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The Impact of Agricultural Digitalization on the Export Quality of China's Agricultural Products

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Abstract. As a key factor in promoting the prosperity of international trade, the quality of export products has increasingly become a focal point in the economic and trade development strategies of many countries. Based on provincial panel data from 30 provinces in China during the period 2011–2022, this paper employs the demand-information-inference method to estimate the export quality of agricultural products and applies panel data regression models to systematically analyze the impact of agricultural digitalization on export quality. The empirical results indicate that agricultural digitalization significantly enhances China's agricultural export quality, and this conclusion is validated through various robustness checks, including controlling for multiple influencing factors, instrumental variable estimation, and robustness tests. Heterogeneity analysis shows that the positive effect of agricultural digitalization is more pronounced in the central and eastern regions, in processed agricultural products, and at the levels of digital infrastructure and industrial digitalization. Mechanism analysis reveals that agricultural digitalization primarily drives improvements in export quality indirectly through two pathways: enhancing agricultural technological innovation and improving financial development. Based on these findings, this study recommends, at the policy level, accelerating the construction of digital agricultural infrastructure, strengthening the driving force of technological innovation, optimizing the rural digital financial system, implementing region-specific development strategies, and prioritizing the digital transformation of deep-processing sectors so as to comprehensively improve the export quality of China's agricultural products.

Keywords: Agricultural Digitalization; Export Quality of Agricultural Products; Agricultural Technological Innovation; Financial Development.

1. Introduction

Agriculture serves as the "ballast stone" of the modernized economic system, and its high-quality development is one of the core tasks in building a socialist modernized power. According to the overall deployment of the National Quality Agriculture Strategy Plan (2018–2022), to ensure decisive progress in building a strong agricultural nation by 2035, enhancing the quality of agricultural products and strengthening international competitiveness have been established as key development goals. One important pathway is to "benchmark against advanced international standards" in order to promote Chinese agricultural products to reach internationally advanced quality levels. Since China's accession to the World Trade Organization, the scale of agricultural trade has steadily expanded, securing China's position as the world's second-largest agricultural trader. Statistical data show that the gross agricultural output increased from approximately 9,317.37 billion yuan in 2013 to about 15,850.7 billion yuan in 2023, demonstrating stable and progressive growth.

However, despite the continuous expansion in scale, the quality of China's exported agricultural products remains relatively low (Zeng Huasheng & Xu Jinhai, 2022). Domestically, product quality varies significantly, while internationally, the continuously updated technical trade barriers in developed countries pose considerable restrictions on China's agricultural exports. In reality, the slow growth rate of China's agricultural exports has resulted in a persistent agricultural trade deficit. The notable contradiction of being "large but not strong" remains a pressing issue for China's agricultural development. Upgrading the quality of exported agricultural products is not only an important

determinant for enhancing international competitiveness, but also a core link in improving efficiency, increasing productivity, and advancing the construction of a strong agricultural nation (Yang Xiaoyun, et al., 2025).

In existing academic studies, most scholars have examined the quality trends of agricultural exports primarily from the perspective of trade liberalization. Research indicates that the overall quality of China's exported agricultural products shows a fluctuating upward trend, and trade liberalization has played a significant role in promoting quality enhancement. Meanwhile, with the rapid development of digital technologies and their increasing application in agriculture, agricultural digitalization—an important outcome of the deep integration between the digital economy and agriculture—has emerged as a new driving force for high-quality agricultural development. Scholars generally believe that agricultural digitalization, through the adoption of advanced technologies such as artificial intelligence, big data, and cloud computing, can optimize resource allocation, reduce transaction costs, foster innovations in production methods, and improve the efficiency of financial services, thereby injecting new vitality into industrial upgrading and green transformation. Nevertheless, the development of agricultural digitalization also faces numerous challenges, including insufficient capital investment, heavy reliance on technology, shortages in skilled talent supply, lagging infrastructure construction, and a pronounced urban–rural digital divide (Zhong Wenjing, et al., 2021).

Against this backdrop, this paper aims to systematically analyze the export quality of China's agricultural products from the perspective of agricultural digitalization, seeking to make contributions both theoretically and practically. Theoretically, the study integrates agricultural digitalization into agricultural economics research, combining theories and methodologies from international trade and econometrics, thereby enriching the research framework for high-quality agricultural development. Practically, it seeks to provide scientific evidence for government and relevant departments to formulate and implement agricultural policies within the context of a digital economy. By identifying the pathways through which agricultural digitalization affects the export quality of agricultural products, policymakers can more effectively leverage digital technologies to enhance agricultural production and export quality, design targeted supportive policies, and promote sustainable agricultural development. At the same time, it will help agricultural producers better adapt to changes in the international market, utilize digital tools to acquire market information, and optimize production and marketing strategies, thereby strengthening their capacity to compete in global markets.

2. Theoretical Mechanisms

2.1. Overall Analysis of the Impact of Agricultural Digitalization on the Export Quality of China's Agricultural Products

Agricultural digitalization comprehensively empowers the agricultural industrial chain through informatization, datafication, and intelligent means, reshaping the organization of production factors and processes, and realizing refined management across all stages—from planting, processing, transportation to export. This strengthens process controllability and transparency, effectively reducing post-harvest losses and spoilage during transportation (Ma Zhaoliang & Guo Mengxu, 2023), thereby directly safeguarding the quality of exported agricultural products.

In addition, agricultural digitalization indirectly promotes export quality enhancement through two main pathways. First, the widespread dissemination of digital infrastructure and information technology accelerates agricultural technological innovation, promotes the research and application of new agricultural technologies, and enhances technical sophistication and standardization in production, quality inspection, and transportation, thereby improving export quality. Second, the application of digital technologies in agriculture mitigates financing information asymmetry and expands financial service channels, providing capital support for upgrading production factors and

technology. Based on these arguments, we propose Hypothesis 1: Agricultural digitalization can significantly promote the improvement of agricultural export quality.

2.2. Mechanism Analysis of the Impact of Agricultural Digitalization on the Export Quality of China's Agricultural Products

2.2.1. Enhancement of Agricultural Technological Innovation

Agricultural digitalization facilitates technological innovation, becoming a key pathway for upgrading the export quality of agricultural products. Digital technologies bring innovative resources such as big data, artificial intelligence, and the Internet of Things into agriculture, greatly improving the material basis for technological innovation. Using digital media such as the Internet, farmers and enterprises can more efficiently access advanced global technologies and market information, accelerating the dissemination and application of agricultural knowledge.

A digital environment promotes the rapid diffusion of new methods and technologies, propelling agriculture toward standardization and intelligent transformation in production, transportation, and trade—thereby fostering quality improvements from the supply side. For example, digital traceability technologies such as "quality safety codes" and "ecological origin codes" not only enhance consumer trust but also facilitate compliance with international standards, improving export quality. Moreover, global trading platforms accelerate cross-border information exchange, helping premium agricultural products enter international markets more efficiently. Technological innovation may also influence consumer preferences: according to CES utility theory, under equal pricing, international consumers prefer products with superior performance. Therefore, we propose Hypothesis 2: Agricultural digitalization enhances export quality by improving the level of agricultural technological innovation.

2.2.2. Enhancement of Financial Development

Agricultural digitalization promotes rural financial development, effectively fostering export quality upgrading. The application of digital technologies—such as the Internet, mobile payments, and e-commerce—in agriculture enables financial institutions to better assess farmers' creditworthiness and control lending risks, thus lowering thresholds and costs for financial services and improving accessibility and inclusiveness. This enhances investment willingness in the agricultural sector, directing more loans, guarantees, and financing tools toward agriculture. Such support facilitates the acquisition of advanced equipment, accumulation of technical know-how, and optimization of production processes, indirectly improving export quality through capital deepening. For example, innovative credit models such as "livestock collateral loans" effectively activate idle assets of farm households. Therefore, we propose Hypothesis 3: Agricultural digitalization enhances export quality by improving financial development levels.

2.3. Heterogeneity Analysis of the Impact of Agricultural Digitalization on Export Quality

2.3.1. Regional Heterogeneity

The effect of agricultural digitalization on export quality varies depending on regional economic conditions, industrial structure, product characteristics, and stages of digitalization development. Significant differences exist between China's eastern, central, and western regions in terms of economic development, transportation and logistics, production modes, and informatization infrastructure.

Eastern China, with its advanced economy, mature industrial chain, and high-level digital infrastructure, leads in rural Internet penetration, broadband subscriptions, and meteorological observation capability. These factors facilitate deep integration of digital technologies into production, processing, warehousing, and logistics, enabling comprehensive quality control and thus maximizing the potential for export quality improvement (Zhang Hongyuan et al., 2025). Central China enjoys relatively good resource conditions and has experienced rapid digital dissemination in recent years, yet its infrastructure and technology application levels lag slightly behind the east; thus, export quality

improvements are more likely to occur indirectly via enhanced distribution efficiency and processing capacity. In contrast, Western China suffers from underdeveloped economies, inconvenient transportation and logistics, and lagging digital infrastructure, limiting the short-term ability of agricultural digitalization to significantly improve export quality. Therefore, we propose Hypothesis 4: The effects of agricultural digitalization on export quality are more significant in the central and eastern regions.

2.3.2. Product Heterogeneity

The degree to which different types of agricultural products benefit from digital technologies depends on their processing intensity. Deep-processed agricultural products feature long production chains, high technological content, and stringent quality standards, requiring high levels of standardization and consistency in raw material selection, processing techniques, quality inspection, and supply chain coordination. These requirements align closely with real-time monitoring, data management, and traceability functions provided by digital technologies. As a result, digitalization may have a greater impact on improving the quality of deep-processed agricultural exports.

By contrast, primary agricultural products, which are generally raw materials or minimally processed goods, have export quality that is more sensitive to natural conditions, preservation and transport capabilities, and international inspection standards. Digitalization can improve efficiency and quality management in production processes to some extent, but its effect is relatively limited under such external constraints. Therefore, we propose Hypothesis 5: Agricultural digitalization is more effective in improving the export quality of deep-processed agricultural products.

2.3.3. Heterogeneity in Agricultural Digitalization Development Levels

The role of agricultural digitalization varies across different development dimensions. Agricultural digital infrastructure construction is the prerequisite for digital applications. It includes rural Internet and telephone penetration rates, meteorological observation capacity, and other elements that facilitate access to information, weather forecasting, and production decision-making—laying a solid foundation for quality enhancement.

Agricultural industry digitalization refers to the comprehensive embedding of digital technologies in agricultural production, processing, and distribution, covering activities such as digital trade in agricultural products, investment in agricultural production, and development of agricultural e-commerce. This stage improves standardization in production and efficiency of supply chain coordination, thereby enhancing export quality.

Agricultural digital industrialization involves feeding back the outcomes of the digital industry into agriculture—for example, developing rural e-commerce platforms, applying information technologies, and expanding online payment systems. Although its potential is significant, this stage typically requires gradual cultivation of industrial ecosystems, and its direct short-term impact on export quality may be limited. Therefore, we propose Hypothesis 6: The impact of agricultural digitalization on the export quality of China's agricultural products varies across different dimensions of digital development.

3. Research Design

3.1. Model Construction

To investigate the impact of agricultural digitalization on the export quality of China's agricultural products, the level of agricultural digitalization development in each province is used as the core explanatory variable, and the following econometric model is constructed:

$$EQ_{it} = \alpha_0 + \alpha_1 Adig_{it} + \alpha_2 Control_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (1)$$

In Equation (1), index i denotes province, and t denotes year. EQ_{it} represents the export quality of agricultural products, $Adig_{it}$represents the level of agricultural digitalization, and $Control_{it}$ denotes the set of control variables.$\mu_i$and$\gamma_t$represent time fixed effects and province fixed effects, respectively, and ε_{it} is the random error term.

3.2. Variable Definitions and Index Selection

Dependent Variable:Export Quality of Agricultural Products (EQ_{it})

The measurement of agricultural export quality follows the demand-information-inference method proposed by Hallak and Sivadasan (2009). Compared with the unit value approach, the inference method incorporates both product price and market performance information, allowing for a more accurate characterization of product quality.

Core Explanatory Variable: Level of Agricultural Digitalization Development ($Adig_{it}$)

Drawing on Liu Jun et al. (2020), the agricultural digitalization index system is constructed from three dimensions: agricultural digital infrastructure, agricultural industry digitalization, and agricultural digital industrialization. The entropy-weight method is employed to assign weights to the selected indicators, and the weighted scores are then aggregated to obtain the comprehensive index of agricultural digitalization. The specific indicators are presented in Table 1.

Table 1 Evaluation Index System for the Development Level of Agricultural Digitalization

Primary Indicator	Secondary Indicator	Indicator Description	Indicator Attribute
Agricultural Digital Infrastructure	Rural Internet penetration rate	Number of rural broadband access users (10,000 households)	Positive
	Rural telephone penetration rate	Number of fixed-line and mobile phone subscriptions owned by rural households (units)	Positive
	Rural meteorological monitoring sites	Number of agricultural meteorological monitoring service stations (units)	Positive
Agricultural Industry Digitalization	Digital trading level of agricultural products	Total value of agricultural product e-commerce transactions (including sales and purchase amounts), in 100 million CNY	Positive
	Agricultural production investment level	Investment in fixed assets for agricultural production, in 100 million CNY	Positive
	Agricultural product e-commerce development level	Number of enterprises engaged in e-commerce activities for agricultural products	Positive
Agricultural Digital Industrialization	Level of rural digital infrastructure construction	Number of Taobao villages (units)	Positive
	Application of rural information technology	Volume of telecommunications services, in 100 million CNY	Positive
	Scale of rural network-supported finance	Balance of rural inclusive financial loans, in 100 million CNY	Positive

Control Variables:Referring to existing studies and taking into account the characteristics of the agricultural industry, five control variables are incorporated into the model: the economic development level (GDP), measured by gross domestic product; foreign direct investment (FDI), measured by the actual amount of foreign direct investment utilized in the agricultural sector; industrial structure (STR), measured by the ratio of the tertiary industry to the secondary industry; urbanization level (URB), measured by the proportion of urban population to total population; and degree of government intervention (GOV), measured by the ratio of local government general budget expenditure to gross regional product.

3.3. Descriptive Statistics

This study selects agricultural products categorized under the first 24 chapters of the HS Commodity Classification at the four-digit code level from 30 provinces (municipalities and autonomous regions) in China, excluding Tibet, during the period 2011–2022, as the research sample. The raw dataset contains a total of 73,440 observations. In measuring the export quality of agricultural products, the demand-information-inference method is employed. Specifically, for each province and each year, the export value and export volume of agricultural products under each HS four-digit code are used to calculate the unit value, on the basis of which the product quality index is obtained.

Subsequently, the quality indices of all agricultural products for a given province in a given year are weighted and aggregated to derive a province-level agricultural export quality indicator, resulting in 360 valid observations. The data required to calculate agricultural export quality are obtained from the Development Research Center's Foreign Trade Statistical Database. The data for computing the agricultural digitalization development level are sourced from the Peking University Digital Finance Research Center, the China Industrial Statistical Yearbook (various years), the China Statistical Yearbook, and provincial statistical yearbooks. The data for the control variables are obtained from the National Bureau of Statistics. Descriptive statistics for each indicator are presented in Table 2.

Table 2 Descriptive Statistics

Variable	Sample Size	Mean	Std. Dev	Min	Max
EQ	360	0．747	0．04	0．69	0．90
Adig	360	0．223	0．16	0．04	0．80
FDI	360	0．019	0．02	0．00	0．12
STR	360	1．357	0．74	0．53	5．24
URB	360	0．601	0．12	0．35	0．90
GDP	360	9．864	0．90	7．22	11．77
GOV	360	0. 247	0. 10	0. 10	0. 64

4. Empirical Analysis

4.1. Baseline Regression

Using the data collected and processed as described above, Model (1) is estimated with Stata, and the results are reported in Table 3. Columns (1) through (6) in Table 3 present the results obtained by sequentially adding different control variables. All regressions control for year fixed effects and province fixed effects.

Table 3 Baseline Regression Results

	(1) EQ	(2) EQ	(3) EQ	(4) EQ	(5) EQ	(6) EQ
Adig	0．0834***	0．0601**	0．0581**	0．0523**	0．0827***	0．0909***
	(3．20)	(2．50)	(2．42)	(2．11)	(3．41)	(3．66)
GDP		0．0635***	0．0597***	0．0649***	0．0785***	0．104***
		(5．58)	(4．75)	(4．86)	(6．51)	(6．10)
FDI			0．0974	0．0956	0．218***	0．190**
			(1．16)	(1．13)	(3．11)	(2．53)
STR				0．00699	-0．0123**	-0．0127**
				(0．87)	(-1．97)	(-2．01)
URB					-0．410***	-0．413***
					(-6．64)	(-6．60)
GOV						0．105**
						(2．08)
_cons	0．728***	0．107	0．143	0．0838	0．213*	-0．0667
	(127．54)	(0．95)	(1．16)	(0．62)	(1．80)	(-0．38)
Time Effects	YES	YES	YES	YES	YES	YES
Province Effects	YES	YES	YES	YES	YES	YES
N	360	360	360	360	360	360
R^2	0．828	0．839	0．840	0．841	0．859	0．861

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively; values in parentheses are robust standard errors.

In columns (1) to (6) of Table 3, the coefficients of the agricultural digitalization development index (Adig) are consistently positive and statistically significant, indicating that improvements in the level of agricultural digitalization indeed have a significant effect in promoting the export quality of China's agricultural products. Hypothesis 1 is thereby validated.

4.2. Endogeneity Test

In the regression analysis, two sets of instrumental variables (Iv1) and (Iv2) are introduced to address potential endogeneity issues. The instrumental variable approach is employed to mitigate such concerns. Considering that the number of telephones and post offices in 1984 can reflect the potential for agricultural digitalization development, while having no direct connection to current agricultural product exports, these variables satisfy both the relevance and exclusion restrictions required of valid instruments. Referring to the methodology of Huang Qunhui et al. (2019), Iv1 is constructed as the interaction between the number of fixed telephone subscribers per 100 rural residents in each province in 1984 and the one-period-lagged amount of internet investment. Similarly, Iv2 is defined as the interaction between the number of post offices per one million people and the one-period-lagged internet investment amount. These variables serve as instruments for the agricultural digitalization development level, and the estimation is conducted using the two-stage least squares (2SLS) method. The estimation results are presented in Table 4.

Table 4 Endogeneity Test Results

Variables	Phase 1 (Adig)	Phase 2 (EQ)
Adig		0.681***
		(0.129)
Instrument Var Iv1	2.01e-10***	
	(3.82e-11)	
Instrument Var Iv2	7.77e-08***	
	(1.98e-08)	
Control Variables	YES	YES
N	360	360
R^2		-0.9351
Time Effects	YES	YES
Province Effects	YES	YES
Under-identification Test (K-P rk LM)	28.64***	28.637***
Weak Identification Test (K-P Wald rk F)	20.41[19.93]	20.415[19.93]
Over-identification Test (Hansen J)		0.454 (p=0.5006)

Note: Figures in brackets are critical values from the Stock–Yogo weak instrument test at the 10% significance level.

According to the results reported in Table 4, in the first-stage regressions, both sets of instrumental variables are positively and significantly correlated with the endogenous variable—the agricultural digitalization development level—at the 1% significance level. This indicates that they can effectively explain the variation in agricultural digitalization development and satisfy the relevance condition for valid instruments. In the second-stage regressions, regardless of whether Iv1 or Iv2 is used as the instrument, the coefficient of agricultural digitalization development on agricultural export quality remains positive and highly significant, further confirming the conclusion that agricultural digitalization development can significantly improve the quality of export products.

4.3. Robustness Checks

To further verify the reliability and robustness of the baseline regression results, three robustness check methods are employed.

4.3.1. 1% Winsorization

To mitigate potential disturbances caused by extreme values, the main variables are winsorized at the top and bottom 1% levels, thereby reducing the influence of outliers on the estimation results. As shown in column (1) of Table 5, the coefficient of the agricultural digitalization development level (Adig) on agricultural export quality (EQ) is 0.0909 and remains significantly positive at the 1% significance level. This result is entirely consistent with the baseline regression findings, indicating that the positive effect of agricultural digitalization on agricultural export quality remains robust after removing extreme values.

4.3.2. Exclusion of Municipality Samples

Given that municipalities may have distinctive characteristics in terms of economic development, digitalization infrastructure, and agricultural export structure, which might affect the generalizability of the regression results, Beijing, Tianjin, Shanghai, and Chongqing are excluded from the sample for re-estimation. As shown in column (2) of Table 5, compared with column (6) of Table 3 in the

baseline regressions, the coefficient of Adig decreases from 0.0909 to 0.0735 after the exclusion of municipality samples, yet remains significantly positive at the 1% level. This change suggests that while municipalities overall increase the marginal effect of agricultural digitalization on export quality in the full sample, the promoting effect remains robust even after their removal.

4.3.3. Addition of Control Variables

To alleviate potential omitted variable bias, additional control variables are introduced based on the baseline model. In column (3) of Table 5, the agricultural mechanization level (AMP) is added, while column (4) introduces the degree of openness (OPEN). Compared with the baseline results, after including AMP and OPEN in the model, the coefficient of Adig changes from 0.0909 to 0.0903 and 0.0888, respectively, showing a slight decline but still remaining significantly positive at the 1% level. This indicates that even after considering important factors such as the degree of agricultural mechanization and openness—which could potentially affect export quality—the promoting role of agricultural digitalization in improving agricultural export quality remains robust.

Table 5 Robustness Test Results

	(1) 1% Winsorized	(2) Excluding Direct-controlled Municipalities	(3) Adding Control Variable: Agricultural Mechanization Level	(4) Adding Control Variable: Degree of Openness
Adig	0．0909***	0．0735***	0．0903***	0．0888***
	(3．66)	(3．35)	(3．60)	(3．57)
FDI	0．190**	0．00753	0．190**	0．195**
	(2．53)	(0．05)	(2．53)	(2．56)
STR	-0．0127**	-0．0211***	-0．0128**	-0．0124*
	(-2．01)	(-4．10)	(-2．00)	(-1．94)
URB	-0．413***	-0．211**	-0．418***	-0．445***
	(-6．60)	(-2．13)	(-6．56)	(-5．74)
GOV	0．105**	0．0925*	0．103**	0．103**
	(2．08)	(1．81)	(1．99)	(1．99)
GDP	0．104***	0．0892**	0．104***	0．106***
	(6．10)	(5．76)	(6．01)	(5．96)
AMP			0．00196	0．00162
			(0．29)	(0．24)
OPEN				0．00880
				(0．54)
_cons	-0．0667	-0．0244	-0．0747	-0．0770
	(-0．38)	(-0．14)	(-0．43)	(-0．44)
Time Effects	YES	YES	YES	YES
Province Effects	YES	YES	YES	YES
N	360	312	360	360
R^2	0．861	0．903	0．861	0．861

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively; values in parentheses are robust standard errors.

4.4. Heterogeneity Tests

4.4.1. Regional Heterogeneity

To further investigate the regional differences in the impact of agricultural digitalization on the quality of agricultural product exports, the national sample is divided into three regions—eastern, central, and western—according to geographical location and economic development characteristics, and separate regressions are conducted for each region (see Table 6). This classification not only reflects differences in economic development levels, agricultural foundations, and digital infrastructure construction across regions, but also reveals the applicability and effectiveness of agricultural digitalization policies in different areas.

The regression results show that, in the eastern region, the coefficient of the agricultural digitalization development index is 0.0670 and is significantly positive at the 1% significance level. This indicates that for every one-unit increase in the agricultural digitalization level, the export quality index of agricultural products in the eastern region increases by an average of 0.067 units. While this effect is significant, the coefficient is relatively smaller than that of the central region. The likely explanation is that the eastern region, with its advanced economy, high level of agricultural modernization, and well-developed digital infrastructure, is approaching saturation in digitalization development, thus limiting the room for improvement and weakening marginal effects.

In the central region, the promoting effect of agricultural digitalization is most pronounced, with a coefficient of 0.189, significant at the 10% level. This suggests that a one-unit increase in the agricultural digitalization level raises the agricultural product export quality index by approximately 0.189 units. Compared with the east, the central region started digitalization relatively late, and its infrastructure and technology diffusion are at a moderate level. In recent years, driven by policies and the need for industrial upgrading, digital transformation has achieved remarkable results, and marginal benefits have become prominent. In addition, with agriculture accounting for a relatively high proportion of the central region's economy, the adoption of digitalization can effectively improve agricultural product quality.

In the western region, the coefficient of agricultural digitalization is 0.105, but it is not statistically significant, indicating that the promoting effect of agricultural digitalization on export quality is not yet significant in this region. A possible explanation is that the degree of digitalization in the processing and distribution stages is relatively low, digital infrastructure construction remains inadequate, and technology application penetration is limited—factors that jointly weaken the enhancement effect of agricultural digitalization on export quality. Moreover, constraints such as transportation conditions and market accessibility have prevented the full realization of digitalization's potential in improving export quality.

4.4.2. Product Heterogeneity

To further analyze whether the impact of agricultural digitalization on the export quality of agricultural products varies across product types, the sample is classified into two categories according to the Harmonized System (HS) chapters for agricultural product trade (first 24 chapters) and the degree of product processing: deep-processed agricultural products, represented by HS11 and HS15–24 codes, and primary agricultural products, represented by HS01–05, HS06–10, and HS12–14 codes. Separate regressions for these two categories are reported in Table 6.

The results show that, for deep-processed agricultural products, the coefficient of the agricultural digitalization level (Adig) is 0.0825 and is statistically significant at the 5% level, indicating that improvements in agricultural digitalization significantly promote the upgrading of export quality in this category. This finding suggests that the role of digital technology is particularly pronounced in deep-processing sectors, likely because such processes rely more heavily on informatization and intelligent equipment, with digitalization enhancing production processes, increasing product added value, and supporting brand development. In contrast, for primary agricultural products, the coefficient of agricultural digitalization is 0.0498 and does not reach statistical significance, implying

that agricultural digitalization does not exert a notable effect on their export quality. This is consistent with the fact that primary agricultural products typically involve lower technological content in the production stage, have limited dependence on digitalization, and their quality is more strongly influenced by natural resource endowments and basic processing conditions.

Table 6 Heterogeneity Test Results (1)

	Eastern Region	Central Region	Western Region	Processed Agricultural Products	Primary Agricultural Products
Adig	0．0670***	0．189*	0．105	0．0825**	0．0498
	(3．09)	(1．87)	(1．36)	(2．21)	(1．25)
Control Variables	YES	YES	YES	YES	YES
Time Effects	YES	YES	YES	YES	YES
Province Effects	YES	YES	YES	YES	YES
N	132	96	132	360	360
R^2	0．880	0．626	0．838	0．834	0．581

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively; values in parentheses are robust standard errors.

4.4.3. Heterogeneity in Agricultural Digitalization Development Levels

Building upon the earlier construction of a composite index for agricultural digitalization development and the analysis of its impact on the export quality of agricultural products, this study further examines the role of different dimensions of digitalization in enhancing export quality. Specifically, the three primary indicators within the agricultural digitalization development index—agricultural digital infrastructure, agricultural industry digitalization, and agricultural digital industrialization—are separately used as the core explanatory variables in baseline regressions to assess both the magnitude and direction of their influence.

The regression results in Table 7 indicate that agricultural digital infrastructure and agricultural industry digitalization exert significant positive effects on agricultural export quality, with the latter showing a stronger impact, whereas the effect of agricultural digital industrialization is statistically insignificant. Specifically, a one-unit increase in agricultural digital infrastructure raises agricultural export quality by approximately 0.0498 units, significant at the 1% level. This finding reflects that the improvement of rural internet penetration, communication conditions, and meteorological observation capacity provides essential informational support and technological guarantees for agricultural production, thereby enhancing product quality and international competitiveness.

Moreover, the coefficient for agricultural industry digitalization reaches 0.0664, also significant at the 1% level, suggesting that this dimension has the most pronounced effect on improving China's agricultural export quality. This result underscores the critical role of agricultural e-commerce, digitalized transactions, and fixed asset investments related to the agricultural sector in facilitating production–marketing integration, reducing information asymmetry, and promoting standardized production—making it a core pathway for achieving agricultural digital transformation and export quality upgrading. In contrast, the relatively small and insignificant coefficient for agricultural digital industrialization may be attributable to the fact that developments on the supply side of digital technologies (such as digital finance, the establishment of Taobao Villages, and expansion of telecommunications services) have not yet been fully translated into a tangible driving force for improving agricultural export quality. The growth of agricultural digital industrialization may still be in the stage of infrastructure building and model experimentation.

Table 7 Heterogeneity Test Results (2)

	Agricultural Infrastructure Construction	Agricultural Industry Digitalization	Agricultural Digital Industrialization
Adig1	0.0498***		
	(3.56)		
Adig2		0.0664***	
		(3.32)	
Adig3			0.00475
			(0.46)
Control Variables	YES	YES	YES
Time Effects	YES	YES	YES
Province Effects	YES	YES	YES
N	360	360	360
R^2	0.860	0.860	0.841

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively; values in parentheses are robust standard errors.

5. Mechanism Analysis

Based on the preceding theoretical analysis, agricultural digitalization can influence the export quality of agricultural products through two main channels: by enhancing agricultural technological innovation and by improving the level of financial development. In order to test this mechanism, the present study follows the methodological suggestion of Jiang Ting (2022), who argues that the mediation effect model cannot address the endogeneity problem in the regression of the mediator on the dependent variable. Instead, it is more appropriate to identify mediators whose causal relationships with the dependent variable are relatively straightforward, focusing primarily on the causal link between the explanatory variable and the mediator, without necessarily verifying the direct effect of the mediator on the dependent variable.

In this research, the core causal chain is that agricultural digitalization promotes the export quality of agricultural products via the pathways of agricultural technological innovation and financial development. Following Jiang Ting (2022), the empirical analysis focuses on whether agricultural digitalization can significantly affect agricultural technological innovation and financial development. The measurement of agricultural technological innovation follows Jin Shaorong and Qi Xianghong (2025), and is defined as the product of provincial R&D expenditure and the share of gross output value of agriculture, forestry, animal husbandry and fishery in a region's GDP, denoted as ATFP. The measurement of financial development follows Huang Yongming and Zhang Wenjie (2012), using the ratio of total credit volume to GDP for each province (including autonomous regions and municipalities directly under the central government), denoted as FIN.

Regression results are reported in Table 8. Column (1) shows the baseline regression, where the coefficient of agricultural digitalization on export quality is significantly positive, indicating that improvements in agricultural digitalization can effectively enhance agricultural export quality. Column (2), with agricultural technological innovation (ATFP) as the dependent variable, shows that the coefficient of agricultural digitalization is 1.721, significant at the 1% level, which suggests that the development of agricultural digitalization significantly promotes agricultural technological innovation. Combined with the result from Column (1), this implies that agricultural technological innovation likely serves as a positive mediator in the relationship between agricultural digitalization and export quality improvement. Column (3), with financial development (FIN) as the dependent variable, reports a coefficient of 0.983, also significant at the 1% level, indicating that agricultural

digitalization has a substantial positive impact on financial development. Furthermore, the positive influence of financial development on export quality is validated, which means that financial development likewise functions as a mediating mechanism in the relationship chain between agricultural digitalization and export quality.

In summary, the results demonstrate that agricultural digitalization can directly improve the export quality of agricultural products, while also exerting an indirect effect by fostering agricultural technological innovation and enhancing financial development. Both channels contribute meaningfully to the overall upgrading of export quality.

Table 8 Mechanism Test Results

	(1) EQ	(2) ATFP	(2) FIN
Adig	0．0909***	1．721***	0．983***
	(3．66)	(3．54)	(2．79)
Control Variables	YES	YES	YES
Time Effects	YES	YES	YES
Province Effects	YES	YES	YES
N	360	360	360
R^2	0．8609	0．9264	0．9734

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively; values in parentheses are robust standard errors.

6. Conclusions and Policy Recommendations

6.1. Heterogeneity Tests

Based on inter-provincial panel data from 30 provinces in China for the period 2011–2022, this study employs an export-quality measurement approach and panel econometric models to systematically analyze the impact of agricultural digitalization on the export quality of Chinese agricultural products, with particular attention to the mediating roles of technological innovation and financial development, and further conducts heterogeneity tests from the perspectives of regions and product types. The findings reveal that agricultural digitalization exerts a robust and significantly positive direct effect on export quality, and also indirectly drives quality upgrading by enhancing the level of agricultural technological innovation and improving financial development. Moreover, the positive impact of agricultural digitalization displays notable regional heterogeneity, being significant in the central and eastern regions—with the most pronounced effect observed in the central region—yet insignificant in the western region. In terms of product type, the improvement effect of agricultural digitalization is concentrated in deep-processed agricultural products, while its influence on primary agricultural products is not statistically significant.

6.2. Policy Recommendations

In light of the above research conclusions, the following policy recommendations are proposed:

First, accelerate the construction of new digital infrastructure in rural areas, including the internet, Internet of Things (IoT), 5G networks, and cold-chain logistics, with a particular focus on improving network coverage quality and interconnectivity. This will help eliminate digital bottlenecks throughout the agricultural production, processing, and distribution chains, providing solid hardware support for precision agriculture, intelligent management, and quality traceability, thereby laying a fundamental material foundation for export quality improvement.

Second, increase investment in agricultural technological research and development, and promote the deep integration of big data, artificial intelligence, and other technologies into breeding, intensive

processing, and quality control, so as to drive quality upgrading through technological innovation. In addition, improve the rural digital financial system by leveraging fintech to develop inclusive credit and risk management tools, effectively easing financing constraints for agricultural business entities and providing sustained funding momentum for quality enhancement.

Third, implement targeted region-specific strategies. The central region should focus on expanding application scenarios of technology to unlock growth potential; the eastern region should capitalize on market advantages to lead the upgrading of high-end agricultural product exports; and the western region should prioritize filling infrastructure gaps in networks and cold-chain logistics, as well as supporting the export of locally distinctive products, in order to narrow regional development disparities.

Fourth, concentrate policy resources on the deep-processed agricultural product sector, encouraging enterprises to carry out intelligent upgrading and pursue international certification. By establishing a comprehensive quality traceability system from farm to table, product transparency and international credibility can be enhanced, thereby increasing the added value of deep-processed agricultural products and strengthening their core competitiveness in the high-end international market.

References

[1] Hausmann R,Hang J,Rodrik D. What you export matter[J].Journal of economic growth,2017,12(1）:1-25.

[2] Hallak C J ,Sivadasan J .Product and process productivity: Implications for quality choice and conditional exporter premia[J].Journal of International Economics,2013,91(1):53-67.

[3] Anderson, J.E.and Wincoop, E.V.Trade Costs[J].Journal of Economic Literature, 2004, 42 (3) :691-751.

[4] Costa F., Frecassetti S., Rossini M., et al. Industry 4.0 digital technologies enhancing sustainability:Applications and barriers from the agricultural industry in an emerging economy[J].Journal of Cleaner Production,2023(408):137208.

[5] Simonovska I. and Waugh M E.The Elasticity of Trade:Estimates and Evidence[J].Journal of International E conomics,2014,92(1):34-50.

[6] Zeng, H., & Xu, J. (2022). The impact of free trade zone strategy implementation on the quality of China’s exported agricultural products: A perspective of agreement clause heterogeneity. Chinese Rural Economy, (05), 127–144.

[7] Yang, X., Wang, L., Ran, L., et al. (2025). SPS standard distance and the upgrading of China's agricultural product export quality. World Agriculture, (09), 78–89.

[8] Zhong, W., Luo, B., & Xie, L. (2021). International experience in the development of digital agriculture and its implications. Reform, (05), 64–75.

[9] Ma, Z., & Guo, M. (2023). The impact of the digital economy on agricultural product export trade: Empirical evidence based on provincial panel data. Journal of Xi’an Shiyou University (Social Sciences Edition), 32(04), 10–17, 25.

[10] Wu, Q., & Zhang, X. (2025). Pathways for agricultural transformation and upgrading from the perspective of digital technology. Agricultural Economy, (03), 29–30.