

The Path of Collaborative Innovation in Modern Agricultural Enterprises under the TOE Framework—A Case Study of a Seawater Rice Company

Shanshan Wu *

Wenzhou Polytechnic, Wenzhou, 325035, China

*Corresponding Author: wssapplication@hotmail.com

ABSTRACT

Innovation not only enhances productivity and efficiency in modern agricultural enterprises but also enables them to adapt to changing market dynamics and mitigate risks associated with climate change and resource scarcity. However, relying solely on internal resources and capabilities for innovation has its limitations, prompting an increasing number of agricultural enterprises to explore collaborative innovation. Collaborative innovation involves partnerships between enterprises, research institutions, government agencies, and others to share resources and knowledge, jointly develop and implement new ideas, products, services, or solutions. This approach transcends traditional organizational boundaries, fostering open exchange and co-creation of value among partners, often resulting in more significant outcomes and benefits than individual efforts alone. This paper explores the pathway of collaborative innovation in modern agricultural enterprises under the TOE (Technological, Organizational, and Environmental) framework, focusing on a case study of a seawater rice company in China. By examining dimensions of technological collaboration, organizational complementarity, and environmental coordination, the study elucidates the synergistic effects of collaborative innovation. The findings contribute to understanding how collaborative innovation fosters sustainable growth and resilience in agricultural ecosystems.

KEYWORDS

Collaborative innovation; TOE framework; Modern agricultural enterprises

1. INTRODUCTION

In recent years, the agricultural sector has undergone significant transformations globally, driven by the need to meet the demands of a growing population, ensure food security, and address environmental challenges. In this context, modern agricultural enterprises are compelled to innovate continuously to remain competitive and sustainable. Innovation not only enhances productivity and efficiency but also enables enterprises to adapt to evolving market dynamics and mitigate risks associated with climate change and resource scarcity [1].

However, traditional approaches to innovation within agricultural enterprises often encounter limitations, primarily stemming from the siloed nature of research and development efforts. While internal innovation processes are valuable, they may not fully capitalize on external knowledge and expertise, leading to suboptimal outcomes. Recognizing these constraints, there is a growing recognition of the importance of collaborative innovation to harness diverse perspectives, resources, and capabilities.

Collaborative innovation entails the pooling of resources and expertise across multiple stakeholders, including government agencies, research institutions, industry partners, and communities. By fostering synergy and knowledge exchange, collaborative innovation not only accelerates the pace of innovation but also enhances the relevance and impact of technological advancements. In the context of modern agricultural enterprises, where challenges are multifaceted and interconnected, collaborative innovation emerges as a strategic imperative.

China, as a global agricultural powerhouse, has prioritized the upgrading and transformation of its agricultural enterprises to ensure sustainable development and global competitiveness. With a focus on innovation-driven growth, the Chinese government has emphasized the importance of collaboration among stakeholders to drive technological progress and organizational change within the agricultural sector.

This paper aims to explore the path of collaborative innovation in modern agricultural enterprises under the TOE (Technological, Organizational, Environmental) framework, using a case study approach. Drawing insights from a seawater rice company in China, we examine the dimensions of technological collaboration, organizational complementarity, and environmental coordination to elucidate the synergistic effects of collaborative innovation. Through this analysis, our study contributes to the growing body of knowledge on collaborative innovation in agriculture, offering practical guidance for fostering innovation ecosystems that drive sustainable growth and resilience.

2. LITERATURE REVIEW

2.1. TOE Framework

The TOE (Technology-Organization-Environment) framework was proposed by Tomatzky and Fleischer in 1990 [2]. Initially, the theory emphasized the influence of information technology itself on technology adoption. However, it quickly evolved to consider the impact of organizational and environmental factors, providing theoretical explanations for the adoption and diffusion of emerging technologies based on internal and external conditions of enterprises. Over time, scholars have continuously developed the TOE framework, enriching its content and adjusting it according to the research objects and practical situations to enhance its applicability in research applications. In recent years, the TOE framework has not only been used to explain innovation and technology diffusion within enterprises but has also been widely applied in theoretical analyses of regional economies, industrial upgrading, digital government, and other fields [3-5].

In the TOE model, "T," "O," and "E" respectively represent technological factors, organizational factors, and environmental factors. Technological factors refer to the existing technologies within an organization and those not yet adopted by the enterprise but available in the market. These factors include the basic technological conditions of an enterprise, such as its technological infrastructure and capabilities, as well as the characteristics of the technology to be adopted, such as its relative advantage and compatibility.

Organizational factors typically encompass the scope and scale of the enterprise, management structure characteristics, and human resource conditions, mainly referring to organizational characteristics. Among numerous articles studying enterprise behavior, the role of enterprise size as a variable has been widely accepted. In addition to this, senior management support is also a common major influencing factor in articles studying enterprise behavior. Wang et al. (2010) further break down organizational factors into enterprise size, senior management support, and technological capabilities [6].

Environmental factors refer to the macro-environment in which an organization conducts its business or activities, including the overall industry situation, competition intensity and analysis, government environment, etc. These factors can be broadly categorized into external pressures and external

support. External pressures mainly come from the government, competitors, and trade partners (suppliers and customers), which are basically consistent with the coercive, normative, and mimetic pressures outlined in institutional theory. External support includes government support and support from trade partners. Gibbs and Kraemer (2004) consider environmental factors to include external pressures (from customers and competitors), government promotion, and institutional barriers [7]. Lin and Ho's work includes pressures from customers and management regulations, government support, and environmental uncertainty in environmental factors [8].

The TOE framework is highly comprehensive, as it does not specify the specific explanatory variables for the three categories of factors, thus possessing strong systematic, flexibility, and operability. When applying the TOE framework, it is necessary to analyze and determine influencing factors according to specific situations and refine and expand them accordingly.

2.2. Collaborative Innovation

Collaborative innovation refers to the process by which multiple individuals, organizations, or entities work together to generate, develop, and implement novel ideas, products, services, or solutions. It involves pooling resources, knowledge, expertise, and capabilities from diverse stakeholders to address complex challenges, explore new opportunities, and drive meaningful change. Collaborative innovation often transcends traditional organizational boundaries and fosters open exchange and co-creation of value among partners, leading to synergistic outcomes that may not be achievable through individual efforts alone [9].

Empirical research has shown that collaborative innovation can lead to enhanced product/service quality, accelerated time-to-market, and increased market responsiveness [10-12]. Moreover, collaborations with diverse partners from academia, industry, and government can foster cross-fertilization of ideas and knowledge exchange, driving breakthrough innovations and addressing complex societal challenges.

Although some scholars have recognized the importance of collaborative innovation in the agricultural domain, there has been limited attention to how modern agricultural enterprises achieve collaborative innovation [13-15].

Based on the TOE framework, this paper takes a seawater rice company as a case study to specifically elucidate how this enterprise achieves collaborative innovation through technological collaboration, organizational complementarity, and environmental coordination, thereby filling relevant theoretical gaps.

3. OVERVIEW OF THE SEAWATER RICE COMPANY

The selected case company in this paper is Zhejiang Ruihai Biotechnology Co., Ltd., a seawater rice enterprise based in China. The company was established in 2018 and is primarily engaged in the development and utilization of saline-alkali land along the southeastern coast of China. It is a modern agricultural enterprise integrating seawater rice cultivation, vegetable planting, seed breeding, and smart agriculture. In 2019, with government support, the company acquired the rights to lease 1,500 acres of farmland and collaborated with the Qingdao Seawater Rice Research and Development Center led by academician Yuan Longping. Utilizing the "Four-Dimensional Improvement Method," the company introduced seawater rice cultivation technology. The soil salinity in the company's responsible area has decreased from 6‰ to around 3‰, and the average yield per mu has increased from less than 300 kilograms to 400 kilograms. Currently, the company has established four subsidiaries, one agricultural cooperative, and one agricultural service center. It has also established seawater rice project bases in several coastal areas, with a total planting area exceeding 3,500 acres. It is projected that the total planting area of seawater rice will exceed 10,000 acres in the future.

The company takes seawater rice research and development as its resource carrier, market demand as its guide, technology as its support, and projects as its link. It gathers innovative elements, optimizes resource allocation, and focuses on building a seawater rice ecosystem to create a demonstration model for modern agricultural industry revitalization along the southeastern coast. With the support of national and local government policies, the company has embarked on a path of collaborative innovation through technological collaboration, organizational complementarity, and environmental coordination.

4. COLLABORATIVE INNOVATION MODEL OF MODERN AGRICULTURAL ENTERPRISES UNDER THE TOE FRAMEWORK

The TOE analysis framework categorizes factors influencing technological innovation in enterprises or organizations into three types: technological, organizational, and environmental dimensions. This paper proposes that collaborative innovation in modern agricultural enterprises can similarly be analyzed from these three dimensions. Taking Zhejiang Ruihai Biotechnology Co., Ltd. as an example, advanced seawater rice cultivation technology and intelligent agricultural facilities form the technological foundation for its innovation. The application and diffusion of technology are also associated with the organizational structure and coordination of the enterprise. Additionally, the company's technological innovation benefits from external factors such as government support and collaboration with academic institutions. Therefore, based on the aforementioned TOE framework and the specific situation of Zhejiang Ruihai Biotechnology Co., Ltd., this paper proposes a model for the collaborative innovation path of modern agricultural enterprises. The model encompasses three dimensions: technological collaboration, organizational complementarity, and environmental coordination. Refer to Figure 1 for the model diagram.

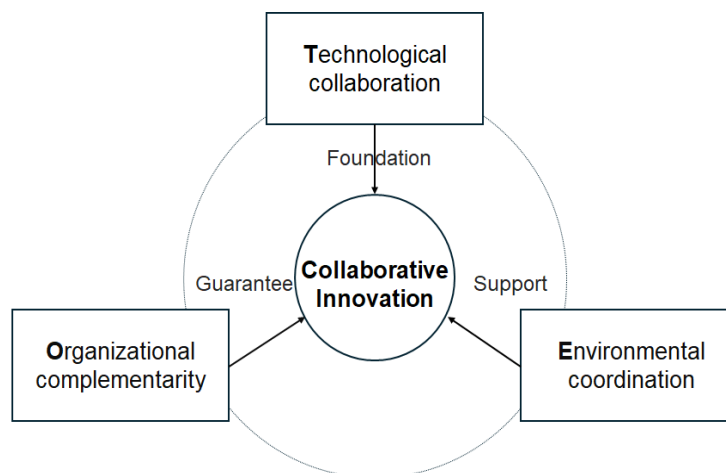


Figure 1. Collaborative innovation model of modern agricultural enterprises under the TOE framework

4.1. Technological Collaboration as a Foundation

Technological innovation is crucial for the sustainable development of modern agricultural enterprises, but it often requires substantial technical expertise and research and development investments. Large-scale cultivation of seawater rice involves high technological complexity and requires strong technical support. If enterprises rely solely on their own capabilities for all technological research and innovation, they will face significant pressure and risks. For instance, breeding seawater rice involves utilizing gene sequencing technology to identify naturally salt-tolerant, alkali-resistant, and disease-resistant genes. Through conventional breeding, hybridization, and molecular marker-assisted breeding techniques, it takes years of selection to develop salt-tolerant rice varieties suitable for industrial promotion, yielding over 300 kilograms per mu.

If companies attempt independent research and development, they will not only face shortages in talent and technology but also struggle with profitability pressures. Therefore, enterprises need to adopt an open approach and actively seek external complementary resources, information technology, knowledge, talent, capital, and channels.

In 2017, Chen Xiuwei, the founder of Ruihai Company, learned about significant breakthroughs in seawater rice cultivation by Academician Yuan Longping's team. He visited the Seawater Rice Research and Development Center in Qingdao to report and explore opportunities for collaboration with Yuan Longping's team. Through his efforts, the Qingdao Seawater Rice Research and Development Center and its team of academicians and experts collaborated with the Wenzhou Seawater Rice Team in 2018 to initiate industry-academia-research integration activities. Based on friendly negotiations and guided by principles of "equality, mutual benefit, complementary advantages, cooperation, and common development," they reached a strategic cooperation agreement. The collaboration aimed to promote professional development, expand cooperation fields, innovate collaboration models, and establish a new technology research and development system for mutual growth. The Qingdao Seawater Rice Research and Development Center provided consultations and technical guidance on seawater rice industry development trends, key industry technologies, and talent cultivation.

In addition to seawater rice breeding technology, the application of smart agriculture is also a significant innovation for Ruihai. Compared to traditional agricultural practices, smart agriculture achieves digitized management throughout the agricultural production process, including seedling cultivation, planting, fertilization, irrigation, pest control, and harvesting. It utilizes sensors, monitoring instruments, and other devices to collect real-time data, which is then analyzed using cloud computing, big data, and other technologies to enhance production efficiency and reduce costs.

Moreover, traditional agriculture involves intensive labor such as plowing, irrigation, fertilization, and harvesting, requiring significant time and effort from farmers. In contrast, smart agriculture employs automated equipment to manage these tasks, thereby alleviating pressures on labor resources amidst urbanization and aging populations. However, implementing smart agriculture demands profound expertise in technologies like the internet and big data, which many agricultural enterprises often lack.

Therefore, Ruihai has collaborated with prominent Chinese internet companies such as Huawei and DJI in the field of smart agriculture. Leveraging Huawei's "Nine Skies" and "Houtu Cloud" Platform's smart agriculture big data equipment, the company advances digitalized farmland construction to comprehensively support rice production. At the core of this system is plant and soil regulation, incorporating small-scale weather stations, communication modules, high-definition cameras, and various sensors for collecting information on light, temperature, salinity, and alkalinity. This data is transmitted to Huawei's cloud-based big data center, where AI (Artificial Intelligence) systems and expert diagnostics provide targeted treatments and precision fertilization, significantly improving water and fertilizer usage accuracy.

Additionally, unmanned aerial vehicles (UAVs) operate nearly 30 times faster than manual labor, performing tasks such as seeding and pest control, thereby substantially reducing costs associated with labor and mechanized operations. In 2020, Zhejiang Ruihai Biotechnology Co., Ltd. collaborated with DJI Agriculture's Wenzhou team to establish a demonstration base for improving saline-alkali rice cultivation in Ruian, which became a new trial site for DJI Agriculture's UAV sowing solution for saline-alkali rice.

From the example of Ruihai, we can see that modern agricultural enterprises often face limitations when innovating solely relying on their own resources. Through collaboration with external entities, companies can overcome constraints in funding, personnel, and technology, and implement innovative outcomes at lower costs and investments. Therefore, we believe that technological collaboration forms the foundation of innovation for modern agricultural enterprises.

4.2. Organizational Complementarity as a Guarantee

China adopts a basic agricultural management system based on household contract operation, with a large number of small and medium-sized farmers engaged in scattered operations. This widespread practice results in small-scale agricultural operations, low efficiency, slow technological progress, and challenges in effectively connecting agricultural production with modern markets.

This situation presents new demands for innovating agricultural management models. It is imperative to accelerate the cultivation of new agricultural entities such as family farms, large-scale agricultural operators, farmers' cooperatives, and leading enterprises in agricultural industrialization. This approach encourages urban industrial and commercial enterprises and social capital to participate in agricultural operations, guiding farmers and various new agricultural entities to collaborate and explore new models of agricultural industrialization.

Modern agricultural enterprises, like Zhejiang Ruihai Biotechnology Co., Ltd., have widely adopted a new organizational model of "leading enterprises + cooperatives + farmers." The leading company is responsible for seedling cultivation, planting, management, and sales, while the cooperative societies handle land transfer, labor employment, and related coordination services. Farmers contribute their land shares to the cooperatives, prioritizing work at the base during regular periods. After the base generates profits, the company, cooperative societies, and farmers distribute dividends according to a predetermined ratio.

This is a new organizational model with complementary characteristics. In this model, the leading enterprises play a guiding role. These enterprises typically operate on a larger scale, have advanced development concepts, well-developed external networks, and exhibit significant characteristics across the industry chain. They possess strong economic strength and capital operation capabilities, making them the most dynamic entities within the modern agricultural management system in terms of scale innovation and industrial chain operation.

Taking seawater rice cultivation as an example, individual farmers face significant limitations and lack the necessary funds and technological reserves. Ruihai Company, with its substantial financial resources and extensive external networks, can collaborate with research institutions and renowned enterprises to innovate in the scientific breeding and cultivation of seawater rice. On the other hand, cooperatives and farmers can help solve Ruihai Company's land and labor issues, allowing the company to concentrate on technological innovation and scientific management. This organizational structure achieves division of labor, mutual complementarity, and fosters a symbiotic ecosystem of collaboration and shared prosperity. It provides assurance for collaborative innovation in modern agricultural enterprises.

4.3. Environmental Coordination as a Support

The development and innovation of enterprises are inseparable from the external environment. This paper primarily discusses how external environmental coordination, from the perspectives of government support and collaboration with universities, promotes collaborative innovation in modern agricultural enterprises.

Firstly, government policies and financial support create a favorable environment for innovation in modern agricultural enterprises. The Chinese government has introduced policies to support the development of smart agriculture, the construction of research and innovation platforms, the research and development of key core technologies, and the transformation of scientific and technological achievements, promoting the development of agricultural science and technology. These policies provide platforms and subsidies for the technological research and development of seawater rice, making it a leader in the technological development of seawater rice. As a local private enterprise, Ruihai faces certain shortcomings compared to state-owned enterprises and big enterprises, especially given the high initial investment and low returns of seawater rice cultivation, as well as the

requirement for substantial land resources. Without government support, Ruihai would encounter significant difficulties in acquiring land. Therefore, prior to the implementation of the seawater rice project, Chen Xiuwei's team actively engaged with the Wenzhou municipal government, seeking support in terms of land and funding.

In accordance with national policy requirements and local development needs, after inspection and assessment, the Wenzhou Rui'an municipal government leased the 1,500 mu of saline-alkali land in the Ding Mountain Phase II reclaimed beach to Ruihai for agriculture, with a lease period of 20 years, including a rent-free period for the first five years, followed by rent replaced by taxes. The Rui'an Municipal Agriculture and Rural Bureau also provided certain scale subsidies and post-reclamation maintenance subsidies, along with technical support. The company received a government subsidy of 4,000 yuan per mu for three years of "post-reclamation maintenance" to enhance soil fertility on newly reclaimed farmland. Local government support in terms of funding and land allowed Ruihai to overcome the challenging initial phase of establishment and enter a period of rapid development. The close collaboration between modern agricultural enterprises and the government provides policy and financial support for enterprise innovation.

Additionally, an increasing number of modern agricultural enterprises are collaborating with educational institutions such as universities. For example, China's first Sea Rice Academy is a new type of industry-academia collaboration, jointly established and managed by both academia and enterprises. It relies on the strengths of the Qingdao Sea Rice Research and Development Center and Qingdao Hengxing Technology College, focusing on cultivating talents for the industrial promotion of sea rice and conducting talent development in the sea rice field. Ruihai has also partnered with Ningbo University to establish an integrated practice base for industry-education collaboration. Universities possess advantageous resources such as talent, research, platforms, and patents. Through collaboration with universities, enterprises can leverage these resources, fully exploit the advantages of university disciplines, engage in product research, development, and innovation activities, reduce the cost of technological innovation, effectively enhance innovation quality and efficiency, and continually improve enterprise market competitiveness.

Through the example of Zhejiang Ruihai Biotechnology Co., Ltd., we believe that by collaborating with the government and higher education institutions in the external environment, modern agricultural enterprises can alleviate pressures related to funding, talent, and other aspects, thereby achieving more efficient innovation.

5. CONCLUSION

This paper explores the practices and experiences of collaborative innovation pathways in modern agricultural enterprises through a case study of Zhejiang Ruihai Biotechnology Co., Ltd.

Firstly, modern agricultural enterprises face challenges and necessities in technological innovation, but relying solely on internal resources often limits them due to constraints in funding, talent, and technical capabilities. Therefore, this paper emphasizes technological collaboration as the foundation of innovation in modern agricultural enterprises. Through collaboration with external entities, enterprises can achieve innovative outcomes at lower costs and investments.

Secondly, organizational complementarity is highlighted as a crucial aspect for ensuring collaborative innovation in modern agricultural enterprises. Addressing the characteristics and current status of China's basic agricultural management system, the paper proposes the accelerated cultivation of new agricultural entities such as family farms, large-scale agricultural operators, and farmers' cooperatives. Through the synergistic interaction between these new agricultural entities and enterprises, a new organizational model with distinct complementary features is established.

Lastly, from the perspective of environmental coordination, the paper discusses how government support and collaboration with higher education institutions promote collaborative innovation in

modern agricultural enterprises. Government policies and financial support create a favorable environment for enterprise innovation, particularly in technologies like seawater rice cultivation. Collaboration with universities enables enterprises to leverage talent and research resources, enhancing innovation quality and efficiency.

In conclusion, using the TOE analytical framework, this paper proposes a path model for collaborative innovation in modern agricultural enterprises, encompassing technological collaboration, organizational complementarity, and environmental coordination. This model not only enriches understanding of collaborative innovation in agriculture but also provides practical guidance amidst complex market environments and technological challenges. As modern agricultural enterprises gain increasing global importance, the research outcomes of this paper contribute to integrating agricultural innovation with sustainable development, fostering high-quality development of the agricultural economy.

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