A Study on Digital Cognitive Characteristics and Integrated Innovation Behavior of New Agricultural Business Entities

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Abstract: Under the background of the deep development of the digital economy, digital empowerment has become the core driving force for promoting high-quality agricultural development. This paper takes new agricultural business entities as the research object and adopts a combination of questionnaire survey and empirical analysis to explore the influence mechanism of digital cognitive characteristics on their integrated innovation behavior. The findings are as follows: First, digital cognitive characteristics encompass five core dimensions—ease or difficulty of digital technology, application level, requirements, adoption risk, and adoption cost—which demonstrate good construct validity and can comprehensively reflect the digital cognitive level of new agricultural business entities. Second, digital cognitive characteristics have differentiated effects on integrated innovation behavior. Specifically, the ease or difficulty of digital technology, application level, requirements, and adoption cost all have a significantly positive impact, with the application level exerting the most prominent influence. The impact of adoption risk on integrated innovation behavior is not significant, which may be related to factors such as the controllability of risks in agricultural digital technology application and the degree of policy support. Third, integrated innovation intention plays a partial mediating role between digital cognitive characteristics and integrated innovation behavior, specifically serving as a full mediator for the ease or difficulty of digital technology, application level, requirements, and adoption cost, while showing no mediating effect for adoption risk. This verifies the applicability of the Theory of Reasoned Action and Rational Choice Theory in the field of agricultural innovation. The research conclusions provide policy implications for promoting the integrated innovation development of new agricultural business entities.

Keywords: Digital Cognitive Characteristics; New Agricultural Business Entities; Integrated Innovation Behavior; Digital Empowerment

1. Introduction

Against the backdrop of the deep development of the digital economy, digital empowerment has become the core driving force for promoting high-quality agricultural development and facilitating rural revitalization. It encompasses the extensive application of digital technologies across the entire chain of agricultural production, processing, and marketing [1]. Digital empowerment serves as a crucial driver for high-quality development across various industries in the era of the digital economy, with digital transformation in the agricultural sector being a key pathway to breaking through development bottlenecks and enhancing agricultural competitiveness [2,3].

As the core carriers of agricultural modernization, the development level of new agricultural business entities is directly related to the effectiveness of agricultural digital transformation [4]. Early research defines agricultural business entities as individuals and organizations that are directly or indirectly engaged in the production, processing, marketing, and servicing of agricultural products. Currently, new agricultural business entities in China mainly include leading agricultural industrialization enterprises, large specialized operators, family farms, and farmer professional cooperatives [5,6]. However, at present, the digital penetration rate in China's agricultural sector remains generally low. New agricultural business entities face many challenges in the process of digital transformation, such as insufficient technology application, limited cognitive ability, and weak

market competition [7]. The issue of the "digital divide" is prominent, and there is an urgent need to seize the opportunities presented by the development of the digital economy to accelerate integrated innovation.

Existing research has confirmed that digital cognition serves as the core psychological foundation for new agricultural business entities to interface with digital technologies and engage in innovation activities, directly influencing their willingness to adopt digital technologies and the depth of application [8,9]. The deep integration of the digital economy with agricultural and rural economies hinges on the digital cognitive level of business entities, and cognitive differences directly lead to divergence in integrated innovation behaviors [10,11]. However, existing research has mostly focused on the overall effects of digital empowerment, lacking a unified standard for the dimensional division of digital cognitive characteristics. Furthermore, studies that systematically analyze its influence mechanism on the integrated innovation behaviors of new agricultural business entities in conjunction with survey data are relatively scarce.

Based on this, this paper takes new agricultural business entities as the research object, combines questionnaire surveys with empirical analysis, identifies the core dimensions of digital cognitive characteristics, and constructs a model of the impact of digital cognitive characteristics on integrated innovation behavior. Through empirical testing, it reveals the mechanism of action between the two, aiming to provide theoretical support and practical guidance for promoting the digital transformation of new agricultural business entities, facilitating the deep integration of the agricultural digital economy and the real economy, and contributing to rural revitalization.

2. Conceptual Model and Research Hypotheses

2.1 Connotation and Dimensions of Digital Cognitive Characteristics

Digital cognition refers to the subject's comprehensive perception, judgment, and evaluation of digital technologies, digital applications, and their related value. It serves as the core capability for individuals and organizations to adapt to digital development in the era of the digital economy. The essence of digital cognition lies in the subject's mastery of digital technology knowledge, as well as their attitudes, judgments, and evaluations regarding the application of digital technologies [12]. Digital cognition is the core psychological foundation for subjects to engage with digital technologies, encompassing the comprehensive perception of the attributes, application value, and potential risks of digital technologies [8].

Drawing on existing literature and the preliminary survey data of this study, digital cognitive characteristics can be defined as the stable perceptions, judgments, and evaluative tendencies formed by new agricultural business entities during the process of accessing and applying digital technologies, concerning the relevant attributes of digital technologies (such as difficulty, cost, risk, etc.) [13]. It constitutes a multi-dimensional comprehensive cognitive system, including:

(1) Ease or Difficulty of Digital Technology: The subject's perception of the complexity of learning, operating, and applying digital technologies, which serves as the foundation for their willingness to attempt integrated innovation.

(2) Application Level of Digital Technology: The subject's self-assessment of their own and their team's proficiency and depth of application in utilizing digital technologies to carry out agricultural production, processing, marketing, and other business activities.

(3) Requirements of Digital Technology: The subject's cognition and judgment regarding the technical standards, supporting conditions, and personnel capabilities required for the application of digital technologies in agricultural production and operations.

(4) Adoption Risk of Digital Technology: The subject's perceived degree of potential risks associated with adopting digital technologies, such as technical failures, data security issues, and investment losses.

Adoption Cost of Digital Technology: The subject's cognition and evaluation of the various costs required for adopting digital technologies, including financial investment, equipment, human resources, and training.

2.2 Integrated Innovation Behavior of New Agricultural Business Entities

The innovation behavior of new agricultural business entities should align with the essence of agricultural production and management,

balancing the foundational nature of family operations with the trend toward specialization [14]. Integrated innovation in the agricultural sector involves the deep adaptation and reorganization of digital technologies with the entire agricultural industry chain, with the core objective of achieving synergistic development between technology and industry. Based on existing research, this paper defines the integrated innovation behavior of new agricultural business entities as a systematic innovation behavior driven by digital cognition, in which the entities transcend traditional business boundaries and deeply integrate digital technologies with agricultural production, processing, marketing, management, and other aspects, thereby achieving optimal allocation of factors, synergistic industrial development, and the upgrading of business models [10,11].

Based on the results of exploratory factor analysis for the dependent variables (KMO = 0.822, Bartlett's test of sphericity Sig. < 0.05, total variance explained = 63.927%), integrated innovation behavior and integrated innovation intention constitute the dependent variable system. Among them, integrated innovation behavior serves as the core explained variable, manifested as the integration practice of digital technologies with production, operation, and organizational coordination, with factor loadings for all corresponding items ≥ 0.767. Integrated innovation intention acts as a mediating variable, representing the subjective inclination of entities to actively adopt digital technologies and engage in integrated innovation (factor loadings for all items ≥ 0.813). It functions as a bridge connecting digital cognitive characteristics and integrated innovation behavior, aligning with the core logic of the "attitude-intention-behavior" framework of the Theory of Reasoned Action.

2.3 Influence Model and Research Hypotheses

Based on digital innovation theory, the theory of reasoned acceptance, and related theoretical frameworks, along with preliminary research expectations, this study constructs a core influence model of "digital cognitive characteristics → integrated innovation intention → integrated innovation behavior of new agricultural business entities," clarifying the action paths of each variable. The core explanatory variables are digital cognitive characteristics (five dimensions), the mediating variable is integrated innovation intention, and the dependent variable is integrated innovation behavior of new agricultural business entities. The following research hypotheses are proposed:

H1: The ease or difficulty of digital technology positively and significantly affects the integrated innovation behavior of new agricultural business entities.

H2: The application level of digital technology positively and significantly affects the integrated innovation behavior of new agricultural business entities.

H3: The requirements of digital technology positively and significantly affect the integrated innovation behavior of new agricultural business entities.

H4: The adoption risk of digital technology negatively and significantly affects the integrated innovation behavior of new agricultural business entities.

H5: The adoption cost of digital technology positively and significantly affects the integrated innovation behavior of new agricultural business entities.

H6: Integrated innovation intention mediates the relationship between digital cognitive characteristics and the integrated innovation behavior of new agricultural business entities (with H6a–H6e corresponding to the mediating effects of the five dimensions respectively).

3. Empirical Testing

3.1 Survey Design and Sample Description

The formal survey in this study was conducted using an online questionnaire distribution method. With the assistance of the WJX (Questionnaire Star) online survey platform, the questionnaire link was distributed via communication channels such as WeChat and email, targeting new agricultural business entities precisely. The survey specified the time, location, and types of respondents: the survey period was from December 14, 2023, to February 1, 2024, the survey locations focused on areas with concentrated clusters of new agricultural business entities in China, and the respondents covered various types of new agricultural business entities, including leading agricultural industrialization enterprises, family farms, large specialized operators, and farmer professional cooperatives, ensuring the representativeness and coverage of the sample.

A total of 827 questionnaires were distributed in this formal survey, and 827 were collected. After

excluding invalid questionnaires characterized by incomplete responses, logical inconsistencies, and perfunctory answers, 719 valid questionnaires were obtained, yielding an effective response rate of 86.94%. The sample size meets the requirements for empirical analysis and effectively supports the reliability of the subsequent research conclusions.

3.2 Scale Reliability and Validity Testing

To ensure the scientific rigor and reliability of the survey data, reliability and validity tests were conducted on the scale after the formal survey. Reliability testing primarily employed Cronbach's α coefficient to measure the internal consistency of the scale. The results showed that the overall Cronbach's α coefficient of the scale was 0.946. Among the subscales, the Cronbach's α coefficient for digital cognitive characteristics was 0.923, for integrated innovation intention was 0.917, and for integrated innovation behavior was 0.908. All Cronbach's α coefficients of the subscales exceeded 0.6 and were all ≥ 0.8, indicating good internal consistency and satisfactory reliability of the scale.

Validity testing included construct validity and discriminant validity. Construct validity was examined through confirmatory factor analysis. The results showed that for the five-dimensional model of digital cognitive characteristics, χ^2/df = 1.423, RMSEA = 0.021, GFI = 0.968, AGFI = 0.952. For the integrated innovation behavior model, χ^2/df = 1.387, RMSEA = 0.019, GFI = 0.972, AGFI = 0.956. All indices met the criteria for good model fit ($\chi^2/df < 3$, RMSEA < 0.08, GFI and AGFI both > 0.9), indicating satisfactory model fit. The square roots of the AVE for the dimensions of digital cognitive characteristics ranged from 0.782 to 0.856, while the square root of the AVE for integrated innovation intention was 0.834, and for integrated innovation behavior was 0.817. All were greater than the correlation coefficients with other variables (which ranged from 0.321 to 0.678), indicating no severe multicollinearity issues, further confirming the validity of the scale.

3.3 Path Analysis

AMOS 26.0 was used to construct a structural equation model to examine the influence paths of digital cognitive characteristics on the integrated innovation behavior of new agricultural business entities. The model fit results met the criteria (χ^2/df = 1.574, RMSEA = 0.025, GFI = 0.965, AGFI = 0.951, NFI = 0.968, CFI = 0.982), with all fit indices satisfying the required standards, indicating a good model fit. The specific analysis results are as Table 1:

Table 1. Path Analysis Results of the Structural Equation Model for Digital Cognitive Characteristics

Path Relationship	Standardized Path Coefficient	S.E.	C.R.	P
Ease or Difficulty of Digital Technology → Integrated Innovation Behavior	0.252	0.039	6.288	***
Application Level of Digital Technology → Integrated Innovation Behavior	0.288	0.037	7.243	***
Requirements of Digital Technology → Integrated Innovation Behavior	0.299	0.034	7.776	***
Adoption Risk of Digital Technology → Integrated Innovation Behavior	0.048	0.036	1.262	0.207
Adoption Cost of Digital Technology → Integrated Innovation Behavior	0.226	0.041	5.251	***

[a] Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

(1) The Influence of Each Dimension of Digital Cognitive Characteristics on Integrated Innovation Behavior. The ease or difficulty of digital technology (CR=6.288, P<0.01, standardized coefficient=0.252), the application level of digital technology (CR=7.243, P<0.01, standardized coefficient=0.288), the requirements of digital technology (CR= 7.776, P<0.01, standardized coefficient=0.299), and the adoption cost of digital technology (CR=5.251, P<0.01, standardized coefficient=0.226) all have a significantly positive impact on integrated innovation behavior. Thus, hypotheses H1, H2, H3, and H5 are supported. The adoption risk of digital technology (CR = 1.262, P=0.207>0.05) does not have a significant impact on integrated innovation behavior, so hypothesis H4 is not supported. Further analysis reveals that the

application level of digital technology has the largest coefficient of influence on integrated innovation behavior, indicating that the subject's digital application capability is the core driver for promoting integrated innovation.

(2) The Mediating Role of Integrated Innovation Intention. The Bootstrap method was used to test the mediation effect (with 5,000 resamples and a 95% confidence interval). The results show that the mediation effect of integrated innovation intention between the ease or difficulty of digital technology and integrated innovation behavior is 0.187 (95% CI = [0.123, 0.251], excluding 0); between the application level of digital technology and integrated innovation behavior, the mediation effect is 0.213 (95% CI = [0.148, 0.278], excluding 0); between the requirements of digital technology and integrated innovation behavior, the mediation effect is 0.225 (95% CI = [0.156, 0.294], excluding 0); and between the adoption cost of digital technology and integrated innovation behavior, the mediation effect is 0.162 (95% CI = [0.105, 0.219], excluding 0). All of these indicate full mediation. However, the mediation effect between the adoption risk of digital technology and integrated innovation behavior is 0.032 (95% CI = [-0.021, 0.085], including 0), indicating no mediation effect. Thus, hypothesis H6 is partially supported.

4. Conclusion Analysis

This study takes new agricultural business entities as the research object, combines questionnaire surveys with empirical analysis, clarifies the five-dimensional structure of digital cognitive characteristics, and reveals its influence mechanism on integrated innovation behavior. The following core conclusions are drawn:

First, digital cognitive characteristics comprise five core dimensions: ease or difficulty of digital technology, application level, requirements, adoption risk, and adoption cost. This five-dimensional structure has been empirically tested and demonstrates good construct validity, comprehensively reflecting the digital cognitive level of new agricultural business entities.

Second, digital cognitive characteristics have differentiated effects on the integrated innovation behavior of new agricultural business entities. The ease or difficulty of digital technology, application level, requirements, and adoption cost all have a significantly positive impact on integrated innovation behavior, with the application level of digital technology exerting the most prominent influence. However, the adoption risk of digital technology does not have a significant impact on integrated innovation behavior, which may be attributed to factors such as the controllability of risks associated with digital technology application in agriculture and the level of policy support.

Third, integrated innovation intention plays a partial mediating role between digital cognitive characteristics and integrated innovation behavior. Specifically, it plays a full mediating role between the ease or difficulty of digital technology, application level, requirements, adoption cost, and integrated innovation behavior, while it plays no mediating role between adoption risk and integrated innovation behavior. This confirms the applicability of the Theory of Reasoned Action and Rational Choice Theory in the field of agricultural innovation.

Based on the research conclusions, the following core countermeasures are proposed for the integrated innovation development of new agricultural business entities:

First, optimize the supply of agricultural digital technologies to align with the cognitive needs of business entities. Develop simple, practical, and low-cost agricultural digital technologies to lower the threshold for application.

Second, strengthen digital technology promotion and training to enhance the digital capabilities of business entities.

Third, improve the support system to stimulate integrated innovation vitality. Increase investment in digital education, cultivate agricultural digital compound talents, and guide them to provide on-site services in villages.

Acknowledgments

This research was funded by the Philosophy and Social Science Foundation of China (Grant No: 21AGL034)

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