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INFORMATION

New pathways for "three rural" development: private sector forces and technological engines drive agricultural modernization

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As 2025 unfolds, China's emphasis on the "three rural" (agriculture, rural areas, and farmers) has reached new heights. In February, two landmark events—the Private Enterprise Symposium[1] and the release of the annual "No. 1 Central Document"[2]—sent a clear signal of the nation's unwavering commitment to prioritizing rural revitalization. With the deepening implementation of the national rural revitalization strategy, the modernization of agriculture has become a critical engine for driving comprehensive socioeconomic progress in rural areas. The integration of private sector's dynamism and technological innovation has emerged as an indispensable pillar for advancing agricultural modernization. This article delves into the profound implications of the Private Enterprise Symposium held in Beijing on February 17, 2025, interprets the policy directions outlined in the "No. 1 Central Document" released on February 23, 2025, and examines the success of the "Science and Technology Backyard" (STB)[3] model founded and led by Academician Fusuo Zhang. Together, these elements illuminate the synergistic pathways for modernizing agriculture through private sector engagement and technological empowerment.

1 National prioritization of agriculture: private enterprises take center stage

The Communist Party and the Chinese government have consistently prioritized the "three rural issues", enshrining them as a cornerstone of national policy and adhering to a strategy of rural-urban coordinated development. The high-profile Private Enterprise Symposium held in Beijing on February 17, 2025, captured widespread attention, not only showcasing private sector achievements but also signaling the state's intensified focus on agriculture. The symposium convened four visionary entrepreneurs deeply rooted in rural revitalization: Yonghao Liu of New Hope Group, Youbin Leng of Feihe Dairy, Yinglin Qin of Muyuan Foods Corporation, and Denghai Li of Denghai Seeds. Yonghao Liu, one of six representatives invited to speak, underscored the pivotal role of private enterprises in advancing rural development[4–6]. This landmark event highlighted the state's strategic resolve to prioritize agriculture while charting innovative pathways for modernizing the sector.

1.1 Digital-intelligent transformation reshapes production paradigms

New Hope Group, a long-standing player in agriculture and animal husbandry that continues to revitalize the traditional industry through innovation, exemplify the ingenuity of Chinese private enterprises—an ingenuity that has captured the world's attention[7,8], has built an integrated industrial chain spanning feed production, livestock farming, and meat

processing, empowering farmers to participate in modernized breeding operations. By deploying smart pig farms and unmanned inspection systems, the group has pioneered a digital-intelligent upgrade for traditional agriculture. Its "cloud-based pig farms" utilize IoT systems to enable millisecond-level environmental adjustments. Similarly, Muyuan Foods has integrated smart technologies into breeding processes, enhancing efficiency and product quality[9]. By expanding into slaughtering, processing, and feed production, Muyuan has achieved full-chain coverage, offering smallholder farmers a replicable model for accessing modern agricultural systems. Muyuan has been adhering to its vision of "serving people with safe pork" and has devoted itself to producing safe, tasty and wholesome pork products with high quality, so as to improve customers' life quality so that they might enjoy a richer life[10].

1.2 Whole-industry chain integration elevates value creation

Feihe Dairy has embedded social responsibility into its corporate DNA, harmonizing environmental, social, and economic benefits. Through its "shared prosperity chain", Feihe has synergized upstream and downstream sectors—from forage cultivation and dairy farming to logistics—creating 170,000 jobs and lifting over 150,000 farmers out of poverty in Northeast China[11]. Its operations have also boosted the value of 1 million ha of farmland in Heilongjiang Province, exemplifying a successful rural revitalization model[12].

1.3 Seed industry innovation fortifies agricultural foundations

Denghai Li, a pioneer in seed breeding, has set seven national and two world records for summer corn yields. Over the past five decades, Denghai Li and Denghai Seeds have promoted the cultivation of corn across more than 1.5 billion mu (approximately 100 million ha) of farmland, generating over 150 billion yuan in socioeconomic benefits. Their efforts have made outstanding contributions to increasing agricultural production, boosting farmers' incomes, and safeguarding China's food security, providing a robust guarantee for national and global food security[13].

1.4 Driving agricultural modernization and jointly creating a new chapter for "three rural"

This symposium revealed the underlying logic of agricultural modernization transformation: as land productivity approaches physical limits, the digital reorganization of production factors, ecological restructuring of industrial forms, and engineering breakthroughs in technological innovation are forming a "triple driving force" propelling agriculture into higher dimensions. The practices of the four entrepreneurs demonstrate that private capital, through the dual engines of technological and model innovation, can effectively address the challenge of integrating small-scale farming with modern agriculture. Looking ahead, the agricultural technology revolution requires more market entities to achieve sustained breakthroughs in critical fields such as intelligent equipment, biotechnology, and digital agriculture, collectively charting an innovation blueprint for an agricultural powerhouse.

This symposium (1) not only affirms the significant achievements and contributions of private enterprises but also recognizes the substantial catalytic role of private entrepreneurs in promoting technological innovation, cultivating new productive forces, advancing rural revitalization, and improving people's livelihoods; (2) not only offers a profound summary of the current state of agricultural development but also provides an important vision for its future path. We firmly believe that under the leadership of the Party and the State, and through the joint efforts of the entire society, China's endeavors in "three rural" will surely embrace an even brighter tomorrow.

2 2025 "No. 1 Central Document": deploying new quality productive forces in agriculture

On February 23, 2025, China's annual "No. 1 Central Document" was officially released[2], ushering in fresh momentum for agricultural modernization and charting the course for rural development throughout the year. Since 2004, this marks the 22nd consecutive year that the document has prioritized the "three rural". More than a policy guideline, the document serves as an action blueprint, articulating the core drivers and pathways for agricultural modernization. It underscores reform, opening-up, and scientific innovation as key forces to safeguard national food security and resolutely prevent large-scale relapse into poverty. Centered on developing new quality productive forces in agriculture, the document emphasizes breakthroughs in core technologies, nurturing leading enterprises in agricultural science and technology, and injecting new dynamism into modernization efforts. It further mandates strengthening agricultural sci-tech innovation, expanding artificial intelligence (AI) applications, and advancing smart farming[14].

2.1 Technology-driven transformation and upgrading of agriculture

The "No. 1 Central Document" elevates agricultural sci-tech innovation to unprecedented strategic importance. It calls for increased R&D investment to solidify technology as the cornerstone of high-quality agricultural development. Key measures include advancing the development and application of domestically produced, cutting-edge agricultural machinery, supporting smart agriculture, and broadening AI utilization scenarios[2,15]. The document encourages deeper collaboration between research institutions, universities, and industries to accelerate the translation of scientific achievements into practical solutions, ensuring research outcomes take root and benefit farmers. Additionally, it stresses the cultivation of a skilled, passionate, and farmer-oriented contingent of agricultural science and technology professionals, laying a robust talent foundation for modernization.

2.2 Private enterprises as modernization catalysts

Recognizing private enterprises' historical contributions, the document encourages their deeper involvement in agricultural innovation, industrial chain integration, and modern agricultural demonstration zones[2,16]. Market mechanisms and policy incentives will spur private sector leadership in agri-tech, processing, and rural e-commerce, fostering synergistic development across the value chain.

2.3 Industrial chain integration and upgrade

The document calls for stronger integration of primary, secondary, and tertiary industries, nurturing leading enterprises, cooperatives, and family farms to build cohesive interest-sharing mechanisms. Deep processing, brand building, and quality enhancement are emphasized to boost competitiveness and farmer incomes[2,17].

2.4 Construction of modern agricultural demonstration zones

The document proposes the establishment of a number of agricultural modernization demonstration zones serving as the "experimental fields" and "showcases" for exploring agricultural modernization. These zones will pilot innovations in green development, smart agriculture, and management models, creating replicable templates for nationwide agricultural modernization[2,17].

2.5 Policy support and incentives

Enhanced fiscal, financial, and land-use policies will create an enabling environment for private sector participation. Incentive mechanisms for agricultural innovation and talent development will further drive progress[2].

2.6 The "Science and Technology Backyard" (STB) has been mentioned in the "No. 1 Central Document" for two consecutive years

The 2025 "No. 1 Central Document" clearly mentioned "support STBs in taking root in rural areas to help and benefit farmers"[2]. It is the second time that this innovative practice has been included in the "No. 1 Central Document", following the first proposal to "promote the STB model" in 2024[18]. This not only recognizes the past achievements of STBs but also expresses high expectations for their future development. This continuous policy deployment signifies the elevation of STBs from grassroots innovative practices to an important component of the national rural revitalization strategy, injecting new momentum into addressing "three rural issues" and promoting the modernization of agriculture and rural areas.

3 Technology empowerment: Academician Fusuo Zhang's STB initiative

In the tide of agricultural modernization, the power of technology acts like a vigorous driving force, sweeping across vast farmlands and propelling agriculture to new heights. The STB initiative launched by Academician Fusuo Zhang vividly embodies this technological momentum. With its unique model and remarkable outcomes, it has become a paradigm of technology-driven agricultural modernization. By addressing the "last-mile" challenge in disseminating agricultural techniques, it fosters innovation in agricultural technology and talent development, injecting fresh vitality into rural revitalization and agricultural advancement.

3.1 The STB: a frontier for agricultural innovation

The STB initiative is a pivotal effort by Academician Fusuo Zhang and his team to align with China's agricultural modernization strategy and innovate agricultural technology services. By stationing expert teams and graduate students directly in production sites, the project bridges the gap between researchers and farmers, integrating scientific research with

practical farming. This "zero-distance" service model not only resolves the "last-mile" bottleneck in technology dissemination but also brings cutting-edge innovations directly to the fields, illuminating the path toward agricultural modernization.

3.2 Solving technical challenges and enhancing agricultural productivity

As pioneers in agricultural technology promotion, STBs enable experts to immerse themselves in rural areas and collaborate with farmers to tackle technical challenges in the fields, spanning areas such as soil amelioration, pest and disease control, crop breeding, and field management. Experts stationed at the frontline impart scientific cultivation and breeding techniques through easy-to-understand explanations and on-site demonstrations, earning deep trust through farmer-centric service initiatives. Meanwhile, the STBs focus on the deep integration of scientific research and production, conducting technological breakthroughs aimed at addressing bottlenecks in agriculture and accelerating the transformation of research outcomes into practical applications. These innovations not only address the practical difficulties faced by farmers but also provide continuous impetus for agricultural modernization, driving innovations in production methods, leading to significant leaps in productivity, and injecting robust scientific and technological momentum into rural revitalization efforts.

3.3 Dual wins: talent cultivation and rural revitalization

The STBs in China represent a novel model that links the farming community and the science community for mutual benefit in technology development and knowledge dissemination[3]. By employing the "four zeros" method: zero-distance, zero-time difference, zero-threshold, and zero-cost, they provide immediate, cost-effective tech support to farmers. Tailored to local production conditions, the STB model promotes technological innovations from regional to national scales, empowering smallholders for sustainable agriculture. Africa has also embraced this model[19].

STBs serve dual roles: as platforms for innovation and nurseries for talent. Graduate students gain hands-on experience in agriculture, acquiring problem-solving skills beyond textbooks and infusing rural areas with fresh ideas. From version 1.0 (STB 1.0) to version 2.0 (STB 2.0), the focus shifts to strengthening farmer trust, real-time consultation, and establishing open dialog between scientists and farmers. STB 2.0 fosters collaborations between public and private sectors to overcome farmers' barriers, including access to pesticides, training, subsidies, and machinery, with an emphasis on long-term investment[19,20].

3.4 E-commerce empowerment: maximizing agricultural value

The project leverages e-commerce to empower agriculture, enabling farmers to expand sales channels and transition from successful growing to successful selling. By connecting farmers directly to markets through online platforms, intermediaries are minimized, product value is enhanced, and farmers' resilience to market risks is improved. This holistic integration of the agricultural value chain fosters modernization and rural income growth. The STB, in collaboration with various entities, has implemented strategies such as the "1+4" intelligent farm model in Xifangezhuang Village, Beijing, which enhances agricultural output and quality through scientific management. Furthermore, the STB has developed branded agricultural parks and standardized production chains, such as in Shandong's sweet potato industry, achieving green food certification. Technological advancements have facilitated online sales, motivating farmers to learn e-commerce. STBs have established free training programs, like the "Party Building + Technology Classroom", to equip farmers with e-commerce skills and promote scientific and low-carbon production concepts. In Dali, Yunnan, STB students offer customized training on new media and e-commerce, attracting local villagers and neighboring households. Internet e-commerce enterprises, such as Pinduoduo, invest in training classrooms and provide resources to launch STB agricultural products on e-commerce platforms, achieving seamless production-sales integration. By innovating industrial models, branding, and building an e-commerce system through cooperation, the STB utilizes e-commerce to increase farmers' production and income, ultimately promoting rural revitalization and sustainable agricultural development.

3.5 Nationwide expansion: driving rural revitalization across China

The STB initiative has now taken root in 31 provincial-level regions of China. From the fertile black soils of the north to the red-clay fields of the south, and from eastern rice-growing regions to western pastoral highlands, the project demonstrates its unique strengths, contributing wisdom and solutions to agricultural modernization and rural revitalization[21–23]. In 2024, 157 graduate training institutions nationwide actively

participated in and led the construction of over 1800 STBs. More than 2700 graduate student advisors and industry experts, accompanied by over 10,000 graduate students, are engaged in the construction and operation of the STB[24]. To support the STB, the General Offices of the Ministry of Education, the Ministry of Agriculture and Rural Affairs, and the China Association for Science and Technology jointly issued policy guidance and support in 2022 and 2024[25,26]. In this process, the service model of the STBs has evolved from version 1.0 (STB 1.0) to version 3.0 (STB 3.0), transitioning from the initial model of assisting individual households to the current STB 3.0 model that comprehensively supports rural revitalization through technological empowerment and talent support[27,28]. With the increasing participation of more institutions and faculty members, the STBs have not only achieved significant results in the integration of production, education, research, and application, but have also been promoted by the Food and Agriculture Organization of the United Nations (FAO), successfully extending to multiple countries and regions overseas[29,30]. Additionally, the STBs are actively expanding their international perspective by establishing "China–Africa Science and Technology Backyard", promoting South–South cooperation, and contributing to global agricultural green development[19,31].

4 Innovative pathways for modern agricultural transformation

Drawing insights from Private Enterprise Symposium, the "No. 1 Central Document", and the STB practices, the following innovative pathways are proposed for modern agricultural transformation.

4.1 Strengthening collaboration between private enterprises and agricultural technology

Leveraging policy directions from the "No. 1 Central Document", private enterprises should deepen partnerships with agricultural research institutions and universities to drive innovation and commercialization of agricultural technologies. Through policy incentives and funding support, private enterprises can actively participate in agricultural value chain integration and modern agricultural demonstration zones.

4.2 Scaling up the STB model

Promote the nationwide adoption of the STB model to strengthen talent cultivation and grassroots agricultural service systems. This will accelerate the translation of research into practical solutions, expanding the reach and impact of agricultural technology services.

4.3 Optimizing agricultural industrial structure

Align with the "No. 1 Central Document" guidelines on structural adjustment to optimize and upgrade the agricultural sector through market mechanisms and policy support. Enhance branding and marketing to boost the competitiveness and added value of agricultural products.

4.4 Strengthening agricultural technology innovation systems

Establish a robust agricultural innovation ecosystem with increased R&D investment and efficient commercialization mechanisms. Guided by the "No. 1 Central Document", prioritize talent development and recruitment to provide a skilled workforce for agricultural modernization.

5 FASE supports "three rural", jointly building a new ecosystem for Agriculture Green Development

As a leading journal in agricultural science and engineering, *Frontiers of Agricultural Science and Engineering* (FASE)[32] has been dedicated to advancing agricultural technological innovation and providing critical academic and intellectual support for the development of the "three rural". By publishing high-quality research papers, reviews, and comments, the journal disseminates cutting-edge agricultural scientific achievements and concepts, facilitates collaboration between academia and industry, and offers theoretical and practical guidance for agricultural modernization and rural revitalization.

The innovative spirit and practical accomplishments demonstrated by four outstanding entrepreneurs specializing in the "three rural" at the recent symposium with private enterprises, along with the successful model of the STB pioneered by Academician Fusuo Zhang, align closely with the principles championed by FASE. Moving forward, we look forward to publishing more forward-looking and innovative research on agricultural technological advancements, industrial upgrading, and rural revitalization in FASE. Together, let us co-create a new ecosystem for China's Agriculture Green Development.

6 Conclusions

The modernization of agriculture hinges on the dual engines of private sector vitality and technological innovation. By aligning policy, market forces, and grassroots ingenuity, China is poised to transform its agricultural landscape into one defined by intelligence, sustainability, and shared prosperity. As scientists, entrepreneurs, and policymakers unite, the vision of a modernized rural China—vibrant, inclusive, and resilient—comes ever closer to reality.

Let us collaborate to advance agricultural science and innovation, contributing collective wisdom to realize rural revitalization and the grand goal of building a modern socialist nation.

Compliance with ethics guidelines

Jianxiang Xu, Yunzhou Li, Jingyue Tang, Liang Shi, Yinkun Yao, and Jie Zhao declare that they have no conflicts of interest or financial conflicts to disclose. This article does not contain any studies with human or animal subjects performed by any of the authors.

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