

Research on the Synergistic Transformation of Digitalization and Greenization in Manufacturing Empowering the Development of New Quality Productive Forces

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Abstract: Against the backdrop of the deep integration of global industrial transformation and the dual carbon strategy, the synergistic transformation of digitalization and greenization has become the core driving force for cultivating new quality productive forces in manufacturing. Based on a theoretical perspective, this paper clarifies the intrinsic connection between digital-green synergy and new quality productive forces, explores the mechanisms by which synergistic transformation empowers new quality productive forces, examines the practical challenges in the current process of digital-green synergistic transformation in manufacturing, and proposes optimized transformation pathways grounded in industrial development realities. The aim is to promote manufacturing to break through transformation barriers, activate development momentum through deep digital-green integration, and contribute to the steady, high-quality development of the real economy.

Keywords: manufacturing; digitalization; greenization; new quality productive forces

1. Introduction

As the technological revolution and industrial transformation continue to accelerate, the dual carbon strategy steadily advances, and the development strategy for new quality productive forces is implemented, manufacturing has entered a new stage of intelligent and low-carbon integrated development. As the foundation of the real economy, manufacturing is the core carrier for cultivating new quality productive forces, and the traditional extensive development model can no longer meet current development demands. Digitalization and greenization are not isolated from each other but rather form a mutually reinforcing whole. An in-depth study of the logic and pathways by which the two synergistically empower new quality productive forces can not only enrich relevant theoretical achievements but also provide practical reference for enterprise transformation and industrial policy formulation, thereby consolidating the foundation for high-quality development in manufacturing.

2. Core Concepts and Intrinsic Logic

(1) The Connotation and Characteristics of New Quality Productive Forces.

New quality productive forces take technological innovation as the core driver, embodying the characteristics of high technology, high efficiency, and high quality, with the primary goal of enhancing total factor productivity, and achieving industrial upgrading through technological innovation and business format innovation. This form of productive forces adheres to the green and low-carbon development ethos, balances economic, ecological, and social benefits, abandons the traditional extensive development model, aligns with the overall sustainable development agenda, breaks through the limitations of old-style productive forces, meets the practical needs of manufacturing's long-term transformation and upgrading, and represents the core development orientation for industrial quality improvement and efficiency enhancement in the new era.

(2) The Mechanism of Synergistic Development between Digitalization and Greenization.

Digitalization and greenization empower each other bidirectionally and advance in synergy. Digital technologies can precisely control production energy consumption, account for carbon emissions, optimize resource allocation, effectively reduce enterprises' green retrofit costs, and serve as an important booster for green transformation. Meanwhile, the rigid requirements of low-carbon development continuously generate new application scenarios for digital technologies, compel digital infrastructure and digital industries to transition toward low-carbon models, and drive the R&D and implementation of emerging products such as green computing power and intelligent environmental protection systems, thereby broadening the development space for digital transformation and fostering a virtuous development pattern of mutual promotion and co-progress between the two.

(3) The Compatibility between Digital-Green Synergistic Transformation and New Quality Productive Forces.

The development of new quality productive forces focuses on three major directions — technological breakthroughs,

factor allocation, and industrial upgrading — which are highly compatible with digital-green synergistic transformation. "Digital-green synergy" emphasizes that enterprises should not only advance digitalization and greenization simultaneously, but also enhance their digital resource allocation efficiency and green total factor productivity through deep integration of the two, thereby promoting the restructuring of production relations and the optimization and upgrading of productive forces, ultimately achieving high-quality development [1]. The synergistic efforts of both can not only accomplish technological innovation and upgrading in manufacturing but also optimize the overall industrial development structure, comprehensively meeting all core requirements for cultivating and strengthening new quality productive forces, making it the optimal development pathway for manufacturing to cultivate new driving forces through industrial transformation.

3. The Internal Mechanisms by Which Synergistic Transformation Empowers the Development of New Quality Productive Forces

(1) Technological Innovation Driving Mechanism.

Technological innovation is the core foundation for the formation of new quality productive forces. Digital-green synergy can promote the deep integration of digital intelligent technologies and green low-carbon technologies, catalyze various new types of fusion technologies, break through the technological limitations of traditional manufacturing, and achieve disruptive technological innovation. New fusion technologies progressively replace backward production processes, driving the dual upgrading of manufacturing production models toward intelligence and low-carbon orientation, continuously improving the technological system of new quality productive forces, helping manufacturing break free from low-end competition by relying on core technologies, and consolidating the foundation for industrial innovation and development.

(2) Factor Allocation Optimization Mechanism.

Traditional manufacturing suffers from problems such as poor circulation of production factors and resource misallocation, which severely constrain the enhancement of production efficiency. Different production factors exhibit significant differences in the efficiency and effectiveness they demonstrate in promoting the digital transformation and green transformation of manufacturing enterprises [2]. Data have become a new type of production factor, breaking down industrial chain information barriers through the industrial internet and promoting the efficient circulation of various traditional production factors. At the same time, market orientation guides high-quality resources to converge in the green manufacturing sector, comprehensively enhancing total factor productivity and laying a solid factor allocation foundation for the development of new quality productive forces.

(3) Industrial Structure Upgrading Mechanism.

Digital-green synergistic transformation continuously compels traditional manufacturing to transform and upgrade, accelerates the exit of high-energy-consumption and low-value-added backward production capacity from the market, and drives industries toward high-end and green-oriented development. In the process of integrated development, new business formats such as carbon asset management and green intelligent services are continuously generated, effectively extending the manufacturing industry chain and enhancing overall industrial added value. The continuously optimized industrial layout keeps expanding the development space for new quality productive forces, building a modern manufacturing industrial system that is innovation-driven, green, and low-carbon.

4. Practical Dilemmas Facing the Synergistic Transformation of Manufacturing

(1) High Transformation Costs.

The early-stage equipment retrofits, platform construction, and other capital investments required for the digital-green synergistic transformation of manufacturing are considerable. Small and medium-sized enterprises, constrained by weak financial resources and financing difficulties, find it hard to bear the high costs of transformation. Moreover, synergistic transformation takes effect slowly, making it difficult to achieve cost reduction and efficiency gains in the short term, and enterprises struggle to balance their transformation investments with actual returns. Out of operational efficiency considerations, many enterprises adopt a wait-and-see attitude and lack the willingness to proactively transform, thereby slowing the overall pace of digital-green synergistic transformation across the entire industry.

(2) Impeded Data Circulation.

At the current stage, the phenomenon of data silos is prevalent in manufacturing. Data within enterprises and across upstream and downstream segments of the industrial chain are difficult to interconnect and share, preventing digital technologies from fulfilling their role in coordinating low-carbon production across the entire industrial chain. Meanwhile, unified standards for carbon footprint accounting, green production assessment, and other related benchmarks have yet to be established within the industry, and various green development norms remain incomplete, resulting in prominent

green barriers within the industry. Enterprises lack unified reference standards for their transformation, their development direction remains ambiguous, and this is not conducive to advancing standardized, synergistic transformation across the whole industry.

(3) Weak Core Technologies.

China's manufacturing sector still exhibits weaknesses in certain high-end intelligent equipment and low-carbon core technologies, with insufficient independent R&D capabilities in key technologies and a relatively high degree of external dependence, thereby constraining deep transformation and development. The talent cultivation system is relatively monolithic, and the industry is extremely short of interdisciplinary talent who possess knowledge of both digital technologies and green manufacturing. The gap in professional talent makes it difficult for enterprises' digital-green synergistic transformation plans to be implemented, resulting in a disconnect between technology application and enterprises' actual production and operations.

5. Practical Pathways for Synergistic Transformation Empowering the Development of New Quality Productive Forces

(1) Centering on Enterprises as the Main Body, Advancing Transformation in a Tiered Manner.

Clarify the principal role of enterprises in transformation and implement a differentiated transformation development model. Industry-leading enterprises should play a leading role, integrate industrial chain resources, build green and intelligent supply chains, and drive upstream and downstream enterprises to transform together. Small and medium-sized manufacturing enterprises should align with their own development realities, abandon large-scale retrofit models, pursue a lightweight transformation pathway via cloud-based sharing platforms, focus on niche areas to complete intelligent and low-carbon retrofits, steadily accumulate transformation advantages, and cultivate endogenous development momentum.

(2) Improving Policies and Strengthening Support.

The government should continuously optimize industrial support policies, implement fiscal and tax reductions and targeted subsidy policies, and alleviate the transformation pressures on enterprises. The range of green financial service products should be enriched, and financing channels for enterprises' low-carbon transformation should be broadened to solve enterprises' funding difficulties. The carbon emission trading market should be further improved, guiding enterprises to proactively conserve energy and reduce emissions through market-based means. High-quality production factors of all types should be coordinated and allocated, tilting toward enterprises with outstanding transformation performance, to comprehensively create a high-quality and stable industrial transformation policy environment.

(3) Building Synergies and Cultivating Talent.

Enterprises should regard talent as the core driving force behind digital and green transformation, particularly in the intersecting fields of digital technology and green development [3]. A collaborative innovation platform integrating industry, academia, and research should be established, along with demonstration parks and public service platforms for digital-green synergistic transformation, so as to provide enterprises with professional transformation services. University talent cultivation programs should be optimized by introducing interdisciplinary integrated courses, thereby channeling interdisciplinary professionals into the industry in a targeted manner. Enterprises should conduct regular on-the-job skills training to enhance existing employees' capabilities in digital application and low-carbon production, comprehensively addressing talent gaps across all dimensions and building sufficient human resource reserves for the synergistic transformation of manufacturing and the development of new quality productive forces.

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