Frontiers in Business, Economics and Management
ISSN: 2766-824X | Vol. 22, No. 3, 2026

Research on the Theoretical Basis and Analytical Framework of Digital Technology-driven Intelligent Transformation of Marine Ranches

Tao Li [1], Tongtong Li [2, a, *], Mo Zhang [3, b, *]

[1] Management College, Ocean University of China, 266100 Qingdao, Shandong, China

[2] School of Marxism, Shandong Jianzhu University, Jinan, 250014, China

[3] School of Accountancy, Shandong University of Finance and Economics, Jinan 250014, China

[*] **Corresponding author**: [a] litongtong19@sdjzu.edu.cn, [b] beethmo@163.com

Abstract: Marine ranches are complex systems with multiple functions including production supply, ecological restoration, quality and safety, and social services. Their operating objects are open, mobile, and highly uncertain. Traditional management methods that rely on experiential judgment and decentralized operations are difficult to adapt to the development requirements of refinement, collaboration, and sustainability. With the maturation of technologies such as the Internet of Things, intelligent perception, artificial intelligence, cloud-edge collaboration, digital twins, and blockchain, Marine ranches are shifting from single-point equipment updates to systematic reconfiguration around data, processes, organizations, and institutions. Based on the digital transformation theory, the technology-organization-environment framework, the technology implementation and assimilation theory, the absorptive capacity theory, the dynamic capacity theory, and the resource orchestration theory, this paper systematically reviews the theoretical logic of digital technology-driven intelligent transformation of Marine ranches and constructs an analytical framework of "antecedent conditions - stage processes - capability embedding - performance results". The study suggests that the intelligent transformation of Marine ranches is not a simple technology introduction, but an organizational evolution process gradually advanced by digital technology adoption, digital technology absorption and digital technology institutionalization; Technological attributes, organizational foundations and environmental pressures jointly determine the starting point of transformation, dynamic capabilities, absorptive capabilities, resource orchestration capabilities and innovation capabilities jointly determine the depth of transformation, while economic performance, ecological performance and social performance constitute the combined result of value realization. Furthermore, this paper reveals the six value realization logics of the intelligent transformation of Marine ranches, namely the logic of efficiency improvement, the logic of decision optimization, the logic of ecological governance, the logic of collaborative governance, the logic of credit enhancement and the logic of resilience improvement, and puts forward a set of research propositions for subsequent empirical testing. This paper aims to provide an interpretive and scalable comprehensive analytical framework for the study of the intelligent transformation of Marine ranches, and also to provide theoretical support for the high-quality development of Marine ranches in the context of the blue economy.

Keywords: Digital technology; Marine ranches; Intelligent transformation; Theoretical basis; Analysis Framework; Value realization.

1. Introduction

Marine ranches, as an important organizational form for Marine resource development, fishery transformation and upgrading, and Marine ecological restoration, are moving from a construction logic dominated by restocking, artificial reefs, and traditional conservation to an advanced development stage characterized by digital perception, intelligent decision-making, and collaborative governance. Compared with land-based agriculture and closed industrial systems, Marine ranches face stronger environmental fluctuations, higher monitoring costs and more complex subject relationships: on the one hand, factors such as sea conditions, temperature and salinity, dissolved oxygen, red tides, biological growth and disaster risks are highly coupled, requiring managers to have real-time perception and rapid response capabilities; On the other hand, Marine ranches undertake multiple functions such as aquatic product supply, ecological protection, quality traceability, leisure tourism and science popularization education. The value goal is not the single maximization of profit, but the coordinated realization of economic, ecological and social goals. Therefore, the difficulty of the transformation of Marine ranches lies not only in "whether there is technology", but also in "whether technology can be transformed into organizational capabilities and continuously translated into comprehensive performance".

In recent years, digital technology has become a key variable driving industrial transformation. Vial (2019) points out that digital transformation is essentially a process in which digital technologies trigger the reshaping of organizational value creation paths; Verhoef et al. (2021) further emphasized that digital transformation is not merely the replacement of digital tools, but rather an overall redesign involving strategy, processes, structure, and business logic. For Marine ranches, the significance of digital technology lies not in the deployment of individual sensors, platforms, or algorithms, but in whether these technologies can be deeply coupled with production scenarios, ecological governance, and organizational systems, enabling Marine ranches to move from experience-driven to data-driven, from post-disposal to predictive management, and from decentralized entities to collaborative governance. As a result, the intelligent transformation of Marine ranches should be understood as an evolving systems engineering.

Although existing research provides important insights for understanding digital technology and industrial transformation, there are still three deficiencies in research on Marine ranches. First, the discussions have mostly focused on equipment application, platform building, or local scenario innovation, lacking a process analysis that explains as a whole "how technology enters the organization, how it is absorbed, and ultimately results in performance." Second, existing research often establishes a direct link between technological effects and performance results, and pays insufficient attention to organizational learning, resource integration, institutional embedding, and capability reconfiguration in the middle links, making it difficult to explain why similar technological inputs produce so different results across different Marine ranches. Third, most studies interpret performance as a single improvement in output, cost, or benefit without fully considering the specific ecological, social, and governance performance of Marine ranches. Based on this, this paper attempts to answer three questions: What is the theoretical basis for digital technology-driven intelligent transformation of Marine ranches? How a unified analytical framework should be constructed for the intelligent transformation of Marine ranches; What are the stage characteristics and inherent laws of the value realization logic and performance formation mechanism of the intelligent transformation of Marine ranches?

Centering on the above questions, this paper takes theoretical integration as the main thread and systematically introduces theories of digital transformation, technology-organization-environment framework, technology implementation and assimilation theory, absorptive capacity theory, dynamic capacity theory and resource orchestration theory, and builds a comprehensive analysis framework of digital technology-driven intelligent transformation of Marine ranches on this basis. The main contributions of this paper are as follows: First, it clarifies the theoretical basis of the intelligent transformation of Marine ranches from the perspective of multi-theory integration, avoiding simplifying it to a single technology adoption problem; Second, it presents an analytical framework of "antecedent conditions - stage processes - capability embeddings - performance results", highlighting the stage evolution and capability amplification effect of the intelligent transformation of Marine ranches; Third, expand the performance results into three dimensions of economy, ecology and society to reveal the complexity and lag of the release of digital technology value.

2. Literature Review and Theoretical Basis

2.1. Theory of Digital Transformation

Digital transformation research generally holds that digital technologies do not automatically generate organizational performance, and their true value depends on whether the technology changes the way the organization creates value, the decision-making model, and the resource allocation structure. Vial (2019) noted in a systematic review that the infiltration of digital technologies can trigger organizational strategic responses, structural adjustments, and path repositioning, which may result in efficiency, innovation, and value enhancement, as well as organizational frictions, capability mismatches, and institutional conflicts. Verhoef et al. (2021) further distinguished the three levels of digitalization, digital application, and digital transformation, emphasizing that transformation is a systemic process of change that crosses boundaries, levels, and functions. Warner and Wager (2019) pointed out from the perspective of strategic renewal that digital transformation requires organizations to continuously develop new capabilities of perception, capture and reconstruction in order to support the continuous deepening of transformation.

These studies offer three key insights into the intelligent transformation of Marine ranches. First, the intelligent transformation of Marine ranches must be seen as an organizational change rather than a technological upgrade. Second, the transformation is phased; technology deployment, business reconfiguration and institutional embedding do not occur simultaneously. Third, the outcome of the transformation is dual and uncertain. If there is no matching organizational foundation and governance mechanism, technology investment may turn into a cost burden or even governance risk. Therefore, the theory of digital transformation provides an overall understanding of the "nature of transformation" and the "uncertainty of outcomes" for this article.

2.2. Technology-Organization-Environment Framework

The Technology-organization-environment framework emphasizes that the adoption of new technologies by organizations is not determined solely by the technologies themselves, but rather by the combined effect of technological characteristics, organizational conditions, and the external environment. For Marine ranches, the technical dimension involves the reliability of sensing devices, the compatibility of platform systems, the interpretability of algorithmic models, the real-time nature of data collection, and stability in the complex Marine environment; The organizational dimension involves managers' perception, strategic orientation, capital investment, personnel skills, data base and process norms; The environmental dimension includes policy support, regulatory requirements, market competition, consumer demand for traceable and green aquatic products, and the digital maturity of upstream and downstream collaborative entities. The external environment of Marine ranches is more institutional and public than that of general enterprises, as sea area use, ecological constraints, quality and safety, and public regulation largely affect the feasibility of technology adoption and the intensity of incentives.

The advantage of the TOE framework lies in its ability to explain "why" the intelligent transformation of Marine ranches. External pressures and policy incentives will drive Marine ranches to embark on digital transformation when the technology has visible benefits and the organization has a certain level of readiness; Conversely, even if the technology is available, the transformation may remain in a wait-and-see and pilot stage if the organization lacks the resource base or the environmental incentives are insufficient. Therefore, the TOE framework provides the basis for the analysis of antecedent conditions in this article.

2.3. Technology Implementation and Assimilation Theory

The theory of technology implementation and assimilation has shifted the research focus from "whether to adopt" to "how to truly embed and form regular applications". Cooper and Zmud (1990) suggest that technology implementation is a diffusion process from initiation, adoption to adaptation, acceptance, regularization and embedding. Purvis et al. (2001) further pointed out that the true value of complex technology in an organization depends on whether it makes the leap from surface adoption to deep assimilation, and the buying and installation of technology does not mean it has become an everyday capability of the organization. This is particularly crucial for Marine ranches. Many digital technologies can create visual displays or partial improvements in the early stages of introduction, but they are difficult to sustain without being combined with aquaculture operations, environmental monitoring, risk warnings, quality traceability, and management assessment.

Therefore, this paper divides the process of intelligent transformation of Marine ranches into three stages: digital technology adoption, digital technology absorption, and digital technology institutionalization. Adoption emphasizes the introduction and use of technology, absorption emphasizes the organization's transformation of technology into actionable knowledge through learning, debugging, and process reengineering, and institutionalization emphasizes the further embedding of technology into rules, processes, responsibilities, and assessment systems as part of a stable operating logic. By this division, transformation can be avoided from being understood as a static event, but rather as a continuous process of organizational evolution.

2.4. Absorptive Capacity, Dynamic capacity and resource Orchestration Theory

Cohen and Levinthal (1990) put forward the concept of absorptive capacity, emphasizing that organizations need to rely on their existing knowledge base to identify, absorb and utilize new external knowledge; Zahra and George (2002) further divided absorptive capacity into dimensions such as acquisition, digestion, transformation and utilization, noting that the transformation of knowledge value depends on the learning and reconfiguration mechanisms within the organization. For Marine ranches, the application of digital technology is highly dependent on data interpretation, scenario adaptation and experience accumulation. With only technology input but lacking absorptive capacity, it is easy to have the "equipment in operation, data not used, decision-making not improved" break.

The dynamic capability theory emphasizes that in a rapidly changing environment, organizations need to continuously perceive opportunities, capture opportunities, and restructure their resource bases in order to achieve long-term competitive advantages. The "perception-caption-reconfiguration" logic proposed by Teece (2007) provides an important perspective for understanding the intelligent transformation of Marine ranches: in the face of changes in the Marine environment, upgraded market demand and strengthened regulation, Marine ranches must promptly identify digital technology opportunities and transform them into new organizational arrangements and business models. Furthermore, the resource orchestration theory of Sirmon et al. (2011) suggests that resources themselves do not automatically form advantages; the key lies in how managers structure, bundle, and leverage resources. The equipment, data, platform, talent, capital and institutional arrangements of Marine ranches need to be effectively coupled in order to transform fragmented technical elements into overall capabilities.

In summary, the absorptive capacity theory explains how technology is internalized, the dynamic capacity theory explains why organizations can continue to advance transformation, and the resource orchestration theory explains how multiple types of resources are integrated and utilized during the transformation process. Together, they form the theoretical basis of "capability embedding" in the intelligent transformation of Marine ranches.

2.5. Review of Existing Studies

Overall, existing research has provided useful clues for the intelligent transformation of Marine ranches from dimensions such as digital technology characteristics, platform construction, perception monitoring, intelligent equipment, quality traceability, and ecological governance, but there is still a lack of a unified framework that can simultaneously explain antecedent conditions, stage processes, capability mechanisms, and performance results. Especially in the production-ecology coupling system of Marine ranches, the realization of the value of digital technology is not a one-off "application as benefit", but a gradual process involving organizational learning, capability reconfiguration and institutional embedding. Therefore, it is necessary for this paper to construct a more explanatory analytical framework based on the integration of multiple theories.

3. Definition and Context Characteristics of The Intelligent Transformation of Marine Ranches

A Marine ranch is not a simple aquaculture area in the general sense, but a complex system built around the proliferation of Marine biological resources, habitat restoration, ecological environment maintenance, aquatic product production and comprehensive utilization of the ocean. The operation process involves biological processes, environmental processes, engineering processes and governance processes, so any transformation is not a partial optimization of a single operation link, but a multi-objective, multi-subject, multi-level system upgrade. Because of this, the intelligent transformation of Marine ranches cannot simply follow the digital paradigms of manufacturing, retail, or platform enterprises, but must fully reflect the particularity of the Marine scene.

In terms of connotation, the intelligent transformation of Marine ranches is supported by digital technologies such as the Internet of Things, sensors, remote sensing monitoring, intelligent devices, edge-cloud collaboration, artificial intelligence, blockchain and digital twins, through the reconstruction of the chain of "perception - analysis - decision-making - execution - feedback" of Marine ranches, The process of transforming production and operation, ecological governance, quality and safety, and collaborative management from experience-driven to data-driven, and from decentralized management to systematic governance. The core is not simply moving traditional operations online, but creating new mechanisms of intelligent identification, risk warning, precise feeding, environmental regulation, quality traceability and collaborative governance based on the continuous accumulation of data and the continuous iteration of algorithms.

Compared with the digitalization of general industries, the intelligent transformation of Marine ranches has at least five situational characteristics. First, the environment is highly open and uncertain. The Marine environment is influenced by a combination of factors such as weather, tides, temperature, salinity, dissolved oxygen, pollution, and disasters. Digital systems must have greater stability, fault tolerance, and real-time response capabilities. Second, the value objectives are diverse. Marine ranches not only pursue output and revenue, but also undertake ecological restoration, resource conservation, food safety and social service responsibilities, so performance evaluation should not be limited to short-term economic indicators. Third, the subject relationship is complex. Government regulators, operators, research institutions, equipment suppliers, platform service providers, consumers and public supervisors may all be involved, and data sharing and collaborative governance become key issues. Fourth, the application of technology is highly context-dependent. Equipment corrosion, communication limitations and high maintenance costs in Marine environments make it necessary for technology deployment in Marine ranches to be deeply tailored to specific scenarios. Fifth, transition benefits have a time lag. Early investments are mainly reflected in equipment purchases, personnel training, system integration and process reengineering, and the combined benefits tend to gradually emerge during the absorption and institutionalization stages.

It is precisely because of these contextual characteristics that the intelligent transformation of Marine ranches cannot be accomplished through one-time investment, but must be gradually deepened through phased advancement, capacity accumulation and institutional support. This also means that the theoretical explanation for the intelligent transformation of Marine ranches must take into account technical logic, organizational logic and institutional logic simultaneously.

4. An Analytical Framework for Digital Technology-Driven Intelligent Transformation of Marine Ranches

Based on the aforementioned theoretical review, this paper constructs an analytical framework for digital technology-driven intelligent transformation of Marine ranches. The framework consists of four parts: antecedent conditions, stage processes, capability embeddings, and performance results. Among them, the anemesis answers "why transform," the phase process answers "how transform," the capability embedding answers "why some entities can transform deeper, more steadily, better," and the performance results answer "what value the transformation ultimately forms."

4.1. Antecedents

The antecedents are mainly composed of three dimensions: technology, organization, and environment. The technical dimension emphasizes whether the digital technology itself is adoptable, including compatibility, scalability, stability, cost-benefit ratio, visualization, and fit to Marine scenarios. If a technology is difficult to operate stably in the complex Marine environment, even if it is theoretically advanced, it will be difficult to trigger large-scale application. The organizational dimension emphasizes whether the Marine ranch operator has the willingness to transform and the implementation basis, including management support, financial availability, data accumulation, personnel skills, process norms, and organizational learning atmosphere. The environmental dimension emphasizes external variables such as policy push, market competition, quality and safety requirements, consumer preferences, and cooperative networks. Marine ranches are more likely to proactively advance their intelligent transformation when government regulation tightens, green consumer demand rises, or the pressure of industrial chain synergy increases.

4.2. Stage Processes

The process of the intelligent transformation of Marine ranches can be divided into three interlinked stages: digital technology adoption, digital technology absorption, and digital technology institutionalization. Digital technology adoption refers to the process where an operating entity, after recognizing the value of digital technology, initiates the application of the technology by means of purchasing equipment, building platforms, launching systems, and introducing algorithms. The core feature of this stage is "from nothing to something", with a focus on addressing issues of technology availability and initial use. Digital technology absorption refers to the transformation of external technical knowledge into internal actionable capabilities by organizations through training, collaboration, trial and error, adaptation, and process reengineering. The core of this stage is no longer "whether to use it", but "whether to really use it, to use it, to use it sustainably". The institutionalization of digital technology refers to the further integration of digital technology into management systems, operational standards, job responsibilities, performance evaluations, and collaboration rules as part of the organization's stable operation. At this point, technology is no longer an add-on but an endogenous mechanism that reconfigures business processes and governance logic.

This stage chain shows that the intelligent transformation of Marine ranches is not a linear direct investment to performance, but rather a gradual deepening of adoption, absorption and institutionalization to unlock value. If it fails to enter the absorption stage after adoption, the technology will remain on the surface; If it fails to enter the institutionalization stage after absorption, it will be difficult for the technology to continue to spread and form a scale effect.

4.3. Capacity Embedding

Capability mechanisms run through the entire transformation process, but they function differently at various stages. Dynamic capabilities are primarily used for early identification and mid-term adjustment, helping organizations perceive environmental changes, seize technological opportunities, and continuously correct the direction of transformation; Absorptive capacity plays a role in the technology absorption phase, determining whether the organization can transform external technical knowledge into internal understanding, process optimization, and problem-solving capabilities; Resource orchestration is mainly at the institutionalization stage, achieving deep coupling of technology and organization through the recombination of equipment, data, talent, capital, and rules; Innovation capabilities amplify across stages, enabling organizations to continuously develop new solutions, new processes, and new scenarios in the application of technology, thereby enhancing transformation depth and performance levels.

4.4. Performance Results

Given the functional complexity of Marine ranches, this paper defines intelligent transformation performance into three categories: economic performance, ecological performance, and social performance. The economic performance is mainly reflected in the improvement of production efficiency, cost control, loss reduction, product premium and operating income; Ecological performance is characterized by enhanced environmental monitoring capacity, advanced ecological risk warning, optimized resource utilization and improved ecological restoration quality; Social performance is mainly reflected in enhanced food safety and quality traceability, increased consumer trust, upgraded fishermen 'skills, improved public service supply and enhanced regional collaborative governance capabilities. The three types of performance are not isolated from each other but interlinked: economic performance provides resource support for sustained investment, ecological performance provides an environmental foundation for the sustainable development of industries, and social performance guarantees the legitimacy and external trust of industries.

Based on the above analysis, the intelligent transformation of Marine ranches can be summarized as: driven by technological, organizational and environmental factors, Marine ranches initiate the adoption of digital technologies; Backed by dynamic and absorptive capabilities, digital technology is gradually digested and transformed into operational capabilities; Under the amplification of resource orchestration and innovation capabilities, digital technology is further institutionalized, ultimately forming multi-dimensional performance through production optimization, ecological governance, and collaborative control.

5. The Logic of Value Realization Driven by Digital Technology for The Intelligent Transformation of Marine Ranches

The value of the intelligent transformation of Marine ranches does not manifest as immediate improvements in a single indicator, but rather gradually emerges through multiple logical chains. This article summarizes it as six logics of value realization.

First, the logic of efficiency improvement. Traditional Marine ranching operations rely heavily on manual inspection, experience-based judgment, and decentralized management, with lagging and costly access to information. Digital technology, through real-time perception, automatic collection, remote monitoring and intelligent control, enables continuous recording and rapid feedback of operational status, environmental changes and biological behavior, thereby reducing information search costs, shortening decision-making times and lowering human reliance. Especially in areas such as feeding, inspection, disease identification and equipment maintenance, digital technology can significantly enhance the level of refined management. The precision fishery farming framework proposed by Føre et al. (2018) shows that continuous monitoring and control can enhance the visualization and adjustability of the production process, thereby improving production efficiency.

Second, decision-making optimization logic. One of the core challenges faced by Marine ranches is the uncertainty of decisions in complex environments. Digital technology shifts decision-making from experience-driven to evidence-driven by integrating environmental data, production data, historical data and external data. Sensors and platforms provide the data foundation, algorithms and models provide analytical capabilities, and edge-cloud collaboration and visualization systems enhance the timeliness and accuracy of decision execution. A review by Biazi and Marques (2023) shows that intelligent systems can enhance real-time monitoring and management decision-making in aquaculture processes through sensors, visual recognition, and integrated interfaces. For Marine ranches, this means that the transformation not only saves costs but also reshapes the decision-making mechanism itself.

Third, the logic of ecological governance. The long-term value of Marine ranches is based on ecosystem stability. Digital technology can shift ecological governance from post-restoration to pre-warning and process intervention: on the one hand, by continuously monitoring indicators such as temperature, salinity, dissolved oxygen, turbidity and pollutants, abnormal changes can be identified in a timely manner; On the other hand, ecological risks can be managed in advance through model analysis and threshold early warning. In this way, digital technology is no longer just a tool for improving productivity, but also a carrier of ecological governance capabilities. Under intelligent conditions, Marine ranches can better achieve a dynamic balance between aquaculture production and ecological protection, thus creating a positive feedback loop where "economic benefits - ecological improvement" promote each other.

Fourth, the logic of collaborative governance. Marine ranching involves multiple entities such as the government, enterprises, research, supply chains, and consumers. Information asymmetry and collaborative costs have always been governance challenges. Digital technologies can reduce the information gap between entities through platform-based connectivity and data sharing, and promote cross-entity collaboration. Blockchain, platform systems, and unified data interfaces help to break through the data chain between farming, processing, logistics, sales, and regulation, thereby enhancing traceability efficiency, regulatory transparency, and collaboration levels. This logic of collaborative governance is particularly important for Marine ranches, as its value is not only determined by on-premises production but also closely related to off-premises regulation, market circulation and social trust.

Fifth, the logic of credit appreciation. The market value of high-quality seafood is increasingly dependent on consumers' trust in its safety, greenness and traceability. Digital technology can record information about the production process, ecological environment and circulation links, forming a verifiable quality certification system for Marine ranch products. When consumers have access to more transparent production information, Marine ranch products are more likely to generate brand premium and market recognition. As a result, digital technology creates not only internal operational value, but also market value and institutional value by enhancing external trust.

Sixth, resilience enhances logic. Marine ranches face a wide range of uncertainties, including extreme weather, market volatility, disease risks, equipment failures and policy adjustments. Digital technologies enhance Marine ranches' ability to identify, absorb and recover from shocks by improving monitoring capabilities, early warning capabilities, remote control capabilities and emergency response capabilities. Dynamic capability theory suggests that the key for organizations in an uncertain environment is not to maintain the original equilibrium, but to continuously reconfigure resources and actions. Digital technology is the key infrastructure for enhancing the resilience of Marine ranches, enabling them to maintain high adaptability and continuous operational capacity in volatile environments.

The six logics suggest that the value realization of the intelligent transformation of Marine ranches is not single-point, immediate, but multi-layered, progressive and complex. Only when technology is integrated into organizations, processes, institutions and collaborative networks will value expand from local efficiency improvements to governance capacity enhancement and overall performance formation.

6. Performance Formation Mechanisms and Research Propositions for The Intelligent Transformation of Marine Ranches

Based on the above theoretical basis and value realization logic, this paper further discusses the performance formation mechanism of the intelligent transformation of Marine ranches and puts forward propositions that can be tested by subsequent research.

First, the adoption of digital technology is the starting point of performance formation, but its direct performance is often limited. The technology adoption phase mainly addresses the issue of "bringing in the technology", and organizations often face costs such as new investment, personnel training, system integration and business adaptation at this time, and thus may not show significant performance improvement in the short term. Proposition 1: Digital technology adoption can significantly promote subsequent digital technology absorption, but its direct impact on economic, ecological and social performance may not be significant or show a weak impact.

Secondly, digital technology absorption is an important mediator in performance formation. The absorption phase means that the organization begins to understand the principles of the technology, master the application methods and integrate them into the workflow. At this point, digital technology shifts from "external input" to "internal capability" and gradually improves operational quality through process optimization, collaboration enhancement, and problem identification. Proposition 2: Digital technology absorption plays a key mediating role between digital technology adoption and the performance of intelligent transformation; Proposition 3: Digital technology absorption has a significant positive impact on economic performance, ecological performance and social performance.

Again, the institutionalization of digital technology is a key link in the stable release of performance. Only when digital technology is embedded in institutional rules, job responsibilities, assessment systems, and collaborative networks can technological effects transcend individual experience and short-term projects and translate into sustained capabilities at the organizational level. Institutionalization makes technology no longer dependent on a few people to drive, but an integral part of the daily operation of Marine ranches. Proposition 4: Digital technology absorption can significantly promote the institutionalization of digital technology; Proposition 5: Digital technology institutionalization has a stronger promoting effect on three types of performance than digital technology adoption and digital technology absorption, and its effect is more stable and sustained.

Fourth, the capability factor has a significant amplification effect in the transformation process and performance formation. Dynamic capabilities help Marine ranches identify technological opportunities, adjust paths and allocate resources in a timely manner in complex environments; Absorptive capacity helps digest and transform knowledge; Resource orchestration helps with cross-resource collaboration and scenario embedding; Innovation capabilities enable organizations to continuously create new ways of application and value scenarios. Proposition 6: Dynamic capabilities, resource orchestration capabilities, and innovation capabilities have a positive moderating effect on the relationship between digital technology adoption to absorption, absorption to institutionalization, and institutionalization to performance.

Fifth, there are interlocking relationships and stage differences among multi-dimensional performance. Economic performance usually shows up first because efficiency improvements and cost controls are more likely to be observed in the short term; Ecological performance relies on longer periods of data accumulation and governance sustainability; Social performance, on the other hand, is associated with factors such as traceability, trust, collaboration, and public service, and its formation is more dependent on institutionalization and synergy. Proposition 7: The economic performance of the intelligent transformation of Marine ranches emerges earlier than the ecological performance and social performance, the latter of which have more obvious lag and accumulation.

Sixth, antecedent conditions have boundary constraints on performance formation. Even if the stage processes and capability mechanisms are in place, the intelligent transformation of Marine ranches can still be disrupted or inefficient if there is insufficient technological fit, a weak organizational foundation, or inadequate external environmental support. Technical stability, institutional support and data governance rules will significantly affect the outcome of the transformation, especially in complex sea conditions, multi-subject and strictly regulated scenarios. Proposition 8: Technical adaptability, organizational readiness, and environmental support have significant contextual boundary effects on the formation of the performance of the intelligent transformation of Marine ranches.

In terms of mechanism structure, the formation of the performance of the intelligent transformation of Marine ranches can be summarized as a progressive structure of "transformation triggered by ancausal conditions - transformation promoted by stage processes - transformation amplified by capability mechanisms - transformation reflected by multi-dimensional performance". Among them, the adoption of digital technology mainly reflects the starting logic, the absorption of digital technology mainly reflects the internalization logic, the institutionalization of digital technology mainly reflects the solidification logic, the capability mechanism reflects the amplification logic, and the final economic, ecological and social performance reflects the result logic. This mechanism helps explain why different Marine ranches show different depths of transformation and performance results in the face of similar technology supply and policy environments.

7. Theoretical Contributions, Practical Implications and Future Research Directions

The theoretical contributions of this article are mainly reflected in three aspects. First, this paper breaks through the research path of simplifying the intelligent transformation of Marine ranches as a technology adoption problem and defines it as an organizational evolution process that progresses gradually through adoption, absorption and institutionalization, thereby distinguishing the surface phenomenon of "technology entering the organization" from the deep mechanism of "technology transforming into value". Second, this paper constructs an integrated analysis framework of "antecedent conditions - stage processes - capability embeddedness - performance results", organically integrating the TOE framework, technology assimilation theory, absorption capacity theory, dynamic capacity theory and resource orchestration theory, enhancing the interpretive power for the complexity of the intelligent transformation of Marine ranches. Third, this paper extends the performance of the intelligent transformation of Marine ranches to the three-dimensional results of economy, ecology and society, and reveals the phased, lagging and complex nature of value realization, providing a more complete perspective of performance analysis for subsequent research.

At the practical level, the implications of this paper are mainly manifested as follows. First, when Marine ranches are advancing their intelligent transformation, they should not focus solely on equipment procurement and platform construction, but should simultaneously strengthen data governance, process reengineering, talent cultivation and rule embedding. Second, the transformation strategy should be carried out in stages: in the early stage, focus on technology pilot and scenario identification; in the middle stage, focus on organizational absorption and process synergy; and in the later stage, focus on institutional solidification and ecological diffusion. Third, managers should put capacity building at the core and improve the efficiency of transforming digital technology into multi-dimensional performance by enhancing environmental perception, cross-departmental collaboration and resource integration capabilities. Fourth, policy design should shift from a one-off subsidy orientation to a capacity building and collaborative governance orientation, forming sustained support in areas such as infrastructure construction, data standards, interconnection and talent supply.

Future research could continue in four directions. First, conduct more systematic quantitative research to test the research proposition proposed in this paper and analyze the mediating and moderating effects between different stages. Second, further distinguish the differences in the roles of different types of digital technologies in Marine ranching, such as the differences in the value realization paths of perception technology, analysis technology, control technology and trust technology. Third, incorporate institutional environment, regional differences, and organizational size into the framework to examine the heterogeneity of the intelligent transformation paths of Marine ranches in different contexts. Fourth, focus on the issue of digital collaborative governance of Marine ranches and study how multi-agent data sharing, responsibility allocation, and benefit incentive mechanisms affect the depth and boundaries of intelligent transformation.

8. Conclusion

Digital technology driving the intelligent transformation of Marine ranches is essentially a process of value reconstruction driven by the combined effect of digital technology, organizational capabilities and institutional arrangements. The Marine ranch is not a scenario that can be automatically transformed through simple equipment upgrades. Instead, its open environment, multiple goals, and complex synergy relationships determine that the transformation must go through a gradual evolution from technology adoption to technology absorption and then to technology institutionalization. Only when digital technology is truly understood by the organization, absorbed by processes, institutionalized, and continuously optimized with the support of dynamic capabilities, absorption capabilities, resource orchestration capabilities, and innovation capabilities can Marine ranches achieve stable and sustainable performance improvements at the economic, ecological, and social levels.

Therefore, understanding the intelligent transformation of Marine ranches should not only be about "whether the technology is useful", but also about "how the technology is utilized, embedded, stabilized and ultimately transformed into comprehensive value". The comprehensive analysis framework proposed in this paper emphasizes both the importance of anjunctive conditions and the progressive relationship between stage processes, capability mechanisms and performance results. This framework helps to grasp the key structure of the intelligent transformation of Marine ranches theoretically and provides a relatively clear analytical starting point for subsequent empirical research, policy design and management practice.

References

[1] G. Vial, “Understanding digital transformation: A review and a research agenda”, The Journal of Strategic Information Systems, 2019, Vol. 28 (2), p118-144.

[2] P. C. Verhoef, T. Broekhuizen, Y. Bart, A. Bhattacharya, J. Q. Dong, N. Fabian and M. Haenlein, “Digital transformation: A multidisciplinary reflection and research agenda”, Journal of Business Research, 2021, Vol. 122, p889-901.

[3] K. S. R. Warner and M. Wäger, “Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal”, Long Range Planning, 2019, Vol. 52 (3), p326-349.

[4] W. M. Cohen and D. A. Levinthal, “Absorptive capacity: A new perspective on learning and innovation”, Administrative Science Quarterly, 1990, Vol. 35 (1), p128-152.

[5] S. A. Zahra and G. George, “Absorptive capacity: A review, reconceptualization, and extension”, Academy of Management Review, 2002, Vol. 27 (2), p185-203.

[6] D. J. Teece, “Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance”, Strategic Management Journal, 2007, Vol. 28 (13), p1319-1350.

[7] D. G. Sirmon, M. A. Hitt, R. D. Ireland and B. A. Gilbert, “Resource orchestration to create competitive advantage: Breadth, depth, and life cycle effects”, Journal of Management, 2011, Vol. 37 (5), p1390-1412.

[8] R. L. Purvis, V. Sambamurthy and R. W. Zmud, “The assimilation of knowledge platforms in organizations: An empirical investigation”, Organization Science, 2001, Vol. 12 (2), p117-135.

[9] M. Føre, K. Frank, T. Norton, et al., "Precision fish farming: A new framework to improve production in aquaculture", Biosystems Engineering, 2018, Vol. 173, p176-193.

[10] V. Biazi and C. Marques, "Industry 4.0-based smart systems in aquaculture: A comprehensive review", Aquacultural Engineering, 2023, Vol. 103, 102360.