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The Integration of "Three Modernizations" under the Dual Carbon Goal: A Study on the Green Transformation Path of the Modern Industrial System to Consolidate the Foundation of the Real Economy

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Abstract

Purpose – The purpose of this paper is to focus on the core proposition of green transformation of the real economy, which is enabled by the integration of green, intelligent and integrated "three modernizations" under the dual carbon goal, and solve the practical bottlenecks such as the dilemma of enterprise transformation and the lack of industrial coordination, so as to provide support for consolidating the foundation of the real economy and building a modern industrial system.

Design/Methodology/Approach – Based on the theories of green development and industrial integration, the collaborative mechanism of "three modernizations" is systematically deconstructed, and the four-dimensional transformation path of "industry region factor system" is constructed in combination with policy guidance and practice status.

Findings – This paper studies the dynamic logic of the mutual empowerment of the "three modernizations", and makes it clear that the transformation has achieved phased results, but still faces multiple constraints such as technical costs, standard barriers, and talent shortages.

Research Implications – In the management of the real economy, it is necessary to promote the deep integration of "three modernizations" and achieve its green and high-quality development through the simultaneous advancement of industrial upgrading and emerging industry cultivation, the coordination of regional differentiated development, the precise supply of factors, and the synergy of systems.

Keywords: Double carbon target; "Three modernizations" integration; Real economy; Green transformation
JEL Classifications: Q58,O14,L52

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I. Introduction

1. Research Background and Problem Proposal

The dual carbon goal is China's strategic choice under the reconstruction of the global climate governance system. It is also the core fulcrum of high-quality development defined in the 2025 State Council's dual carbon work report, bearing the dual mission of international responsibility and domestic transformation. As the ballast stone of the national economy, the real economy has become an urgent proposition in the era of tighter resource and environmental constraints and the superposition of the digital wave. The coordinated promotion of industrial system modernization and green transformation has become an urgent proposition(Qian Liu, Yuanji Zhang, Xiaoqing Sun, 2025). The efficiency bottleneck and ecological weakness of the traditional development model need to be solved. Green, intelligent and integrated integration, with technology collaboration and business innovation as the core, has become the key to activate new productivity and solve the deep contradictions of industrial transformation, providing systematic solutions for the green transformation of the real economy (Li Jing, Zhang Hui, Han Qing, 2025).

Under the guidance of policies and driven by the market, the transformation practice has achieved phased results: at the policy level, the "1+n" policy system of carbon peaking and carbon neutralization has been continuously improved. In 2025, the transformation mechanism from dual control of energy consumption to dual control of carbon emissions will be officially implemented, and a full chain system guarantee will be built; At the practical level, the intelligent transformation has been promoted in depth, the digital transformation rate of Industrial Enterprises above designated size has been steadily increased, and the enabling effect of industrial Internet platform has been continuously released; The green development has achieved remarkable results, with the installed capacity of non fossil energy accounting for 60.9%, the number of green plants exceeding 6000, and the national carbon market covering 60% of the total carbon emissions (Hu min, 2025); The trend of integration has accelerated, the collaborative ecology of new energy industrial clusters and "green power+" has gradually taken shape, and the vitality of cross-border industrial integration has burst out(Liu, Q., Xiang, R., Yang, Q., & Haq, S. ul., 2025).

However, in the process of transformation, multiple bottlenecks still restrict the in-depth promotion: at the enterprise level, SMEs are generally faced with the dilemma of "not wanting to turn, not daring to turn, and not being able to turn". The four deficiencies of technology, talent, experience, and trial and error ability constitute the transformation obstacles; At the industrial level, the digital level of the upstream and downstream of the industrial chain is unbalanced, the standardization process is lagging behind, the commercialization cost of green technology is high, and the return cycle of intelligent investment is long, which restricts the efficiency of collaborative transformation (Lushan, 2025); At the policy level, there is a dislocation between the inclusive policy and the precise needs of enterprises, and the cohesion and synergy of the "three modernizations" related policies are insufficient; At the basic level, the quality of carbon accounting data is uneven, and compound talents who are familiar with industrial laws and AI and green technology are scarce, which has become the core

short board for the in-depth promotion of transformation (yeyanfei, 2025). The above contradiction directly points to the key sticking point of the green transformation of the real economy enabled by the integration of "three modernizations", which needs to be solved through systematic research.

2.Research Review

2.1 Research status at home and abroad

Domestic research has formed a multidimensional exploration context around the core proposition of the dual carbon goal and industrial transformation. In the field of industrial green transformation under the dual carbon goal, the academic community focused on the evolution logic of the "1+n" policy system of carbon peaking and carbon neutralization, focused on analyzing the institutional innovation of the transformation from dual control of energy consumption to dual control of carbon emissions in 2025, discussed the combined application and synergy of policy tools, carried out research on emission reduction potential around clean energy substitution, energy conservation and carbon reduction, and built an effectiveness evaluation system including carbon emission intensity, energy efficiency and other indicators. In the research on the integration of intelligence and greening, the single dimension research has formed a mature theoretical framework, but there is a clear separation - intelligence research focuses on efficiency improvement, and greening research focuses on low-carbon goals. Although the research on the integration of two is gradually starting, it mostly stays at the level of Technology tool superposition, and does not deeply deconstruct the two-way collaborative logic. The research on Integration Oriented Industrial Synergy focuses on cross industry resource optimization and cross regional policy synergy, affirming the role of integration in cost sharing and emission reduction and efficiency enhancement, but lacks deep correlation with the upgrading of modern industrial system and the consolidation of the foundation of the real economy.

In the context of global climate governance, foreign research shows the characteristics of technology driven and international collaboration. In the research of dual carbon related policies, scholars focused on the differentiated design of national policies under the framework of the Paris Agreement, focused on the implementation effect of cross-border policy tools such as the carbon border regulation mechanism, and explored the international carbon pricing synergy and technology transfer mechanism (Zhong Yan, 2024). Based on the development of industry 4.0, the research on the integration of intelligence and greening focuses on the in-depth application of AI, digital twins and other technologies in low-carbon production, emphasizing the role of technology integration and innovation in improving emission reduction efficiency, but paying insufficient attention to the cost constraints and standard barriers in the integration process. The research on Industrial Synergy focuses on the low-carbon reconstruction of the global value chain, and explores the mechanism of collaborative emission reduction of transnational industrial chain and the mode of "low-carbon cluster+digital platform". However, the research is mostly based on the industrial situation of developed countries, and lacks consideration of the suitability of industrial transformation in developing countries, and does not involve the

overall exploration of the systematic integration of "three modernizations".

2.2. Research review at home and abroad

Research at home and abroad has accumulated rich achievements in the fields of policy design, technological innovation and collaborative mode of industrial transformation under the dual carbon goal, forming a complementary research pattern. Domestic research closely follows China's policy guidance and transformation practice, and has distinctive localization characteristics in terms of local policy interpretation and regional industrial collaboration, which provides practical support for understanding the characteristics of the transformation stage; With the advantages of technological innovation and a global perspective, foreign research has accumulated theories in terms of international policy coordination and high-end technology integration, highlighting the core logic of technology driven transformation. The two types of research jointly verified the core values of greening, intelligence and integration in industrial transformation, and clarified the dual driving role of policy guidance and technological innovation, which laid an important theoretical foundation for this study.

There is still a significant gap in the existing research, which is difficult to fully respond to the core proposition of "three modernizations" integration enabling the green transformation of the real economy. First, the theoretical framework for the systematic integration of the "three modernizations" is missing. Domestic and foreign studies are mostly focused on a single dimension or the integration of two, and the three are not regarded as an organic whole, lacking a systematic deconstruction of the interactive logic and collaborative mechanism. Second, the research on the correlation mechanism with the consolidation of the foundation of the real economy is insufficient. The existing achievements either focus on the environmental and economic benefits of the transformation, or explore the development path of the real economy in isolation, and fail to reveal the improvement mechanism of the integration of "three modernizations" on the toughness of the industrial system and the competitiveness of the real economy. Third, there are limitations in the adaptability of research perspective and practice. Domestic research focuses on policy interpretation and single technology exploration, and lacks systematic engineering thinking; Foreign research is not well suited to the situation, and both types of research pay insufficient attention to the practical bottlenecks such as enterprise transformation dilemma, cost constraints, talent shortage, which leads to the disconnection between theory and practice. Based on this, this paper, based on the practice of China's industrial transformation, takes the systematic integration of "three modernizations" as the core perspective, focuses on the goal of consolidating the foundation of the real economy, and makes up for the deficiencies of existing research in systematicness, relevance and practicality.

II. Theoretical review

1. Green development theory

The green development theory is a systematic development theory that takes into account economic growth and ecological protection. The core meaning is to break the traditional cognition of "the opposition between development and environmental protection", take the synergy of pollution reduction and carbon reduction as the core guidance, realize the dynamic balance between economic activities and ecological carrying capacity through technological innovation, system design and model reconstruction, and finally achieve the effective transformation of the value of ecological products. Its core features are systematization, synergy and value orientation, emphasizing the transformation from a single emission reduction to the collaborative promotion of "pollution reduction, carbon reduction and green enhancement", extending from end-of-life governance to green management and control in the whole life cycle, highlighting the unity of ecological benefits, economic benefits and social benefits.

Under the background of double carbon goals, the practical value of the theory is mainly reflected in the action guide for green transformation of industry: on the one hand, it provides theoretical support for policies such as double control of carbon emissions and carbon market construction, and guides the combination of command-based and market-based policy tools; On the other hand, it provides direction guidance for clean energy substitution, energy conservation and carbon reduction technology research and development, and promotes the transformation of the industry from "high carbon growth" to "low carbon and quality improvement". Its deep significance lies in solving the development dilemma of "high energy consumption, high emissions and low efficiency" of the traditional real economy, and making green the bright background of high-quality development of the real economy through the value realization mechanism of ecological products. The practical impact of this theory has deeply reshaped the logic of industrial development, promoted the upgrading of policy design from "fragmentation" to "systematization", guided enterprises to internalize green transformation into core competitiveness, and injected ecological toughness into the consolidation of the foundation of the real economy.

2. Industrial convergence theory

The theory of industrial convergence is derived from the dual drive of technological innovation and market demand upgrading. It refers to the breaking of border barriers between different industries, links within industries or different elements, and the formation of a new industrial form of cross-border collaboration and complementary advantages through technology penetration, business innovation and value chain reconstruction. Its core characteristics are cross-border, innovative and enabling. With digital technology and new energy technology as the key link, it promotes the transformation of industry from "single business" to "multiple integration", and the upgrading from "linear correlation" to "network collaboration" (Wang Hao, Jiang Jinhe,

2025).

At the current stage of development, the core use of this theory is to provide methodological support for the integration of "three modernizations": it not only guides the deep integration of digital economy and real economy, but also promotes the penetration of intelligent technology into the whole industrial chain; It also helps the coupling development of new energy industry and high energy carrying industry, producer services and manufacturing industry, and builds a collaborative ecosystem of "green power+". Its theoretical significance lies in breaking through the limitations of single industry transformation, activating new productivity through factor restructuring and optimal allocation of resources, improving the stability and competitiveness of the industrial chain supply chain, and laying a solid foundation for the construction of a modern industrial system. The practical impact of this theory is reflected in reshaping the industrial competition pattern, promoting the transformation of traditional industries to high-end, intelligent and green ones, promoting the formation of emerging industrial clusters, consolidating the core position of the real economy from the industrial structure level, and providing a path for cross-border collaboration for the transformation under the dual carbon goal.

3. System engineering theory

System engineering theory is an interdisciplinary theory based on integrity, relevance and dynamics. Its core is to regard the research object as a complex system composed of multiple interacting and interrelated elements, and realize the optimization of the overall function of the system through overall planning and collaborative regulation. Its core characteristics are global, dynamic and collaborative, emphasizing the abandonment of the thinking of "looking at a single element in isolation", paying attention to the organic connection and dynamic adaptation of various parts of the system, taking into account short-term goals and long-term benefits, local interests and overall interests.

The core use of this theory in this paper is to build a collaborative mechanism for the integration of "three modernizations" and to break the limitations of the single promotion of intelligence, greening and integration: on the one hand, it guides the overall planning of multi-level elements such as enterprises, industries, regions and systems, and coordinates multiple driving forces such as technological innovation, policy support and factor supply; On the other hand, it provides a theoretical tool to resolve the bottlenecks such as the lack of policy coordination and the imbalance of the industrial chain in the integration of the "three modernizations", so as to achieve the dual improvement of transformation efficiency and basic toughness. Its deep significance lies in providing systematic thinking for the transformation of the real economy under the dual carbon goal, avoiding the fragmentation and waste of resources in the transformation process, and ensuring that the green transformation has both "speed" and "foundation". The practical impact of the theory is reflected in optimizing the transformation path design, promoting the transformation of the policy system from "single orientation" to "collaborative adaptation", promoting the efficient allocation of technology, capital, talent and other elements, providing an overall solution for the green transformation of the real economy enabled by the integration of "three modernizations", and ensuring the stability and sustainability of the transformation process.

III. Synergy mechanism of "three modernizations" integration to promote green transformation of real economy

The integration of "three modernizations" is not a simple superposition of greening, intelligence and integration, but a circular strengthening system with technology collaboration, standard guidance and scene empowerment as the core. The core logic of its coordination mechanism lies in: providing technical tools and efficiency support through intelligence, establishing the transformation direction and value orientation through greening, building a collaborative platform and diffusion channel through integration, enabling and dynamically adapting each other, and jointly solving the efficiency bottlenecks, coordination obstacles and path dependence in the green transformation of the real economy, so as to inject systematic power into the consolidation of the modern industrial system.

1. Intelligent empowerment and greening: efficiency improvement and energy consumption optimization

With digital technology as the core, intelligentization builds a green transformation technology enabling system through the reconstruction of production process, accurate control of energy consumption and coordination of resource circulation, so as to achieve the dual goals of "efficiency improvement" and "energy consumption reduction". In the low-carbon reconstruction mechanism of production process, technologies such as digital twins and artificial intelligence penetrate the whole life cycle of production, optimize process parameters and simplify redundant links through virtual simulation, promote the transformation of traditional high energy consumption process to "precision production and supply on demand", and reduce carbon emission intensity from the source (Lushan, 2025). This mechanism echoes the dual control policy of carbon emissions in 2025, realizing dynamic monitoring and precise regulation of carbon emissions through intelligent means, and turning green transformation from "passive compliance" to "active optimization".

The dynamic energy consumption management and control mechanism relies on the global connectivity function of the industrial Internet platform, integrates multi-dimensional information such as production equipment, energy supply and carbon emission data, and builds an energy consumption management system with real-time perception, intelligent analysis and precise regulation (wangweiguang, wangyangyang, 2024). As the key carrier of technology implementation, virtual power plant can realize peak shaving and valley filling of distributed energy and industrial load through intelligent scheduling, improve the efficiency of non fossil energy consumption, and alleviate the mismatch between energy supply and production demand. At the same time, intelligent technology promotes the implementation of the resource cycle coordination mechanism, optimizes the path of resource recycling, improves the utilization rate of renewable resources, and constructs a closed-loop system of "production consumption recycling" through the digital tracking of material flow, energy flow and information flow, so as to provide resource guarantee for the green transformation of the real economy.

2. Green LED integration: low carbon standards and Industrial Synergy

With low-carbon standards as the core guidance, through system design and value guidance, greenization will promote the breaking of border barriers between industries and regions, form an integrated development pattern of "unified standards, complementary resources and shared risks", and lay a solid foundation for the transformation of the real economy. The synergy mechanism of low-carbon standards is the core traction, with the carbon footprint management system and product carbon identification certification as the core, to build a unified low-carbon evaluation standard for the whole industrial chain, forcing upstream and downstream enterprises to promote green transformation simultaneously (Li Jing, Zhang Hui, Han Qing, 2025). This mechanism solves the problems of "different environmental protection standards and unbalanced emission reduction responsibilities" in the traditional industrial integration, promotes the transformation of integration from "interest driven" to "green value driven", and forms institutional synergy with the carbon peak carbon neutral "1+n" policy system.

Under the guidance of low-carbon standards, the green coupling mechanism of the industrial chain promotes the deep coupling of new energy industry and high energy carrying industry, producer services and manufacturing industry. Through the establishment of green supply chain cooperation mechanism, core enterprises drive supporting enterprises to carry out energy-saving and carbon reduction transformation, forming a collaborative ecology of "low-carbon technology sharing, emission reduction cost sharing, and green benefit sharing". At the same time, the demand for greening promotes the integration of cross industry technologies, spawns new types of businesses such as low-carbon equipment, green materials and carbon management services, and expands the industrial space for green transformation of the real economy. The new energy industry integration mechanism focuses on the precise matching of energy supply and industrial demand, and is supported by a low-carbon energy base to promote the integrated construction of industrial parks and clean energy supply system, build a zero carbon industrial ecology of "new energy supply+green production+carbon sequestration offset", and strengthen the stability and greening of energy supply in the real economy.

3. Integration promotes intelligent upgrading: cross scene technology innovation

As the link of "three modernizations" coordination, integration provides multiple application scenarios and diffusion channels for intelligent technology through scene aggregation and factor flow across industries and regions, promotes the upgrading of intelligent technology from "single point application" to "system integration", and forms a virtuous cycle of "Scene spawning demand, technology responding to demand, and iterative support integration". The cross scenario technology innovation mechanism is the core driving force. The diversified green transformation needs brought about by industrial integration force intelligent technology to break through the limitations of single application and upgrade to a compound and customized direction. For example, carbon monitoring, carbon trading and other scenarios promote the integration of AI and

blockchain technology to form accurate carbon accounting and trusted trading solutions; The demand for cross industry collaboration promotes the upgrading of industrial Internet platforms to cross domain adaptation, and strengthens the ability of multi industry data exchange and resource scheduling.

The acceleration mechanism of technology diffusion relies on the industrial clusters and regional collaborative networks formed by integration to break the "isolated island" application dilemma of intelligent technology. By building a cross regional "core supporting" innovation network, the advanced intelligent technology in the core region will gradually spread to the surrounding regions, and small and medium-sized enterprises will obtain technology empowerment through industrial alliances and sharing platforms to alleviate the "digital divide" and technical barriers (Wang Hao, Jiang Jinhe, 2025). At the same time, integration promotes the cross industry flow of technology, talents, capital and other factors, accelerates the integrated innovation of intelligent technology and green technology, and forms a "1+1>2" technology synergy effect. The iterative optimization mechanism of intelligent technology continuously optimizes the technical algorithm and improves the application functions through the practical feedback of the fusion scenarios, promotes the upgrading of intelligent technology from "adapting to a single scenario" to "supporting multi scenario collaboration", provides more efficient technical support for intelligent enabling green and green leading integration, and finally forms a long-term mechanism for the deep promotion of the integration of "three modernizations" and the continuous consolidation of the foundation of the real economy.

IV. Green transformation path design of "three modernizations" integration under the dual carbon goal

The green transformation path of the integration of "three modernizations" needs to be based on the core goal of consolidating the foundation of the real economy, closely follow the contemporary policy guidance of 2025, such as double control of carbon emissions, "1+n" policy system, and build a four-dimensional path system of "industrial foundation building, regional coordination, factor support, and institutional guarantee" to realize the deep coupling and systematic promotion of greening, intelligence, and integration, in view of the core bottlenecks such as the plight of enterprise transformation, lack of industrial coordination, shortage of factor supply, and weak institutional guarantee.

1. Industry level

At the industrial level, we should focus on the two-way efforts of "stock optimization" and "incremental capacity expansion", solve the structural contradictions of industrial transformation with the integration of "three modernizations", and consolidate the industrial foundation of the real economy. In terms of the "three modernizations" transformation of traditional industries, aiming at the transformation pain points of high energy consuming industries, a collaborative transformation mode of "intelligent energy conservation+Green

replacement" is constructed (chenfuzhong, jiangguohai, Dong kangyin, 2024). Through the digital twin, industrial Internet and other technologies, the production process is reconstructed in the whole cycle, the process parameters and energy allocation are optimized, and the green technology substitution projects such as the "three transformation linkage" of coal and electricity are promoted simultaneously, so as to achieve the double reduction of energy consumption intensity and carbon emission intensity, echoing the rigid constraints of the carbon emission double control policy. Aiming at the dilemma of "three no four shortages" of small and medium-sized enterprises, build a comprehensive transformation service provider platform, integrate resources such as technology supply, talent training and experience sharing, promote lightweight intelligent equipment and modular green transformation scheme, reduce transformation threshold and trial and error cost, and promote small and medium-sized enterprises to integrate into the "three modernizations" integration ecology of the industrial chain (Liujiang, zhaoqianyu, 2023).

In terms of the cultivation of emerging industries, we should take the "new three kinds" of new energy as the core, promote the industry to be high-end, intelligent and green, improve quality and efficiency, strengthen the technical coordination and standard unification of the upstream and downstream of the industrial chain, and build an industrial cluster with global competitiveness. At the same time, focusing on the "neck" low-carbon technologies such as green hydrogen, carbon capture, utilization and storage, the university industry research consortium was established to tackle key problems, improve the transformation mechanism of technology from R&D to commercialization, reduce the cost of green technology application, and expand the technological space for green transformation of the real economy (Xu Simian, Ding Zijia, Xiang hailing, Wu Fei, 2024). Through the benign interaction between traditional industries and emerging industries, we will form an industrial pattern of "stabilizing the foundation of traditional industries and expanding space for emerging industries", and promote the transformation of modern industrial system to green and low-carbon.

2. Regional level

At the regional level, based on the differences in regional resource endowments and the characteristics of the industrial base, we should build a spatial layout of "differentiated positioning and collaborative promotion", solve the imbalance of regional transformation, and strengthen the spatial toughness of the real economy (Wang Hao, Jiang Jinhe, 2025). In resource rich areas, relying on the construction of new energy bases such as the "shage desert", we should promote the deep coupling of new energy supply with high energy carrying industries and computing facilities, build a zero carbon industrial ecology of "green power+industry", realize the transformation of energy resource advantages to industrial competitive advantages, and improve the efficiency of new energy consumption through intelligent dispatching system, so as to ensure the stability and green of industrial energy consumption (chenfuzhong, jiangguohai, dongkangyin, 2024).

In the industrial cluster area, we should build a collaborative transformation network with the "main chain enterprise" as the core, drive supporting enterprises to carry out intelligent transformation and green upgrading synchronously, unify the low-carbon standard and digital interface of the industrial chain, and solve the

problems such as the imbalance of the digital level of the upstream and downstream and the inconsistency of standards. Through the collaborative mechanism of technology sharing, cost sharing and benefit sharing, the overall transformation efficiency of industrial clusters is improved, and the stability and competitiveness of the industrial chain supply chain are strengthened. At the level of Urban-Rural Coordination, we should promote the integration of "three modernizations" to urban-rural construction, transportation and other fields, promote the integration mode of green building and intelligent operation and maintenance, build a collaborative system of clean transportation and digital dispatching, expand the application scenarios of the integration of "three modernizations", realize the collaborative promotion of the green transformation of urban-rural entity economy, and narrow the gap between urban and rural transformation.

3. Element level

At the element level, the focus is on the supply of core elements of the integration of "three modernizations". Through the coordinated efforts of technological innovation, digital empowerment and financial support, the bottleneck of element shortage is broken, and sustainable power is injected into the green transformation of the real economy. In terms of technological innovation, we should establish a carbon neutral technology roadmap, clarify the direction of key technology research in different industries and stages, layout high-level innovation platforms such as national key laboratories and technological innovation centers, and strengthen the source supply of smart green technology (wangweiguang, wangyangyang, 2024). At the same time, we should improve the technology transfer mechanism, promote the diffusion and application of core technologies in the industrial chain and among regions, and accelerate the commercialization of technological achievements.

In terms of digital empowerment, we should take the unification of industrial Internet interface standards and the promotion of MES data specifications as the core, break down data barriers and technology isolated islands, build a cross industry and cross regional digital collaboration platform, and improve the allocation efficiency of data elements (yeyanfei, 2025). Optimize the carbon accounting process through digital means, improve the quality of carbon data, and provide accurate data support for dual control of carbon emissions and carbon market trading. In terms of financial support, we should expand the coverage of green loans and carbon emission reduction support tools, innovate the combined financial products of "green technology+intelligent transformation", explore tax incentive policies such as "information investment plus deduction", and reduce the financing cost and capital pressure of enterprise transformation (Guyuan, 2024). At the same time, we should improve the talent training and introduction mechanism, focus on the shortage of compound talents, build a training system of universities, enterprises and scientific research institutions, strengthen the interdisciplinary talent supply of "industry+ai+green technology", and provide talent protection for the integration of "three modernizations" (Liujiang, zhaoqianyu, 2023).

4. Institutional level

At the institutional level, we should focus on the institutional guarantee weakness of the integration of "three modernizations", build an institutional system of "policy coordination, effective market, and strong supervision", and strengthen the institutional rigidity and sustainability of the transformation. In terms of improving the carbon market, we should further expand the industry coverage of the carbon market, improve the voluntary emission reduction trading mechanism, improve the carbon pricing mechanism, and enhance the incentive and constraint effect of the carbon market on the green transformation of enterprises. At the same time, promote the convergence and coordination of carbon market and carbon emission dual control policies, form the dual constraints of "market pricing+administrative supervision", and guide enterprises to internalize green transformation as the core strategy (nipeigen, Qin Erwa, 2022).

In terms of policy coordination, we should integrate intelligent, green and integrated policy tools such as subsidies, taxes and finance, break the barriers of policy fragmentation, and establish a policy supply mechanism for "precision drip irrigation" (Zhong Yan, 2024). According to the differentiated needs of different industries and enterprises of different sizes, formulate policy plans for classified implementation, and strengthen the pertinence and effectiveness of policies. At the same time, an assessment and evaluation system integrating the "three modernizations" has been established to incorporate the indicators of transformation effectiveness and consolidation of the real economy into the assessment, forming a closed-loop mechanism of "policy guidance - practice promotion - effectiveness evaluation - dynamic optimization". Through institutional innovation, we can solve the problems of insufficient policy coordination and insufficient market incentives, provide stable and efficient institutional guarantee for the green transformation of the real economy enabled by the integration of "three modernizations", and ensure that the transformation process is stable and far-reaching.

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