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Theoretical Mechanisms of New Quality Productive Forces Reshaping the Rural Division of Labor System

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Abstract In the context of the coordinated pursuit of "carbon peak and neutrality" objectives, alongside the strategy to establish a robust agricultural nation, the economic and social development of rural areas is undergoing a profound paradigm shift. The traditional rural division of labor pattern, which depends on tangible factors such as land, labor, and capital, has increasingly encountered developmental challenges characterized by diminishing marginal returns and a detrimental cycle of internal competition. The new quality productive force, centered on data, algorithms, green technologies, bioengineering, and clean energy, offers a potential pathway for the rural division of labor system to overcome the "low-level equilibrium". This force is characterized by attributes such as non-exclusivity, replicability, network collaboration, and ecological compatibility. This paper develops a three-dimensional collaborative analytical framework encompassing "technology, institution, and culture". It systematically elucidates the internal logic by which new quality productive forces drive the transformation of the rural division of labor from "quantitative factor matching" to "qualitative structural reorganization" through three principal mechanisms: technology embedding, institutional reconstruction, and cultural coupling. Furthermore, the study proposes corresponding policy recommendations, thereby offering theoretical insights to support the modernization of China's agriculture and rural areas, as well as the development of a strong agricultural country.

Key words New quality productive force, Rural division of labor system, Technology embedding, Institutional reconstruction, Cultural coupling

0 Introduction

Currently, China is at a critical juncture in implementing its "carbon peak and neutrality" objectives while simultaneously advancing the development of a robust agricultural country. Motivated by these dual goals, the rural development model must urgently transcend the limitations imposed by the traditional "factor-driven" approach. Historically, the rural economic system has heavily relied on conventional production factors such as land, labor, and capital, resulting in a simplistic division of labor characterized predominantly by "small-scale farmers engaging in self-sufficiency, primary markets, and external transactions". This model struggles to overcome the inherent law of diminishing marginal returns in agriculture and has consequently confined rural industries to low value-added links, thereby posing a significant obstacle to the comprehensive revitalization and sustainable development of rural areas.

The emergence of new quality productive forces offers innovative approaches to addressing the aforementioned challenges. These productive forces, centered on data, algorithms, green technologies, biological breeding, and low-carbon energy, exhibit characteristics such as non-exclusivity, near-zero marginal replication costs, pronounced network synergy effects, and environmental sustainability. Collectively, these attributes have the potential to drive a "dimensional leap" in the rural division of labor[1]. Specifically, the rapid transmission of data elements and their minimal cost of sharing facilitate the timely dissemination of agricultural knowledge and technology on a broader scale. Green technologies convert the ecological environment's capacity into quantifiable and tradable economic assets, thereby generating new occupations and industrial chains. Against this backdrop, the present study aims to investigate the following fundamental questions: through which specific mechanisms do new quality productive forces disrupt the "low-level equilibrium" state of the traditional rural division of labor? Furthermore, how can the rural division of labor transition from dependence on "quantitative factor allocation" to an emphasis on "qualitative structural optimization"? This paper develops a three-dimensional collaborative analytical framework encompassing "technology, institution, and culture" to address these questions. It thoroughly examines the interactive relationships among technological embedding, institutional reconstruction, and cultural coupling, systematically elucidating the internal mechanisms through which new quality productive forces drive advancements in the rural division of labor system. The objective is to offer more practical theoretical guidance for advancing the modernization of agriculture and rural areas.

1 Analysis framework: three-dimensional synergy of technology, institution and culture

The reshaping of the rural division of labor system by new quality productive forces is not attributable to a single factor; rather, it constitutes a systematic process driven collectively by technological transformations, institutional innovations, and cultural adaptations. Consequently, developing an integrative analytical framework encompassing the dimensions of technology, institution, and culture facilitates a more comprehensive and dynamic understanding of this transformative process.

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1.1 Technical dimension: fundamental transformation of production tools and knowledge paradigms The technological transformation driven by new quality productive forces extends beyond a mere addition to traditional production factors; it introduces an entirely novel combination of "technology and knowledge". Within this framework, data functions as a "mirror element" comparable to land, algorithms act as "intelligent agents" complementing labor, and green technology operates as an "ecological lever" alongside capital. The primary characteristic of the technical dimension is its high level of "programmability". This enables the use of algorithms for real-time monitoring, analysis, and optimization of agricultural production processes, thereby effectively mitigating and potentially overcoming the constraints imposed by natural rhythms and geographical limitations on agricultural production.

1.2 Institutional dimension: collaborative evolution of formal rules and informal constraints Advanced technologies frequently encounter challenges in establishing themselves and yielding practical outcomes in the absence of an appropriate institution framework. In the process of introducing new quality productive forces, the rural institutional system faces two primary challenges. First, it is essential to reduce the barriers and costs for external actors to enter the rural sector by innovating formal institutions, including the definition of property rights, market access, and risk-sharing mechanisms, thereby attracting talent, capital, and technology to rural areas. Second, informal constraints, such as village regulations and conventions, local trust networks, and community reputation mechanisms, should be leveraged to facilitate cooperation and transactions among multiple stakeholders and to mitigate potential social risks, including "elite capture" and the exacerbation of the "digital divide".

1.3 Cultural dimension: adaptive reshaping of values and social norms The cultural system offers a shared framework of meaning for members of society, directly shaping the acceptance and integration of new technologies and systems within farmer communities. The new quality productive forces encompass modern concepts such as "open collaboration", "ecological prioritization", and "value co-creation". These concepts exhibit certain tensions with traditional rural values grounded in kinship and geographical ties, including "differential trust" and the ethics of acquaintance. The primary function of cultural coupling is to transform external and abstract value concepts into everyday practices that farmers can perceive, engage with, and benefit from. This process establishes a broad foundation of social recognition for the reconstruction of the division of labor system, thereby conferring social legitimacy upon it[2].

2 Mechanism one: technology embedding from "physical superposition" to "chemical fusion"

2.1 The "network externalities" of data elements undermine the diminishing marginal returns of land In traditional agricultural economies, the marginal output of land diminishes as input levels increase. This phenomenon is attributed to the diffusion rate of technical knowledge being significantly lower than the rate of factor input[3]. However, the exceptionally low marginal cost of data elements and the presence of network externalities have altered this dynamic. Once farmland is equipped with multi-source sensors, data concerning soil moisture, nutrient levels, and pest and disease occurrences can be uploaded to the cloud in real time. Subsequently, algorithms process this data through "spatio-temporal integration" to generate replicable "digital agronomy packages". When this knowledge package is disseminated freely or at minimal cost on a broad scale, the average research and development cost becomes effectively negligible, demonstrating increasing marginal returns. Consequently, farmers have specialized into distinct roles: "data custodians", who manage data assets on behalf of small-scale farmers and implement custodian planting guided by algorithmic recommendations; and "algorithmic breeders", who employ high-dimensional phenotypic and genomic data to conduct "digital breeding" in cloud environments, thereby substantially reducing the duration of traditional breeding cycles.

2.2 The "ecological multiplier" effect of green technology reshapes the industrial boundaries Green technologies not only mitigate carbon emissions but also convert "ecological spaces" into tradable production factors. For instance, in the case of forestry carbon sinks, remote sensing monitoring combined with blockchain registration enables the precise measurement and market trading of carbon sink volumes within collective forest lands. Consequently, "carbon sink brokers" have emerged, designing carbon sink projects for village collectives and facilitating their integration into the national carbon market. Additionally, "ecological product managers" package carbon sink revenues alongside forest-derived products such as mushrooms and forest bees, thereby developing a novel category of "carbon-neutral mountain products". Green technology has thus facilitated a transformation in rural labor division, shifting from reliance on "single agricultural products" to a "diversified range of ecological products", thereby achieving horizontal fission of the industrial chain.

2.3 The "modularization" of biotechnology reconstructs the production process Gene editing and synthetic biology conceptualize crops as "programmable biological factories". Farmers no longer simply cultivate "final products"; instead, they have specialized into distinct "biological module suppliers"—such as those producing corn enriched with specific proteins for use as pharmaceutical intermediates—and "bioreactor caretakers", who oversee environmental conditions and gene expression levels within field-based bioreactors. This "modular" division of labor transforms the traditional linear chain of "production, processing, and sales" into a series of "interchangeable" biological modules, thereby enabling greater vertical integration.

3 Mechanism two: institutional reconstruction from "identity constraints" to "capability openness"

3.1 The separation of data property rights breaks the closed "collective membership rights" Traditional rural collective property rights are constrained by household registration status, which hinders the entry of external talent and capital. In response, the central government has proposed the separation of "data resource ownership rights, processing and usage rights, and product operation rights", thereby facilitating the marketization of data elements. Urban "digital migrants" are not required to transfer their household registration; instead, they can obtain the right to process farmland data through county-level data trading platforms and participate in the division of labor for live-streaming e-commerce activities conducted online. Farmers benefit from subsequent profits through "data equity investment" mechanisms, resulting in the formation of a novel organizational model known as "data cooperatives"[4].

3.2 The ecological compensation system creates a division of labor for "new public goods" National parks and horizontal compensation mechanisms for river basins serve to internalize the positive externalities associated with ecology, thereby establishing public roles such as "ecological guardians" and "biodiversity curators". These roles differ from traditional "forest ranger" positions in that their responsibilities encompass the utilization of unmanned aerial vehicles (UAVs) to monitor flagship species, the management of nature education self-media platforms, the design of ecological study routes, the transformation of "public ecology" into "educational services", and the realization of the commercialization of public goods alongside professional specialization.

3.3 The risk-sharing mechanism has given rise to the division of labor in "service outsourcing" The emergence of new quality productive forces is accompanied by significant technological risks and market uncertainties. In response, county-level governments have established "agricultural new technology risk compensation funds" and introduced "technology insurance companies" to assume losses resulting from the failure of new technologies on behalf of farmers. Additionally, "technology management service providers" have been implemented to guarantee minimum yields, share profits from overproduction, and make comprehensive technical decisions for farmers. This externalization of risks has further refined the division of labor, transforming farmers from "all-encompassing operators" into "proficient investors".

4 Mechanism three: cultural coupling from "differential trust" to "ecological ethics"

4.1 Digital platforms reshape the radius of trust Under the traditional "differential pattern", the transaction radius is limited to the network of acquaintances. In contrast, the "visibility" mechanism inherent in live-streaming e-commerce enables the real-time presentation of product growth processes, allowing consumers to establish "remote trust" through interactive features such as bullet comments, likes, and repeat purchases. Within this context, farmers have diversified into distinct roles: "village live-streaming agents", who specialize in training farmer live-streamers, designing scripts, and managing fan communities; and "cloud-based cooperatives", wherein multiple small-scale farmers share a single live-streaming channel, with income distributed in real time according to individual contributions. This model facilitates the formation of "cloud-based acquaintanceship" within a community of previously unconnected individuals.

4.2 Ecological ethics internalize the value recognition New quality productive forces convert "green mountains and clear waters" into quantifiable benefits, facilitating farmers' transition from an "economic identity" to an "ecological identity" at the value level. This transformation manifests in distinct roles, such as "slow-growing breeders" who maintain traditional ecological cycles while utilizing blockchain technology to document the entire process, thereby satisfying the demand of high-end consumers for "slow value". Additionally, "ecological chefs" design "zero-carbon menus" using ecological ingredients in rural homestays, thereby translating ecological ethics into an experiential economy. This shift in cultural identity has advanced the division of labor from a "production-oriented" framework to one centered on "quality and ethical considerations"[5].

4.3 Co-creation and sharing dissolve the "capture of technical elites" Open-source communities and decentralized autonomous organizations (DAOs) publicly share algorithms, brands, and channels to prevent external capital from monopolizing data dividends. Farmers engage as "community partners" in value co-creation, sharing in brand premiums, which preserves their subjectivity amid technological changes and mitigates social divisions.

5 Four typical forms of division of labor transition

5.1 Vertical deepening: full-chain division of labor from digital breeding to intelligent planting and blockchain traceability Digital technology disrupts the traditional linear chain of "production, processing, and sales" by segmenting it into network-like modules, each constituting an independent knowledge cluster. For instance, the "gene editing and breeding" module is collaboratively developed by universities, start-up enterprises, and village collectives; the "remote sensing diagnosis" module is jointly created by satellite operators, county-level big data centers, and agricultural technology stations. Additionally, the "D2C brand planning" module is co-designed by city brand consultants, village live-streaming influencers, and DAOs. These modules achieve interoperability through API interfaces, resulting in an unprecedented level of granularity in the vertical integration of the industrial chain[6].

5.2 Horizontal fission: the "ecology +" division of labor derived from the multi-functionality of agriculture Green technologies enhance the multifunctional roles of agriculture by integrating ecological, cultural, and experiential dimensions. This integration has led to the emergence of novel roles such as "carbon sink designers", who package carbon sequestration assets alongside forest health and wellness pathways; "rural metaverse architects", who recreate ancient villages using digital twin technology to market virtual real estate and NFT tickets; and "ecological healers", who develop meditation programs within rice fields, thereby elevating agriculture to encompass psychological services. This horizontal diversification has transformed rural areas from "mere suppliers of agricultural products" into "providers of varied ecological services".

5.3 Spatial reconstruction: coexistence of "enclave economy" and "cloud village" in county areas The remote accessibility of data elements has rendered the division of labor no longer dependent on geographical proximity. Through "cloud-based investment promotion", the county-level government has attracted digital enterprises from major cities such as Beijing, Shanghai, and Guangzhou to establish operations within the "Cloud Industrial Park". These enterprises are not required to construct local factories; instead, they rent county-level data center and utilize branded intellectual property. Local farmers have transitioned into roles as "cloud warehouse administrators", responsible for tasks such as pre-cooling, sorting, and live-streaming the shipment of agricultural products, and "remote customer service representatives", who provide multilingual after-sales support to global consumers from locations adjacent to the 5G base station at the village entrance. The integration of physical and virtual spaces has thus created a novel geographical phenomenon of the enclave cloud village.

5.4 Subject diversity: from "binary opposition" to "community co-governance" The traditional division of labor in rural areas has been primarily confined to "small-scale farmers and leading enterprises". However, the emergence of new quality productive forces has introduced a third sector, including "DAOs", "social enterprises", and "impact investment funds". For instance, an ancient village in Yunnan Province has issued "tea-related NFTs" through a DAO platform. Global stakeholders collaboratively determine key decisions such as fertilization plans for the tea garden, harvesting schedules, and packaging design. Consequently, villagers have transitioned from being "hired laborers" to becoming "community partners", resulting in a simultaneous paradigm shift in both governance structures and the division of labor.

6 Policy implications

6.1 Building a "county-level data element market" Four primary mechanisms for rural data assets have been established, encompassing rights confirmation, assessment, trading, and income distribution. Urban data operators are encouraged to collaborate with village collectives to form "data cooperatives", thereby enabling farmers to share in the dividends generated from data.

6.2 Implementing the "ecological technology voucher" system Tradable certificates are issued to business entities that implement green technologies. These technology vouchers can serve as collateral within county-level carbon markets and pollution discharge rights markets, thereby facilitating the allocation of labor towards ecological transformation. Furthermore, "rural area new occupational standards" should be established. Professions such as "algorithm breeders", "carbon sink brokers", and "ecological healers" could be incorporated into the national occupational classification system. Skills training, qualification certification, and social security systems should be enhanced, thereby preventing these "emerging occupations" from being relegated to the "gig economy".

6.3 Cultivating "rural DAO experimental fields" Decentralized governance is implemented in regions where favorable conditions exist, and where the legal personhood of DAOs, tax regulations, and smart contract frameworks have been clearly defined, in order to investigate the legal frameworks for community co-governance and the allocation of responsibilities.

7 Conclusions and prospects

This study provides a systematic theoretical analysis of the internal mechanisms through which new quality productive forces transform the rural division of labor system. The research demonstrates that this transformation results from the coordinated interaction among technology embedding, which initiates production process reengineering; institutional reconstruction, which offers an incentive and guarantee framework; and cultural coupling, which establishes the foundation for social identity. Consequently, the rural division of labor system is evolving from a planar structure reliant on the allocation of traditional factor quantities to a networked, modular, and high-quality structure grounded in knowledge, data, and ecological value. This evolution is exemplified by characteristic forms such as vertical deepening, horizontal fission, spatial reconstruction, and subject diversity.

This study presents an integrated analytical framework for comprehending the transformation of agriculture and rural areas within the context of the digital era and green development. Future research may be advanced in the following directions: first, undertaking cross-national or cross-regional comparative analyses to thoroughly investigate the heterogeneous pathways and impacts of new quality productive forces on rural labor division patterns, considering variations in resource endowments, institutional settings, and local cultural contexts; second, closely examining and critically analyzing the potential exacerbation or emergence of inequalities—such as the "digital divide" and "technological exclusion"—arising from the promotion of new quality productive forces, with the aim of developing more inclusive development mechanisms. Such efforts would contribute valuable academic insights and practical strategies toward achieving the objective of a fair and sustainable strong agricultural country.

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4 Discussion

4.1 White-fleshed loquat resources Flesh color is an agronomic trait of significant focus in agricultural production and serves as an important basis for horticultural crops to attract consumers[5]. In this study, using seedlings derived from the reciprocal crosses of Zaozhong 6 and DB1 as experimental materials and employing molecular markers based on the *PSY* gene as a detection method, we screened for loquat resources with white flesh. This work lays a solid foundation for the future breeding of white-fleshed loquat varieties. In this study, a total of 49 samples were tested, including 19 seedlings from the ZZ × DB1 cross and 30 seedlings from the DB1 × ZZ reciprocal cross. Among these, 24 were identified as loquat resources with white flesh, while 25 were identified as resources with yellow flesh, representing a proportion of 48% for the white-fleshed loquat resources. Molecular markers based on the *PSY* gene are of great significance in guiding the breeding of new loquat varieties with desired flesh color[6]. Therefore, emphasis will be placed on observing these 24 white-fleshed loquat resources to select those with excellent traits, strong stress resistance, and high yield. This will be followed by the promotion and extension of new loquat varieties.

4.2 Yellow-fleshed and white-fleshed loquat hybrid The flesh color of loquat is regulated by the *PSY* gene. By crossing Zaozhong 6 (which has yellow flesh) with DB1 (which has white flesh), the resulting offspring include both white-fleshed and yellow-fleshed loquats. From this, it can be inferred that the *PSY* gene in Zaozhong 6 loquat must carry one long band and one short band. In the direct cross, the ratio of white-fleshed to yellow-fleshed loquat resources was 6 : 13, while in the reciprocal cross, the ratio was 3 : 2. No clear inheritance pattern was observed from these results.

4.3 Limitations of this study The sample size obtained in this experiment was relatively small, allowing only for the screening of white-fleshed loquat resources. It remains difficult to identify patterns regarding whether the offspring from crosses between yellow-fleshed and white-fleshed loquats produce white flesh, as well as the underlying genetic probabilities. In the future, the experimental sample size must be expanded to better explain the inheritance patterns of flesh color in hybrid progeny of loquats with different flesh colors.

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