3.2.2 Knowledge Spillover and Industrial Innovation

Knowledge spillover serves as a pivotal driver of industrial innovation (Zhao & Bai, 2009). The externality theory demonstrates that knowledge, as a public good, can be available free of charge (Arrow, 1972). Within the industrial ecosystem, cooperative interactions among enterprises facilitate the extensive circulation of knowledge. Such knowledge spillover diminishes the cost of innovation while accelerating the pace and expanding the scale of innovation diffusion. The endogenous growth theory further highlights the significance of the accumulation of knowledge in long-run economic growth (Romer, 1986), suggesting that sustained economic progress is driven primarily by technological change and the accumulation of knowledge. Within the industrial ecosystem, diverse enterprises establish an extensive innovation network through knowledge interaction and sharing, stimulating continuous innovation across the industry. Silicon Valley serves as a notable example where numerous technology firms and entrepreneurial teams engage in mutual learning and collaboration, significantly accelerating the emergence of new industries, such as information technology and AI. Furthermore, the knowledge spillover effects within the industrial ecosystem extend beyond cooperation between enterprises to encompass collaboration between academia and industry. Research outcomes from universities and research institutes are frequently applied by the industry, facilitating technological diffusion and industrial upgrading. Various entities within the industrial ecosystem collectively address changes in market demand through knowledge transfer and sharing. These endeavors form synergies for innovation, enhance overall competitiveness, and provide substantial knowledge and technological accumulation for the development of new quality productive forces.

3.2.3 Technology Diffusion and Industrial Upgrading

Technology diffusion serves as a crucial driving force for industrial upgrading. Particularly under the networked structure of the industrial ecosystem, new technologies are capable of spreading rapidly across various industrial entities, thereby facilitating the optimization and upgrading of the entire industry. According to technology diffusion theory, the dissemination of technology relies not only on the inherent advancement of the technology itself but is also influenced by social and economic environments. Through its open and collaborative mechanisms, the industrial ecosystem accelerates the diffusion of technology, enabling new technologies to be swiftly adopted across different industries and fields. The theory of industrial upgrading underscores the incremental nature of economic development stages. Technology diffusion achieves the transition from traditional industries to high-tech industries by driving the transformation of industrial structures. For instance, the widespread adoption of information technology has progressively driven the manufacturing sector towards intelligent and digital transformation. The rapid dissemination of various emerging technologies within the industrial ecosystem has facilitated enhancements in production efficiency and improvements in product quality. Technology diffusion entails not only the propagation of technology itself but also the movement of information and experience. Through innovation platforms and technology exchange mechanisms, entities within the industrial ecosystem are enabled to promptly acquire the latest technological advancements and market trends, thereby adjusting their strategic orientations promptly. It is evident that the industrial ecosystem promotes the optimization and upgrading of industrial structures via technology diffusion, offering sustained technological momentum for the development of new quality productive forces.

3.3 The Industrial Ecosystem Achieves Innovative Allocation of Factor Resources

At this stage, the resource allocation model within the industrial ecosystem is required to adapt to the rapid advancements in digitalization, informatization, and intelligence. Therefore, it is essential to re-examine the traditional resource allocation model and its limitations, and explore the introduction and integration of factors of production as well as the dynamic feedback loop mechanisms. In the era of the digital economy, the convergence of data, algorithms and traffic establishes a novel framework for the allocation of factors of production. Furthermore, the dynamic feedback mechanism of data–network–activity provides robust momentum for the recycling and continuous innovation of factors of production, thereby driving the in-depth optimization and sustainable development of the industrial ecosystem.

3.3.1 Data–Algorithm–Traffic: Introduction and Integration of Factors of Production

The introduction and integration of intangible factors, such as data, algorithms and traffic, offer a new avenue for innovative configurations within the industrial ecosystem. Schumpeter (2021) proposed the theory of innovation, positing that innovation extends beyond the mere application of new technologies to encompass the new combinations and expansion of factors. As a novel production factor, data is integrated with traditional factors and propelled by algorithms to facilitate the efficient allocation and utilization of traffic. Within the industrial ecosystem, the incorporation of data empowers enterprises to conduct precise market forecasts through big data analysis and enhance user engagement via personalized services. This process optimizes production models, mitigates decision-making uncertainties, and reduces transaction costs. Algorithms, as the core technology for data processing and application, enable enterprises to fully harness the potential of data, accurately align market demand with production resources, and promote the efficient flow and collaboration of new factors within the industrial chain. The technology augments the adaptability and competitiveness of the entire industrial ecosystem. Driven by the synergy of data and algorithms, traffic serves as a critical conduit for value transmission. Through intelligent data processing, it is precisely transformed into market traffic, ensuring efficient alignment between enterprises and the market. In the context of the e-commerce ecosystem, enterprises refine product recommendations via data-driven algorithms, thereby precisely capturing consumer traffic and maximizing the sales volume and profitability. Under the interaction of data, algorithms and traffic, platform enterprises enhance production efficiency on the supply side while attracting more user traffic through precise marketing on the demand side, thereby continuously reinforcing their market position. Furthermore, the industrial ecosystem drives the innovative allocation of factors of production through ongoing data accumulation and algorithm iteration, strengthens its responsiveness to dynamic market changes, and achieves self-regulation and evolution within the ecosystem.

3.3.2 Data–Network–Activity: Dynamic Feedback Loop of Factors of Production

The positive feedback loop mechanism of data–network–activity provides an efficient and dynamic resource allocation model for the innovative deployment of new factors of production. Firstly, as a critical production factor, data optimizes corporate production decisions and market forecasts in real-time through continuous collection and analysis, facilitating the efficient flow and reorganization of various resources. Precise alignment of factors of production driven by data lays the groundwork for network construction within the industrial ecosystem. This enables enterprises to identify potential partners and market demands and establish cross-industry and cross-regional collaborative networks. Secondly, the network plays a vital role in this mechanism. As big data analytics advances, enterprises are able to enhance the efficiency of resource mobility through network effects while increasing the value of products and services by expanding the participant base. The expansion of the network strengthens collaboration among upstream and downstream enterprises and facilitates the involvement of diverse entities, including research institutions and financial services providers, resulting in more cohesive partnerships. Finally, activities, as the third core component of the positive feedback mechanism, drive the effective execution of production and innovation initiatives. With the advancement of information networks, enterprises have gained greater flexibility in reallocating factors of production, optimizing resource utilization, and ensuring continuous innovation and dynamic progress across all segments of the industrial ecosystem. Through a data-driven feedback mechanism, the industrial ecosystem is able to promptly address changes in market demand, steadily enhance the efficiency and adaptability of resource allocation, and promote the ongoing refinement and evolution of the entire ecosystem. Regarding the relationships of data, network and activities, data consistently supplies new information to the network, which in turn contributes to the expansion of activities. These activities subsequently generate additional data, establishing a positive feedback loop that drives the efficient flow and innovative allocation of resources. This mechanism enables various entities within the industrial ecosystem to engage in closer collaboration, thereby offering a more effective pathway for the development of new quality productive forces.

4 Formation Mechanism of New Quality Productive Forces from the Industrial Ecosystem Perspective

From the industrial ecosystem perspective, the formation mechanism of new quality productive forces is both intricate and multifaceted, encompassing three critical subsystems—the innovation ecosystem, the business ecosystem, and the platform ecosystem. The innovation ecosystem transcends the boundaries of new quality productive forces by aggregating technological resources and promoting knowledge spillover. The business ecosystem emphasizes connecting market demand with technology supply, broadening the application scenarios of new quality productive forces through resource aggregation and innovative models. The platform ecosystem leverages digital technology to enhance the efficiency of resource allocation and factor interconnection, establishing a highly efficient and collaborative network for production factor allocation. These three subsystems collectively establish a dynamic and open industrial ecosystem, providing a systematic foundation for the formation and development of new quality productive forces.

4.1 Transcending the Innovation Boundaries of New Quality Productive Forces in the Innovation Ecosystem

The innovation ecosystem is complex and shaped by the interaction of various factors. Its core components encompass innovation entities, innovation resources, and innovation mechanisms. The ecosystem encourages cross-disciplinary exchanges, collaboration, and the unrestricted flow of factors of production, such as knowledge, technology, capital, and data, while expediting the development and application of diverse new technologies. From the perspective of innovation entities, enterprises serve as the primary drivers of technology innovation. They facilitate the creation and application of new technologies through external demand-driven factors and internal investments in research and development. Firstly, changes in market conditions and consumer preferences require enterprises to continuously adapt to emerging external demands. This adaptation encourages the development of novel technologies or the enhancement of existing ones to address evolving market needs. Secondly, through internal investments in research and development, enterprises establish research centers and attract highly skilled researchers to explore uncharted domains, devise innovative products, and refine current technologies, thereby furnishing both material and human resource support for technology innovation. As the entity of institutional innovation, the government creates an environment conducive to technology innovation and scientific progress by enacting and revising policies and laws. It establishes mechanisms for intellectual property protection and optimizes market access regulations, providing robust institutional support for the emergence and implementation of various new technologies. Research institutes and universities, as original innovation entities, undertake the critical mission of conducting fundamental and frontier scientific research. They are required to offer theoretical support for technology innovation by exploring novel scientific principles and technological pathways. Additionally, they provide essential human resource support for the innovation ecosystem by nurturing innovative talents and technical experts.

The core characteristics of the innovation ecosystem lie in collaboration and openness. Firstly, the innovation ecosystem pools resources, knowledge, and capabilities via collaborative innovation to collectively address challenges in the innovation process, mitigate innovation risks, cut innovation costs, and overcome limitations in innovation inherent to individual entities. This contributes to mutually beneficial outcomes while maximizing innovative outcomes, thereby expediting the expansion and transcendence of innovation boundaries for new quality productive forces. Secondly, through open innovation, the innovation ecosystem incorporates external resources, knowledge, and technologies. By sharing and exchanging innovation outcomes with external entities, it establishes an open innovation platform, breaking free from the constraints of traditional closed innovation models and further driving the expansion and transcendence of innovation boundaries for new quality productive forces. Essentially, the innovation ecosystem engages in multi-dimensional interactions through collaborative and open innovation, creating an environment that is conducive to technology innovation. Such an environment continuously generates new technologies. The most representative ones are disruptive and cutting-edge technologies. These technologies challenge conventional thinking, break technological barriers, involve cross-disciplinary integration across multiple fields, transcend the boundaries of traditional technology innovation, and achieve revolutionary breakthroughs. Globally, numerous cases have demonstrated how an innovative ecosystem drives new technologies to surpass the innovation boundaries. As a disruptive technology, the rapid advancement of AI benefits from a collaborative and open innovation ecosystem. Close collaboration among leading technology companies, research institutes, and government agencies has enabled continuous refinement of AI algorithms, substantial enhancement of computing power, and significant expansion of application scenarios. Looking ahead, it is essential to establish a collaborative and open innovation ecosystem, consistently stimulates the emergence and application of new technologies and transcends the innovation boundaries of new quality productive forces. Efforts are required to advance original and foundational technologies that enable the ecosystem to operate efficiently and sustainably, achieve groundbreaking technological advancements, and accelerate the formation of new quality productive forces.

4.2 Expanding Application Scenarios for New Quality Productive Forces in the Business Ecosystem

The business ecosystem refers to an interactive network comprising consumers, suppliers, major producers, financial companies, governments, and other stakeholders who collectively participate in and influence innovation, production, sales, and consumption activities within a specific application domain. The business ecosystem links enterprises, innovators, and users across different industrial chains, offering a platform for the collaborative development of upstream and downstream sectors. It facilitates resource sharing and efficient allocation, promotes the commercialization of innovation outcomes, and continuously broadens the application scenarios for new quality productive forces.

From the demand side, the business ecosystem drives technology innovation through consumer demand, thereby promoting the expansion of new quality productive forces across various application scenarios. In a consumer-centered economic framework, technology innovation is required to address the rapid market changes and the growing demand for personalization. For instance, the rapid emergence of the new energy vehicle market is attributed to the robust demand of consumers for environmentally sustainable and highly efficient modes of transportation. Enterprises across the relevant industrial chain within the business ecosystem are able to collaborate effectively, swiftly channeling resources for the development of innovative products. This process meets consumer demands while contributing to the incubation and growth of new industries. This innovation, driven by consumer demand, is further amplified within the business ecosystem through cross-industry synergy. Such dynamics accelerate the expansion of application scenarios for new quality productive forces in strategic emerging industries, including new energy vehicles. Furthermore, the expansion of application scenarios for new quality productive forces depends on the capacity of the business ecosystem to deliver customized and diversified products and services to consumers. With the growing demand for personalized experience among modern consumers, the business ecosystem leverages open technology platforms and multi-party cooperation to promptly address and fulfill these personalized requirements. For instance, the rapid advancement in smart home and smart healthcare sectors is primarily attributed to the ability of the business ecosystems to integrate technologies and services across diverse fields. Such integration achieves cross-sector collaboration and thereby enables a broader range of personalized application scenarios. Evidently, the business ecosystem facilitates the efficient integration of resources and technologies from various fields, driving the continuous expansion of application scenarios for new quality productive forces and establishing operational mechanisms propelled by consumer demand.

From the supply-side perspective, the business ecosystem offers extensive technological and market support for the development and application of new quality productive forces by integrating innovation resources. The business ecosystem pools innovation resources through an open innovation platform, enabling the intersection and fusion of technologies and resources from different industries and fields to generate entirely new application scenarios. In the smart city field, intelligent management systems have been developed across transportation, energy, healthcare and other sectors through the integration of technologies, such as big data, the Internet of Things (IoT), and cloud computing. These systems have enhanced the efficiency of public services while contributing to the rise of numerous emerging industries. The business ecosystem has advanced the ongoing application and iterative improvement of new quality productive forces by offering an innovation-driven environment that encourages multi-party participation. Moreover, the business ecosystem drives the expansion of application scenarios for new quality productive forces through the optimization and upgrading of supply chains. The intelligent transformation of modern supply chains depends on collaborative innovation and information sharing across all segments of the business ecosystem. The adoption of intelligent logistics technology has enhanced logistics efficiency, reduced operational costs and refined the operational model of supply chains. For instance, the IoT and blockchain technology allow enterprises across the supply chain to share production and logistics data in real time, enabling more precise scheduling and enhanced collaboration. Through the optimization of intelligent supply chains, the business ecosystem has successfully advanced the expansion of application scenarios for new quality productive forces across multiple fields, including logistics, manufacturing, and retail, driving the overall digital and intelligent transformation of the industrial chain. Whether driven by consumer demand on the demand side or resource aggregation on the supply side, the synergistic interaction between demand and supply creates a self-reinforcing cycle within the business ecosystem. It consistently advances the application scenarios of new quality productive forces toward broader fields and deeper levels.

4.3 Optimizing Factor Allocation for New Quality Productive Forces in the Platform Ecosystem

The platform ecosystem is a novel industrial system that is centered around digital platforms and leverages special factors, such as data, algorithms, and traffic, to establish a multi-product and service framework spanning various industries (Li & Zhang, 2024). Through collaborative engagement with suppliers, developers, consumers, and other stakeholders, this ecosystem integrates factors like transactions, collaboration, rules, and governance, thereby deepening industrial integration and transformation. At the current stage of economic development, the platform ecosystem has become a pivotal force in optimizing the allocation of new quality productive forces, demonstrating significant influence in multiple areas, such as supply-demand alignment, resource aggregation, and cross-sector collaboration. Regarding supply-demand alignment, the platform ecosystem notably broadens the scope of trade by enhancing the matching efficiency between service supply and demand. By providing a variety of new business forms and services, the platform addresses the increasingly diverse needs of consumers (Liu & Xia, 2021). This process generates opportunities for the supply side to explore the potential of service consumption through the platform ecosystem, thereby facilitating market growth. In terms of resource aggregation, the platform leverages advancements in digital technology to establish an open and shared environment that connects diverse participants, such as suppliers, consumers, and service providers, thereby forming a mutually beneficial economic community. The platform ecosystem efficiently aggregates various resources, ensures their optimal allocation and utilization, and drives the transformation and upgrading of industries. By pooling multi-party resources and enhancing information flow, the platform ecosystem restructures traditional industrial frameworks, providing fertile ground for the emergence of new quality productive forces and the integration of new factors. Regarding cross-sector collaboration, the platform ecosystem demonstrates its strength by responding flexibly to market dynamics, fostering dynamic interactions among various resources, and further advancing the sustainable development of industries. The platform ecosystem has achieved cross-sector collaboration by dismantling industry barriers and secured the flow and sharing of factors of production, such as capital, technology, and talent, across a broader scope. The effective allocation of various factors has notably enhanced resource utilization efficiency, thereby expediting the formation of new quality productive forces.

As the core driver of competition within the platform industry ecosystem, data factors are utilized with algorithms to ultimately establish a data–algorithm–traffic competitive landscape. Through optimization in data, algorithms, and traffic, the platform ecosystem has realized innovative allocation of factors of production. Firstly, data assumes a pivotal role in the platform ecosystem, which facilitates the release of value throughout the entire process of production, transaction, consumption and regulation through its natural attributes and technological-economic features (Xia, 2023). By collecting, consolidating, and analyzing vast amounts of data, the platform gains profound insights into user demands, market trends, and industrial dynamics, offering precise decision-making support and market forecasts for enterprises and innovators. Based on data analysis, the platform precisely identifies user demands to optimize product design and service strategies, thereby enhancing the allocation efficiency of factors of production. Secondly, algorithms play an important role in the platform ecosystem. The application of intelligent algorithms equips the platform with personalized recommendations, accurate pricing, and intelligent services, improving the alignment between products and services and enhancing user experience. For instance, an e-commerce platform utilizes algorithms to analyze user behaviors and preferences and recommend products that align with individual tastes. This increases transaction volumes and order conversion rates while optimizing the allocation efficiency of factors of production. Thirdly, traffic is another key factor within the platform ecosystem. The platform attracts and directs traffic, offering enterprises and innovators access to a wider market and generating additional business opportunities. By effectively directing traffic and refining user experience, the platform achieves precise allocation and optimal utilization of factors of production, advancing substantial productivity growth and robust industrial development. In short, the platform ecosystem promotes the efficient allocation of new quality productive forces factors through the optimization of data, algorithms, and traffic.

5 Paths for Developing New Quality Productive Forces from the Industrial Ecosystem Perspective

From the industrial ecosystem perspective, the development of new quality productive forces necessitates systematic planning and diversified pathways. First, it is essential to establish a comprehensive industrial ecosystem based on synergy, agglomeration, and network effects for the deep integration of new quality productive forces within the ecosystem. Second, it is beneficial to leverage the dual driving forces of technology innovation and institutional innovation, propelling industrial upgrading through both technological breakthroughs and policy optimization. Third, it is crucial to deepen the integration of innovation, industrial, capital, and talent chains. This contributes to resource aggregation and coordinated development, thereby enhancing the coherence and adaptability of the ecosystem.

5.1 Building a System

A well-established industrial ecosystem plays an indispensable role in advancing the development of new quality productive forces. The industrial ecosystem and new quality productive forces reinforce the development of each other, giving rise to multiple interactive mechanisms, such as synergy, agglomeration, and network effects. Firstly, synergy serves as the core of interaction between the industrial ecosystem and new quality productive forces. The ecosystem facilitates the generation of new quality productive forces by integrating the resources and capabilities of diverse entities, encouraging communication and collaboration among innovation entities, and promoting the industrial application and scaling of new technologies. Secondly, the agglomeration effect is particularly pronounced within the ecosystem. The industrial ecosystem attracts various innovation entities through the establishment of open innovation platforms, achieving efficient agglomeration of innovation resources. The agglomeration of capital, technology, talent, and knowledge has expedited the sharing of information and experience, advanced technology transfer and industrial upgrading, and enhanced overall productivity levels. Finally, the network effect plays an indispensable role in the development of the industrial ecosystem. As the number of participating entities grows, the innovation capability and market competitiveness of the ecosystem are significantly strengthened. The emergence of digital platforms has enhanced interactions between users and enterprises. By leveraging user feedback and data sharing, enterprises are able to refine their products and services, thereby reinforcing the market responsiveness and adaptability of new quality productive forces.

From a policy standpoint, developing new quality productive forces necessitates systematic thinking and a comprehensive perspective. Therefore, it is necessary to build an industrial ecosystem aligned with the complexities of modern economies. To establish a robust industrial ecosystem, efforts are required to focus on subsystems, such as the innovation ecosystem, the application ecosystem, and the platform ecosystem. It is imperative to adopt ecological, integrative, and network-oriented thinking to shift traditional industry development paradigms and drive high-quality, sustainable economic growth. First, it is crucial to strengthen governmental support for the innovation ecosystem through the introduction of incentive mechanisms that promote collaboration among innovation entities and resource sharing. This includes increasing investment in the development of innovation platforms, encouraging industry-university-research partnerships, and advancing the transformation of scientific and technological achievements. Second, the government is advised to improve the business ecosystem through policy guidance and rational allocation of resources. Particularly in the development of strategic emerging industries and future industries, policy tools, such as special funds and financial support, may be utilized to stimulate the widespread adoption and sustainable advancement of new quality productive forces. Third, the government is recommended to vigorously support the establishment of a platform ecosystem, with efforts directed at eliminating institutional barriers impeding the development of new quality productive forces. Additionally, it is essential to establish an efficient market system and a flexible factor allocation mechanism to ensure the seamless flow and effective diffusion of new quality productive forces within the industrial ecosystem.

5.2 Leveraging the Dual Driving Forces

The dual driving forces of technology innovation and institutional innovation serve as the two primary sources of momentum for the development of new quality productive forces (Xia & Li, 2024). These two elements complement one another, collectively advancing the overall development of industries. Firstly, technology innovation acts as the core driving force behind the development of new quality productive forces, contributing to the emergence of new industries, business models, and drivers of growth. Within a healthy industrial ecosystem, close interactions are established among enterprises, research institutes, governments, and social organizations for the sharing of resources, knowledge, and technologies. Such collaboration expedites the transformation of innovation outcomes from theoretical concepts into practical applications. It is imperative to address the bottleneck issues associated with key technologies by firmly prioritizing independent innovation as the central focus. Vigorous efforts are required to advance the research and development of core technologies in key fields, minimize reliance on external technologies, and achieve self-reliance and strength in science and technology. Continuous technology innovation is essential to drive the enhancement of total factor productivity, realize transformations in quality, efficiency, and momentum, and further expand new quality productive forces. Secondly, institutional innovation offers the external environment and framework required for technology innovation. In the context of rapidly evolving markets and technologies, traditional systems may struggle to meet the demands for developing new quality productive forces. The establishment of the industrial ecosystem urges stakeholders to reassess existing systems. Institutional innovation is advanced through feedback and practical experience, dismantling barriers that impede the growth of emerging industries and new models while providing policy support and a favorable market environment for the diffusion of new technologies. Furthermore, the interplay between technology innovation and institutional innovation is significant—technology innovation offers a practical foundation for institutional innovation, which creates room for technology innovation in turn. The synergy between the two embodies the positive interactions among various entities within the industrial ecosystem, while facilitating mutually beneficial outcomes for all participants in the ecosystem.

In the development of new quality productive forces, technology innovation and institutional innovation complement each other, jointly forming the core driving force of the industrial ecosystem. Through policy support and institutional frameworks, the government ensures the healthy development of the industrial ecosystem, thereby fully enhancing the development of new quality productive forces. Regarding technology innovation, it is recommended to establish a special innovation fund to support research and development activities of start-ups and technology-oriented small and medium-sized enterprises. Such measures are expected to alleviate funding shortages while effectively motivating these enterprises to explore core technologies in key fields, thereby expediting the transformation and application of technological achievements. In addition, it is necessary to establish an incentive mechanism for technology transfer and achievement transformation, and encourage in-depth collaboration between research institutions and enterprises, so as to ensure the faster entry of innovation outcomes into the market. Moreover, it is advised to build common technology platforms and pilot testing platforms, where resources are pooled to make breakthroughs in cutting-edge technologies, form technology clusters, and enhance the overall competitiveness of the industry. In terms of institutional innovation, the government needs to streamline approval processes, optimize market access mechanisms, and eliminate monopolies and barriers. These endeavors will reduce entrepreneurial barriers and stimulate market vitality. Specific measures include simplifying administrative approval procedures and providing one-stop services. This will result in the continuous emergence of innovative activities. Furthermore, for emerging industries and factors, particularly data factors, it is imperative for the government to promptly refine relevant laws and regulations, clarify data property rights, and establish security management systems to unlock the potential of data in driving economic growth.

5.3 Promoting the Integration of Four Chains

The deep integration of innovation, industrial, capital, and talent chains serves as the fundamental pathway for constructing a robust industrial ecosystem and acts as a pivotal component in expediting the formation of new quality productive forces. Throughout the process, the innovation chain functions as a guiding factor, advancing the upgrading and transformation of the industrial chain via technology innovation and knowledge transfer. The modernization and expansion of the industrial chain, in turn, supply market demand and resource support to the innovation chain, thereby contributing to a mutually beneficial interaction between the industry and innovation. The capital chain ensures financial support for both innovation and industrial chains by refining capital allocation. This mechanism drives the seamless transformation of technological achievements while augmenting the ongoing enhancement and resilience of the industrial chain. The talent chain infuses the entire ecosystem with intellectual resources and innovative momentum. Advanced talent development and recruitment efforts propel the harmonized progression of the innovation and industrial chains, enabling leapfrog development of technologies and the industry with the support of the capital chain. Only through the deep integration of four chains will the sustainable development of new quality productive forces be effectively advanced.

To ensure the integration of four chains and maximize their synergy, systematic policy measures are required (Liu, 2023). Within the innovation chain, significant emphasis is placed on general technologies and fundamental research. It is necessary to support the research and development of key generic technologies and encourage the industrial application of technological achievements. Additionally, it is recommended to utilize science and technology innovation platforms, along with industry-university-research collaboration mechanisms, to facilitate the efficient flow of knowledge, technology, capital, and other critical factors, thereby enhancing the innovation ecosystem. Furthermore, it is imperative to strengthen, supplement, extend, and refine the industrial chain to address risks associated with broken, missing, or blocked links. It is crucial to fortify weak links, further expand strong links, implement industrial cluster development strategies, and establish an early warning system for risks along the industrial chain. These measures aim to enhance the resilience and competitiveness of the industrial and supply chains, elevate their modernization standards, and improve self-reliance and control capabilities (Zhu et al., 2024). In the capital chain, it is suggested to deepen capital market reform and promote financial innovation, scientifically allocate resources and guide investments toward key industries, and direct social capital toward strategic emerging industries and future industries, so as to ensure efficient capital flows. The government is advised to encourage venture capital and equity investment through policy support, particularly for high-risk, high-return technology innovation projects, thereby strengthening the capital chain's role in supporting innovation and industrial upgrading. Regarding the talent chain, innovation-driven development is fundamentally driven by talents, a crucial resource for developing new quality productive forces. It is important to adhere to the strategy of invigorating China through science and education and the workforce development strategy, promoting the integration of education, technology, and talents to establish a virtuous cycle development model. The focus lies in cultivating a new type of workforce, including innovative talents with strategic vision and application-oriented talents proficient in utilizing new means of production. These endeavors will provide intellectual support and technological reserves for the development of new quality productive forces.

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