

# Mechanism Analysis and Strategy Simulation of Digital Economy Empowering Low-Carbon Rural Construction in Wenzhou

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**Abstract:** This study focuses on how to advance the construction of low-carbon rural areas in Wenzhou by virtue of the digital economy, with an emphasis on exploring the specific implementation paths and internal mechanisms of agricultural carbon sink trading driven by data. A mixed research method combining qualitative case study, crisp-set qualitative comparative analysis and system dynamics simulation is adopted to conduct an in-depth analysis of multiple stakeholders. The study finds that digital technologies have spawned three differentiated implementation paths, namely the leading type, the supply chain coordination type and the sci-tech finance integration type, among which digital trust is an almost necessary core condition. Strategy simulation shows that long-term investment in public data infrastructure can more effectively reduce transaction costs and promote market scaling compared with short-term technology subsidies. The study indicates that constructing a "technology-institution-organization" co-evolution framework can provide a theoretical basis and strategy reference for the design of localized agricultural carbon sink markets.

**Keywords:** Digital Economy; Low-Carbon Rural Construction; Mechanism Analysis; Strategy Simulation

## 1. Introduction

With the in-depth advancement of the global climate change and sustainable development agenda, nature-based solutions have become a key path to achieve carbon neutrality goals. Agricultural ecosystems are not only crucial to food security, but their huge carbon sink potential is also regarded as an important ecological product. How to convert this potential into measurable, tradable and incentivizable market value, thereby driving the green

transformation of agricultural production methods, has become a core proposition at the intersection of rural revitalization and low-carbon development strategies[1]. The Chinese government has successively issued policy documents such as Opinions on Establishing and Improving the Mechanism for Realizing the Value of Ecological Products, explicitly requiring the promotion of the construction of market-oriented mechanisms such as carbon sink trading. However, agricultural carbon sink trading has long faced three inherent bottlenecks in practice: high accounting and monitoring costs lead to insufficient project economic efficiency; the complex process of carbon sink measurement and certification results in doubts about information transparency and credibility; the high participation threshold for scattered smallholder subjects leads to huge transaction costs. These bottlenecks have severely restricted the large-scale development of the market and the effective transformation of ecological benefits[2].

The rapid development of digital technologies, especially the integrated application of the Internet of Things (IoT), remote sensing, big data and blockchain, provides unprecedented technical possibilities to break through the above predicaments. Theoretically, data-driven development can realize real-time and accurate monitoring of the carbon sink generation process, automation and transparency of the accounting process, and reduce transaction frictions through smart contracts. Existing studies have been carried out in two main directions: one is to focus on the application efficiency of specific digital technologies in carbon measurement, such as using remote sensing inversion to calculate biomass; the other is to analyze the design of carbon market policies and financial tools from a macro perspective. However, existing literature has significant limitations: most studies follow a linear thinking of "technology-result", or simplify digital

technologies as tools to improve efficiency, ignoring the complex co-evolution process in which they are embedded and reshape localized institutional arrangements, organizational networks and benefit distribution mechanisms. Specifically, what structural role does data play in empowering agricultural carbon sink trading? How do different technology application models interact with differentiated local contexts (such as government capacity, market structure, social capital) to spawn diverse implementation paths? What policy interventions can most effectively cultivate a data-driven carbon sink market? Systematic answers to these mechanistic and path-based questions are still lacking.

To fill the above research gaps, this paper focuses on a highly typical region—Wenzhou, China, aiming to deeply explore the implementation paths and internal logic of agricultural carbon sink trading driven by data. As a pioneer in China's private economy and market innovation, Wenzhou's vibrant private capital, developed e-commerce foundation and local government's active exploration of digital governance jointly form a natural experimental field to observe how data factors reshape the traditional ecological trading system under the "dual drive of market and government" model. This study is committed to answering three core questions:

What representative practical paths of agricultural carbon sink trading driven by data have formed in the context of Wenzhou? What specific combinations of technical, institutional and organizational conditions do the successful construction of these paths depend on? How do different public policy choices dynamically affect the evolutionary efficiency and market scale of these paths?

To solve these problems, this study adopts a sequential explanatory mixed research design. First, qualitative case studies are used to identify and describe preliminary practical models. Then, crisp-set qualitative comparative analysis is used to conduct configuration analysis on multi-case data to test the core condition combinations that facilitate trading realization. Finally, a system dynamics model is constructed to simulate and evaluate the long-term impact of key policy variables. The contribution of this paper lies not only in providing operable policy design basis for Wenzhou and similar regions, but also in revealing the micro-mechanisms and diverse paths of data empowering the realization of

ecological product value from the theoretical perspective of

"technology-institution-organization" co-evolution, thus enriching the theoretical dialogue in the fields of digital rural development and sustainable development.

The subsequent structure of this paper is as follows: the second part constructs a theoretical analysis framework; the third part elaborates on the research methods and data sources; the fourth and fifth parts present the empirical results of configuration analysis and policy simulation respectively; the sixth part summarizes the research findings and discusses their theoretical implications and practical enlightenment.

## 2. Theoretical Framework and Analytical Logic

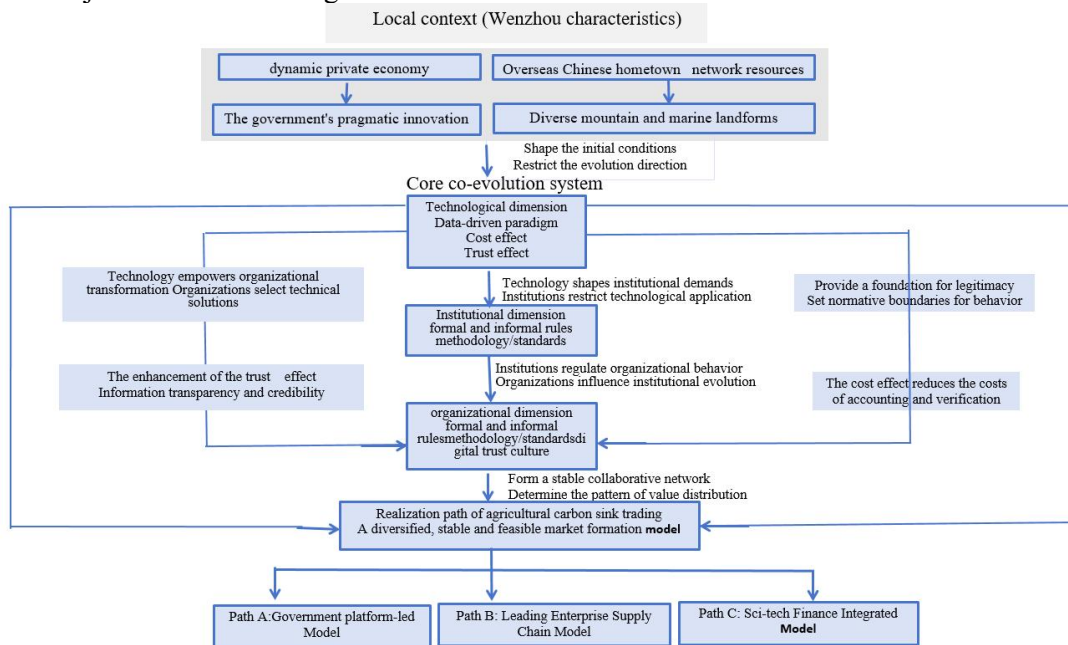
### 2.1 Definition of Core Concepts

Agricultural carbon sink trading is essentially a complex process of transforming the carbon sequestration services of ecosystems into economic value through market mechanisms. Data-driven development in this process is not a single technology application, but a systematic empowerment paradigm, whose core lies in realizing the process reengineering of the entire chain of "monitoring – accounting – certification - trading" of agricultural carbon sinks through the coordination of IoT perception, remote sensing monitoring, blockchain certification and big data analysis. This reengineering not only improves technical efficiency, but also profoundly changes the way of information production, transmission and trust establishment. Correspondingly, the implementation path refers to a set of stable role division, collaboration rules and value distribution models formed by various actors (government, enterprises, farmers, platforms, etc.) around the generation and monetization of carbon sink products after the embedding of data technologies in a specific regional context. This study aims to go beyond the phenomenological description of "paths" and deeply analyze the structural mutual construction relationship among technical elements, institutional rules and organizational networks behind them.

### 2.2 Construction of the "Technology-Institution-Organization" Co-evolution Analytical Framework

Existing theories in explaining the formation of environmental markets either focus on the pulling effect of technological innovation or emphasize the leading role of institutional design. This study holds that the realization of agricultural carbon sink trading driven by data is a typical co-evolution process of "technology-institution-organization". As an initial impact, data technologies trigger adaptive adjustments of the original institutions

and organizations by reshaping information costs and credibility, and the latter in turn restrict or promote the application direction and depth of technologies. institution-organization". The following chart shows the "technology-institution-organization" co-evolution path for the realization of data-driven agricultural carbon sink trading (Figure 1)



**Figure 1. The "Technology-Institution-Organization" Co-evolution Analytical Framework for the Realization of Data-Driven Agricultural Carbon Sink Trading**

**3. Research Methods and Data**

**3.1 Research Design: Sequential Mixed Method**

To systematically answer the core question of the path formation mechanism of agricultural carbon sink trading driven by data, this study adopts a sequential explanatory mixed research design[3]. This method follows the logical chain of "exploration-verification-prediction": first, qualitative case studies are used to identify and understand preliminary practical models and key constructs in real contexts; then, the set-theoretic method of qualitative comparative analysis is used to conduct systematic comparison and configuration analysis on multi-cases to test the complex causal relationships between different condition combinations and results; finally, a system dynamics model is constructed to dynamically simulate key policy interventions based on the aforementioned findings and evaluate their long-term effects. This design

takes into account the exploration depth, causal explanatory power and policy prospect of the research, and can effectively deal with the complex system problem of "technology-institution-organization" co-evolution[4].

**3.2 Data Sources and Collection**

This study constructs a multi-source database containing three types of data: qualitative, quantitative and simulation parameters, to ensure triangulation validation.

**3.2.1 Qualitative data**

Qualitative data are mainly used for path exploration and mechanism understanding. Through purposive sampling, diverse subjects involved in agricultural carbon sink trading in Wenzhou City and its subordinate counties and cities such as Yueqing, Yongjia and Rui'an were selected for semi-structured in-depth interviews. A total of 28 interviewees include:

- 6 staff from government and regulatory agencies: from the Municipal Development and

Reform Commission, Bureau of Agriculture and Rural Affairs, and Bureau of Ecology and Environment, with an understanding of top-level design and policy intentions[5].

- 4 representatives from trading platforms and certification institutions: from Wenzhou Carbon Inclusiveness Operation Platform and third-party verification institutions, with an understanding of trading processes and certification difficulties.
  - 10 agricultural operators: including family farmers, cooperative leaders and managers of agricultural leading enterprises, with an understanding of their participation motivation, technical adoption barriers and income perception.
  - 5 technology and service providers: from digital agricultural technology companies, blockchain service providers and financial institutions, with an understanding of technical solutions and business models.
  - 3 industry experts and scholars: providing external perspectives and theoretical insights.
- Each interview lasted 20-30 minutes, forming original interview materials. At the same time, relevant policy documents, project reports, cooperation agreements and other archival materials were collected as supplements.

### 3.2.2 Quantitative data

For configuration analysis, this study constructs a small sample data set containing 40 agricultural business units. Case selection takes into account the business type, scale and whether carbon sink trading has been attempted or realized. Through structured questionnaires and archive extraction, the following variable data of each case from 2020 to 2023 were collected:

- Outcome variable: Realization status of carbon sink trading.
- Conditional variables: Based on the theoretical framework, five aspects of antecedent conditions are mainly measured:
  - (1) Depth of data technology application: A Likert scale is used to comprehensively measure the degree of adoption of IoT, remote sensing, big data and other technologies in carbon sink monitoring, measurement and management links.
  - (2) Intensity of organizational capital: Including whether embedded in the supply chain of core enterprises, the tightness of cooperatives, and connection with scientific research institutions, etc.
  - (3) Perception of formal institutional support: Measuring the degree of understanding and

utilization of local carbon sink policies, subsidies and methodologies by business entities.

(4) Level of digital trust: Measuring the degree of trust in data-based certification methods and platform credibility.

(5) Subject resource endowment: Including control variables such as business scale, education level of managers and self-owned capital status.

### 3.2.3 Simulation parameter data

The parameters required for the system dynamics model are mainly obtained through three ways: first, extracting key relationships and feedback structures from interview records and literature; second, obtaining benchmark values from public statistical yearbooks, industry reports and local statistical data of Wenzhou; third, estimating some parameters that are difficult to obtain directly by using the Delphi method through expert consultation to form a reasonable value range.

## 3.3 Data Analysis Methods

### 3.3.1 Qualitative data analysis

Directed content analysis was conducted on interview transcripts and archival materials. First, based on the theoretical framework, texts involving technology application, rule changes, subject interaction, trading barriers and facilitating factors were coded[6]. Through constant comparison, recurring patterns were summarized, several prototype paths of data-driven carbon sink trading were initially refined, and qualitative basis was provided for the calibration of conditional variables in QCA analysis.

### 3.3.2 Qualitative comparative analysis

Crisp-set qualitative comparative analysis was used to analyze multi-case data. First, based on theoretical and qualitative findings, all conditional variables and outcome variables were calibrated as binary variables. Then, a truth table was constructed, and fsQCA software was used to conduct necessity analysis and sufficiency combination analysis. By observing the consistency between different conditional variable combinations and the occurrence of results, several equivalent paths leading to the realization of carbon sink trading were identified, and their core and auxiliary conditions were analyzed[7].

### 3.3.3 System dynamics simulation

Based on the key variables and feedback

relationships identified by configuration analysis, Vensim software was used to construct a system dynamics model. The model includes four main subsystems:

- (1) Carbon sink supply subsystem: simulating the carbon sink output and project development decisions of agricultural operators under technical and economic incentives.
- (2) Data technology diffusion subsystem: simulating the dynamic process of technology adoption and data credibility improvement.
- (3) Policy intervention subsystem: simulating the input and transmission of different policy tools including subsidies, platform construction and financial innovation.
- (4) Market response subsystem: simulating carbon price formation and trading activity.

After the initial verification of the model through historical data fitting, a baseline scenario and a variety of policy intervention scenarios were set to simulate the dynamic changes of key indicators such as cumulative trading volume, number of participating subjects and average transaction cost from 2024 to 2035, and conduct comparative analysis and sensitivity tests to evaluate policy effects.

## 4. Empirical Analysis

### 4.1 Qualitative Findings: Emergence of Diverse Practical Paths

Based on in-depth interviews with 28 key actors in Wenzhou City and archive analysis, this study finds that the realization of data-driven agricultural carbon sink trading does not follow a single model, but forms three distinct practical paths catalyzed by the local context. Each path has systematic differences in core driving force, technology adoption logic, organizational collaboration model and value distribution mechanism.

**Path A: Government-platform led inclusive path**  
This path takes the active design and public investment of local governments, especially the development and reform and agriculture and rural departments, as the core driving force. A typical practice is to promote the establishment of the "Yueqing City Carbon Inclusiveness Market in Wenzhou", which provides low-cost preliminary accounting and trading services for carbon sink volumes for projects in line with local simplified methodologies. Its technical logic emphasizes the authority and standardization of data, aiming to lower the

entry threshold for small and medium-sized farmers by providing public goods. In terms of organizational form, the government is responsible for rule-making and supervision, state-owned or designated operation platforms are responsible for technical support and transaction matching, and farmers act as passive data providers and carbon sink sellers. The liquidity of carbon sink assets in this path is weak, and most transactions rely on regional carbon neutrality subscription activities initiated by the government. A municipal official admitted in an interview: "Our primary goal is to 'get things done', let farmers have concepts and benefits first, even if the initial methodologies and data accuracy are relatively simplified."

**Path B: Leading enterprise-supply chain coordinated path**

This path is led by local agricultural leading enterprises with brand advantages and complete supply chains. Its core motivation is to use carbon sink labels to enhance product added value, consolidate green supply chains or fulfill corporate social responsibility. Technology application is highly customized and internalized; enterprises invest in deploying IoT devices to monitor agricultural activities in their own or contracted bases, and introduce blockchain to certify key data to build a credible traceability story for consumers. The organizational network presents a tight hierarchical structure; leading enterprises, as "chain masters", output technical standards and production norms to their cooperative cooperatives and large farmers, and usually pay carbon sink benefits indirectly by purchasing agricultural products at a premium. This path embeds carbon sink trading deeply into the existing commodity trading. A tea enterprise manager explained: "Our consumers are willing to pay a premium for the story of 'zero-carbon tea gardens'. We do our own monitoring and claim carbon sinks ourselves; although the cost is high, it ensures the integrity and credibility of the brand story."

**Path C: Technology service provider-financial integrated path**

This path is driven by astute digital technology start-ups or financial service institutions. They develop lightweight SaaS platforms or mobile applications to provide one-stop services of "monitoring equipment leasing + data hosting + carbon sink account management" for scattered farms. The key innovation of its business model is to attempt to take the preliminarily certified

expected carbon sink income as an asset and cooperate with local rural commercial banks to develop financial products such as carbon sink income right pledge loans. Its technical logic emphasizes the convenience of services and the financial operability of assets. The organizational form is a dynamic star network, with technology service providers as the hub connecting farmers, verifiers and financial institutions. This path is highly dependent on the vibrant local private capital and a flexible financial innovation environment. A founder of a technology company said: "We are not simply selling equipment or data, but helping farmers activate the 'dormant' ecological assets into financial rights that can be mortgaged and circulated."

#### 4.2 Configuration Analysis: Necessary Conditions and Sufficient Combinations for Path Formation

To test the universality of the above qualitative findings and reveal the causal complexity of path formation, this study conducted crisp-set qualitative comparative analysis on 40 agricultural business unit cases. The outcome variable "OUT" is whether carbon sink trading is realized (Yes=1, No=0). Five conditional variables were set based on the theoretical framework and qualitative insights and calibrated as binary variables: depth of data technology application "TECH", intensity of organizational capital "ORG", perception of formal institutional support "INST", level of digital trust "TRUST", and subject resource endowment "RES". Calibration anchors were determined based on the upper and lower tertiles of the case data[8].

##### 4.2.1 Necessity analysis

The necessity test of individual conditions shows that no single condition is a necessary condition for the realization of carbon sink trading (OUT=1), with all consistencies lower than 0.9. However, "high level of digital trust" ("TRUST") has the highest consistency of 0.85, which supports the core position of the "trust effect" in the theoretical framework. This means that the lack of trust in data-based certification methods or trading platforms makes it almost impossible to facilitate transactions; but high trust alone is not sufficient to ensure transaction success.

##### 4.2.2 Sufficiency condition configuration analysis

Truth table analysis generated three sufficient

condition combinations driving the realization of carbon sink trading, with a solution consistency of 0.93 and a solution coverage of 0.68, which highly correspond to the three paths summarized qualitatively.

#### 5. Policy Simulation: Long-Term Efficiency Evaluation of Intervention Strategies

Based on the key mechanisms and path differentiation logic revealed by qualitative exploration and configuration analysis, this chapter adopts the system dynamics method to construct a policy simulation model, aiming to dynamically evaluate the long-term impact of different intervention strategies on the cultivation of the agricultural carbon sink market[9]. System dynamics is good at dealing with complex system problems with multiple factors, nonlinear feedback and time lag, and is suitable for simulating the co-evolution process of "technology-institution-organization".

#### 5.1 Model Construction: Core Subsystems and Feedback Structures

The simulation model takes Wenzhou City as the geographical boundary, with a time span from 2025 to 2035. The model includes four core interactive subsystems, and its stock-flow structure is mathematically defined based on the key variable relationships found in the empirical analysis of Chapter 4.

##### (1) Carbon sink supply and development subsystem

The core stock of this subsystem is the "number of agricultural business units with development potential". Its inflow rate depends on the expected net income of carbon sink projects, which is jointly determined by carbon price, unit carbon sink output and development cost. Among them, development cost is a core regulatory variable, negatively affected by the application cost of data technologies and the complexity of project certification. Configuration analysis shows that the "level of digital trust" is crucial to transaction realization, so the model takes the "market average data credibility" as a key state variable, which positively affects the liquidity premium of carbon sink assets and negatively affects the transaction risk discount.

##### (2) Data technology adoption and diffusion subsystem

The core stock is the "proportion of business units adopting digital monitoring and accounting

technologies". The adoption rate follows the S-curve logic of technology diffusion, affected by the relative advantage of adopters, technical complexity and social network effects. Government technology subsidy policies directly affect the initial relative advantage of adoption; while the construction of public data platforms can effectively reduce the "perceived complexity" of technologies by providing standardized interfaces and verification services.

(3) Institutional and market environment subsystem

This subsystem simulates the evolution of formal and informal institutions. The "institutional completeness index" and "market trust index" are two core accumulation variables. Government investment in public platforms and clarification of rules are the main policy levers to improve these two indexes. At the same time, market trust will be self-reinforced with the accumulation of successful trading cases.

(4) Policy intervention subsystem

This subsystem converts external policy inputs into parameter impacts on the above three subsystems. This study focuses on simulating three types of quantifiable policy tools: capital subsidy rate for monitoring equipment, annual investment intensity in municipal agricultural carbon sink public data platforms, and risk compensation or interest discount intensity provided for carbon sink financial products[10]. Each subsystem is connected through multiple feedback loops. For example, the reinforcing loop: increase in technology adoption → improvement of data credibility → increase in market trust → rise in expected carbon sink income → more subjects participating in development → further increase in technology adoption. The regulating loop: rapid increase in participating subjects → may pull down the average data quality or cause regulatory lag in the short term → damage to market trust → inhibition of new subjects from entering.

## 5.2 Scenario Design: Baseline and Policy Packages

To evaluate policy effectiveness, the following simulation scenarios were set:

Baseline scenario: Continue the current moderate support policies, assuming that all policy parameters remain at the 2023 level.

Scenario P1 (Technology-driven package): Focus on lowering the threshold of technology adoption. Raise the financial subsidy rate for

equipment purchase from the current about 20% to 50% for 5 consecutive years.

Scenario P2 (Institution-empowering package): Focus on building market infrastructure. Substantially increase the annual investment in the municipal agricultural carbon sink public data platform for upgrading computing power, optimizing algorithms and carrying out large-scale training, aiming to systematically improve the "institutional completeness" and "market trust".

Scenario P3 (Financial incentive package): Focus on activating the financial attributes of assets. Provide risk compensation through fiscal funds to encourage banks to develop carbon sink expected income right pledge loan products, and reduce the comprehensive financing cost of such green financial products by 30%.

Scenario P4 (Collaborative combination package): Implement the policy intensity of P2 and P3 simultaneously, i.e., strengthen institutional infrastructure and financial innovation incentives at the same time.

## 5.3 Simulation Results and Comparative Analysis

The model was simulated using Vensim DSS, with the key output variables being the cumulative trading volume of agricultural carbon sinks and the number of active participating subjects. The following rules are presented:

(1) Temporal differentiation and path dependence of policy effects. Scenario P1 shows the fastest market start-up speed in the first 3 years of simulation, with cumulative trading volume leading other scenarios. This verifies the quick effect of directly reducing technical costs in stimulating early adopters and expanding the supply base. However, its growth curve gradually flattens after 5 years, because pure technical investment fails to solve in-depth problems such as asset credibility and market liquidity simultaneously, resulting in a large number of carbon sink assets stranded in a state of "monitorable but difficult to trade".

The effect of Scenario P2 appears slowly, but the growth acceleration is significant after the 4th year, and it surpasses P1 in an all-round way in the medium and long term (6th-12th year). This indicates that investment in "institutional infrastructure" such as data credibility and trading rules, although with a long construction cycle, can provide the fundamental driving force

for sustainable market expansion through the generated network effects and trust externalities. The effect of Scenario P3 is highly dependent on the degree of early market development. In the first 5 years of simulation, its incentive effect is limited due to the small scale of the underlying asset pool and high risks. However, after the 6th year, with the consolidation of the market foundation under Scenario P2, the "catalytic" effect of P3 breaks out, driving the trading volume to grow exponentially, which simulates the leverage amplification effect of financial tools in mature markets.

(2) Multiplier effect of collaborative policies. Scenario P4 performs the best throughout the simulation period. More importantly, it is not a simple superposition of the effects of P2 and P3, but produces a significant synergistic multiplier effect of "1+1>2". Simulation results show that by 2035, the cumulative trading volume under Scenario P4 reaches 4.1 times that of the baseline scenario, and 1.8 times and 2.3 times that of the single scenarios P2 and P3 respectively. This synergy stems from the positive feedback between institutional foundation and financial tools: a sound public platform reduces the risk assessment cost of financial products, and active financial transactions in turn improve the standardization and market recognition of carbon sink assets, further attracting more subjects to enter and forming a virtuous circle.

(3) Sensitivity analysis and robustness test. Perturbation tests of  $\pm 20\%$  were conducted on key parameters: technology adoption rate coefficient, trust establishment time, carbon price fluctuation range, etc. The results show that the efficiency ranking under different scenarios is robust:  $P4 > P2 > P3 > P1 > BAU$  (baseline scenario). However, policy effects are most sensitive to the establishment speed of the "market trust" parameter. This again emphasizes that in the construction of a data-driven environmental market, establishing a credible and transparent information environment is a prerequisite and amplifier for any incentive policy to exert its effectiveness. Ignoring this, pure economic subsidies may achieve half the result with twice the effort.

## 6. Conclusions and Discussion

### 6.1 Main Research Conclusions

Focusing on the core issue of the

implementation paths of agricultural carbon sink trading driven by data, and taking Wenzhou City of Zhejiang Province as a typical case, this paper systematically examines the diverse models, formation mechanisms and policy effectiveness of digital technologies empowering the emergence of the agricultural carbon sink market by adopting a mixed method of qualitative case study, qualitative comparative analysis and system dynamics simulation. The main conclusions are drawn in three aspects as follows:

First, the study finds that the realization of data-driven agricultural carbon sink trading presents clear path differentiation, forming three distinctive practical models, specifically including: (1) the government-platform led inclusive path, whose core is to rely on public data infrastructure and standardized methodologies to lower the participation threshold for small and medium-sized farmers; (2) the leading enterprise-supply chain coordinated path, whose essence is to embed carbon sink management deeply into the existing commodity supply chain and realize value capture through internalized governance and brand premium; (3) the technology service provider-financial integrated path, whose innovation lies in converting expected carbon sink income into mortgageable financial assets through lightweight technical services and financial tool design. These three paths are not mutually exclusive, but co-evolve in the specific context of Wenzhou with dual vitality of market and government.

Second, configuration analysis reveals that path differentiation is rooted in the specific combination of technical, institutional and organizational elements, among which "digital trust" is an almost necessary core foundation. csQCA results show that no single condition can guarantee transaction success, but a high level of digital trust is a common core condition in the three effective paths. The three paths correspond to different sufficient condition combinations respectively: Path 1 relies on the combination of "high trust" and "strong institutional support"; Path 2 relies on the combination of "high trust", "strong organizational capital" and "strong subject resources"; Path 3 relies on the combination of "high trust", "strong subject resources" and "high technology application". This confirms that market emergence is not a linear causal process, but a configuration result

of "concurrent coordination" and "different paths leading to the same goal" of multiple factors. Particularly importantly, formal institutional support and tight organizational capital show a functional substitution relationship under specific conditions, providing micro-evidence for understanding the complementary roles of government and market in environmental governance.

Third, policy simulation shows that different policy tools have significant efficiency differences in different stages of market cultivation, and the construction of institutional infrastructure plays a fundamental role. System dynamics simulation shows that pure technical cost subsidy (P1) can start the market quickly in the short term, but its long-term efficiency is limited; while investment in public data platforms and rule systems (P2), although with a slow effect, can provide underlying support for sustainable market expansion by improving data credibility and market transparency, achieving the optimal medium and long-term effects. The effectiveness of financial incentive tools (P3) is highly dependent on the maturity of the early market foundation. Simulation further reveals that the combined policy of "strengthening institutional infrastructure" and "incentivizing financial innovation" (P4) can produce a significant synergistic multiplier effect, and its long-term effect is far better than the simple sum of single policy tools.

## 6.2 Theoretical Contributions

Through in-depth case analysis and systematic mechanism testing, this study mainly promotes the relevant theoretical dialogue in the following three aspects:

First, this study constructs and verifies an integrated analytical framework for the co-evolution of "technology-institution-organization", enriching the theoretical explanation of digital technologies empowering sustainable transformation. Existing literature often simplifies digital technologies as tools to improve the efficiency of environmental governance, or focuses on macro institutional design. This paper reveals that data technologies play a dual role of trust infrastructure and cost reconstructor in agricultural carbon sink trading, and their effectiveness is deeply embedded and has a complex two-way construction with local institutional rules and existing organizational

networks. This framework elevates technical analysis from the tool level to the system interaction level, providing a more refined theoretical lens for understanding the micro-dynamics of ecological product value realization in the digital age.

Second, by introducing the configuration perspective and QCA method, this study reveals the "multiple concurrent causality" mechanism of environmental market emergence, responding to the theoretical concern of development path diversity. The study confirms that the realization of agricultural carbon sink trading does not rely on a single optimal condition, but there are multiple equivalent causal paths. This finding challenges the linear thinking of seeking universal "best practices", and emphasizes that policy design must consider the specific combination of local technical, institutional and organizational resources (i.e., "configuration"), thus providing rigorous methodological support and theoretical explanation for the policy principle of "adapting measures to local conditions".

Finally, through dynamic simulation, this study clarifies the temporal effects and interaction mechanisms of different policy tools in the evolution of complex systems, enhancing the predictability and systematicness of policy research. The study not only points out the fundamental significance of institutional infrastructure construction, but also quantitatively simulates the long-term effects and collaborative potential of different policy combinations. This provides evidence based on simulation experiments for understanding how policy interventions can find the right focus and timing in the co-evolution process of "technology-institution-organization", makes up for the deficiency of static policy evaluation, and promotes the transformation of policy design from "empirical judgment" to "simulation-assisted decision-making".

## 6.3 Practical Implications

Based on the above conclusions, this study puts forward the following suggestions for local practitioners aiming to cultivate the agricultural carbon sink market:

First, local governments should put the construction of data credibility and transparency at the top of the policy priority sequence. This means going beyond simple subsidies for hardware equipment and making strategic

investments in authoritative, open and easy-to-use public data platforms and standardized local methodologies. This is the "painstaking effort" and "solid foundation" to reduce transaction uncertainty, build the cornerstone of market trust, and thus attract the extensive participation of diverse subjects.

Second, policy design should have a "configuration thinking" and implement differentiated and precise empowerment strategies. Decision-makers need to identify the dominant form of agricultural operation organizations in the region and match the corresponding incentive combinations. For Path 1 (inclusive): the focus is on optimizing platform services and simplifying processes; for Path 2 (supply chain): it is necessary to encourage leading enterprises to formulate supply chain carbon standards and provide certification support; for Path 3 (technology and finance): efforts should be made to optimize the compliance environment for financial innovation and data services.

Third, optimize the temporal combination and collaborative deployment of the policy toolbox. In the early stage of market cultivation, technical subsidies can be appropriately used to start the market quickly; however, institutional capacity building must be deployed simultaneously or even in advance. After the market trust foundation and asset pool reach a certain scale, green financial and other innovative tools should be introduced in a timely manner to release the financial liquidity of assets. Policymakers should consciously plan and evaluate the synergistic effects between different tools to avoid single and isolated interventions.

#### 6.4 Research Limitations and Prospects

This study has several limitations, which point out the direction for future research. First, the case study is mainly based on the practice of Wenzhou, and the extent to which its conclusions can be generalized to regions with weak private economy or different government-led models needs to be tested through cross-regional comparative studies. Second, the parameters of the system dynamics model constructed in the study are mainly calibrated based on cross-sectional data and expert estimates; in the future, if longer time-series tracking data can be obtained, the accuracy and predictability of the simulation can be further improved. Finally, the measurement

of key constructs such as "digital trust" in this study is still in the exploratory stage; in the future, more universal and refined scales can be developed, and the social psychological mechanisms of its formation and evolution can be further explored. With the advancement of the construction of a national unified carbon market and the accumulation of more digital agricultural data, the dynamic tracking and cross-scale linkage research on the diverse paths of agricultural carbon sink trading will become a promising cutting-edge field.

#### Acknowledgements

This paper is supported by the 2025 Wenzhou Annual Planning Project of Philosophy and Social Sciences, "Mechanism Analysis and Policy Simulation of Digital Economy Empowering Low-Carbon Rural Construction in Wenzhou" (Project No.: 25WSK080YB).

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