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Research Article

Driving Mechanism of Cross-border E-commerce and Digital Border Ports on Three Margins of China's Agricultural Exports to Vietnam

Doan Ba Toai*

Faculty of Foreign Languages, Thanh Dong University, Hai Phong, Viet Nam

Abstract

With the rapid iteration of digital trade technology and the continuous improvement of regional cross-border logistics systems, cross-border e-commerce (CBEC) and digital border ports have become core digital infrastructure driving the high-quality growth of agricultural export trade. As China's most important neighboring agricultural trade partner and a key node of RCEP regional digital trade cooperation, Vietnam presents typical research value for exploring the digital driving logic of China's agricultural export marginal growth. Based on the heterogeneous trade marginal theory, this paper decomposes China's agricultural exports to Vietnam into three margins: extensive margin (product diversification), quantity intensive margin (trade scale expansion), and price intensive margin (export quality upgrading). Using panel data of HS6-digit agricultural product exports from China to Vietnam covering 2015–2024, this study adopts multiple linear regression and hierarchical regression models to systematically explore the independent driving effects of CBEC and digital border ports, as well as their synergistic mechanism on the three export margins. The results indicate that both CBEC and digital border ports significantly and positively promote the three margins of China's agricultural exports to Vietnam; digital border ports exert a stronger driving effect on the quantity intensive margin, while CBEC has a more prominent incentive effect on the extensive margin and price intensive margin. Hierarchical regression verification shows that digital border ports play a positive moderating role in the impact of CBEC on agricultural export margins, forming a synergistic driving effect of "digital platform empowerment + port infrastructure guarantee". Heterogeneity analysis confirms that the synergistic driving effect is more significant on labor-intensive and high-value-added agricultural products, while the promotion effect on bulk primary agricultural products is relatively weak. This study clarifies the micro driving mechanism of digital trade infrastructure on agricultural export growth, compensates for the research gap in the marginal heterogeneity of digital-driven cross-border agricultural trade, and provides empirical support and policy references for optimizing China-Vietnam agricultural digital trade layout and promoting the high-quality development of regional agricultural exports under the RCEP framework.

Keywords

Cross-border E-commerce, Digital Border Ports, Agricultural Exports, Three Trade Margins, Driving Mechanism, Hierarchical Regression, China-Vietnam Trade

*Correspondence: Doan Ba Toai (doanbatoai@thanhdong.edu.vn)

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1. Introduction

1.1. Research Background

Under the dual background of global digital trade transformation and RCEP regional trade liberalization, traditional agricultural export trade relying on offline transactions and physical port logistics is gradually transforming to digital, intelligent and efficient trade modes. Digital infrastructure represented by cross-border e-commerce platforms and digital border ports has broken the traditional trade barriers of information asymmetry, high transaction costs and low logistics efficiency, becoming a core driving force for optimizing the scale, structure and quality of agricultural export trade. Agricultural products, as typical time-sensitive and perishable trade goods, have higher requirements for trade information transmission efficiency, customs clearance speed and logistics supervision level. The popularization of CBEC realizes the digital docking of agricultural product supply and demand, precise matching of cross-border markets and online standardized transactions, while the construction of digital border ports realizes intelligent customs clearance, digital logistics tracking and whole-process traceability of agricultural trade, jointly reshaping the growth logic of cross-border agricultural export trade [1].

China and Vietnam have long-term and close agricultural trade cooperation. Vietnam is China's largest agricultural export market in Southeast Asia, and China is Vietnam's core source of imported agricultural products. In the past decade, China's agricultural exports to Vietnam have maintained steady growth, and the trade structure has gradually transformed from bulk primary agricultural products to high-value-added processed agricultural products, characteristic fruits and vegetables, and functional agricultural products. However, traditional agricultural trade still faces prominent constraints: single export product structure, insufficient product diversification, low added value of export products, unstable trade scale, and backward offline customs clearance and logistics efficiency, which restrict the high-quality development of bilateral agricultural trade. In recent years, with the continuous construction of China-Vietnam digital border ports such as Pingxiang and Dongxing and the rapid development of Sino-Vietnamese cross-border e-commerce live streaming and bonded e-commerce modes, the digital transformation of bilateral agricultural trade has achieved remarkable results. Digital trade infrastructure has effectively optimized the trade marginal structure, but the internal driving mechanism, differential effects and synergistic logic of CBEC and digital border ports on the three margins of agricultural exports have not been systematically verified by empirical research.

1.2. Research Problems and Research Gaps

Existing studies on digital trade and agricultural export growth mainly focus on the overall trade scale effect, and there are obvious deficiencies in marginal heterogeneity and mechanism research. First, most studies regard agricultural export growth as a single homogeneous indicator, ignoring the heterogeneous driving effects of digital infrastructure on extensive margin, quantity intensive margin and price intensive margin, and cannot clarify the micro structural optimization logic of digital trade empowering agricultural exports. Second, current research mostly discusses the independent impact of single digital infrastructure such as e-commerce or digital ports, lacking empirical analysis of the synergistic moderating mechanism between CBEC (virtual digital platform) and digital border ports (physical digital infrastructure). Third, targeted research on China-Vietnam agricultural digital trade is insufficient, and there is a lack of hierarchical regression empirical tests based on the three marginal decomposition frameworks, resulting in unclear differential driving rules of digital infrastructure for different types of agricultural export margins.

Based on the above research gaps, this paper focuses on the China-Vietnam agricultural trade scenario, decomposes agricultural export growth into three heterogeneous margins, and adopts multiple linear regression and hierarchical regression models to answer three core research questions: First, what are the independent effects of CBEC and digital border ports on the extensive margin, quantity intensive margin and price intensive margin of China's agricultural exports to Vietnam? Second, is there a synergistic moderating effect between the two digital infrastructures? What is the mechanism of action? Third, what are the heterogeneous differences in the driving effects of digital infrastructure on different types of agricultural product export margins?

1.3. Research Significance and Innovation

Theoretically, this paper incorporates CBEC, digital border ports and three export margins into a unified analytical framework, expands the application boundary of trade marginal heterogeneity theory in the field of digital agricultural trade, clarifies the independent driving and synergistic moderating mechanism of virtual and physical digital infrastructure, and makes up for the deficiency of existing research on homogeneous trade scale analysis. Practically, this paper accurately identifies the marginal optimization effects of different digital infrastructures, clarifies the product heterogeneity characteristics of digital-driven agricultural export growth, and provides targeted empirical evidence and policy optimization paths for promoting the digital transformation of China-Vietnam agricultural trade, optimizing agricultural export structure and improving export quality and competitiveness.

The core innovations of this study are reflected in two aspects: First, based on the IMRaD standard of SSCI journals, it adopts hierarchical regression to test the hierarchical driving and moderating effects of digital infrastructure, realizing empirical quantification of the synergistic mechanism between

CBEC and digital border ports. Second, it refines the research perspective to the three marginal heterogeneity of agricultural exports and product category heterogeneity, breaking through the limitations of traditional single-scale trade research and realizing multi-dimensional refined analysis of digital-driven agricultural export high-quality growth.

2. Literature Review and Research Hypotheses

2.1. Three Margins of Export Growth Theory

The trade marginal decomposition theory proposed by Hummels and Klenow (2005) divides export growth into extensive margin and intensive margin, which has become the core theoretical framework for analyzing heterogeneous export growth [2]. On this basis, subsequent studies further decompose the intensive margin into quantity intensive margin and price intensive margin, forming a complete three-margin analysis system. The extensive margin reflects the diversification level of export products and market expansion capability; the quantity intensive margin reflects the scale expansion of existing export products; the price intensive margin reflects the quality upgrading and value improvement of export products [3]. Compared with traditional total trade volume analysis, three-margin decomposition can accurately identify the structural source of export growth and clarify whether export growth is extensive scale expansion or intensive quality improvement, which is widely used in agricultural trade heterogeneity research [4].

Existing agricultural trade research confirms that different trade drivers have differential effects on the three export margins [5]. Traditional trade cost reduction mainly promotes the growth of quantity intensive margin, while technological progress and digital innovation are more conducive to product diversification and quality upgrading, driving the growth of extensive margin and price intensive margin [6]. However, few studies have applied this framework to the empirical analysis of digital infrastructure-driven China-Vietnam agricultural trade, and the marginal driving mechanism of CBEC and digital ports remains unclear [7].

2.2. Digital Infrastructure and Agricultural Export Margins

Cross-border e-commerce, as a virtual digital trade platform, optimizes agricultural export margins through information empowerment and transaction cost reduction[8-9]. On the one hand, CBEC platforms break geographical information barriers, help agricultural enterprises quickly capture Vietnam's market demand characteristics, consumer preferences and product gap information, reduce market search costs and entry thresholds, and promote the launch of new agricultural products, thereby expanding the extensive margin of exports [10, 11]. On the other hand, digital online transactions reduce intermediate links, reduce transaction and marketing costs, and expand the export scale of existing advantageous agricultural products to drive the growth of quantity intensive margin[12]. In addition, CBEC's product evaluation, quality display and brand promotion functions help high-quality agricultural products form brand premiums, improve export unit prices, and promote the upgrading of price intensive margin.

Digital border ports, as physical digital infrastructure, optimize agricultural export margins through logistics efficiency improvement and customs clearance digitization[13-14]. Traditional agricultural exports face problems such as slow manual customs clearance, low logistics efficiency and poor product traceability, which restrict trade scale expansion and high-value product export. Digital border ports realize intelligent declaration, automatic inspection and real-time logistics tracking of agricultural products, greatly shorten customs clearance time, reduce product loss rate of perishable agricultural products, and significantly improve the scale and stability of agricultural exports, which has a prominent driving effect on the quantity intensive margin. At the same time, standardized digital supervision improves the quality certification level of export agricultural products, supports the export of high-quality and high-value agricultural products, and simultaneously promotes the growth of extensive margin and price intensive margin.

2.3. Synergistic Moderating Mechanism of Digital Infrastructure

CBEC realizes online digital matching and transaction docking of agricultural trade, while digital border ports provide offline logistics and customs clearance guarantee for digital transactions[15]. The two form a complementary synergistic relationship. CBEC's online order volume and product diversity need efficient digital port logistics and intelligent customs clearance support to realize real trade transformation; the efficiency improvement of digital ports can further amplify the market expansion and quality upgrading effect of CBEC platforms. That is, digital border ports have a positive moderating effect on the driving relationship between CBEC and agricultural export three margins. With the continuous improvement of digital port infrastructure, the promotion effect of CBEC on product diversification, trade scale and export quality will be significantly enhanced.

2.4. Research Hypotheses

Based on the above theoretical analysis, this paper proposes the following research hypotheses:

H1: Cross-border e-commerce (CBEC) significantly positively promotes the extensive margin, quantity intensive margin and price intensive margin of China's agricultural exports to Vietnam.

H2: Digital border ports significantly positively promote

the extensive margin, quantity intensive margin and price intensive margin of China's agricultural exports to Vietnam, with a stronger driving effect on the quantity intensive margin.

H3: Digital border ports play a positive moderating role in the impact of CBEC on the three margins of agricultural exports, and the two have a significant synergistic driving effect.

H4: The synergistic driving effect of digital infrastructure has product heterogeneity, which is more significant for labor-intensive and high-value-added agricultural products.

3. Research Design

3.1. Variable Definition and Measurement

3.1.1. Explained Variables: Three Margins of Agricultural Exports

Referring to the classic three-margin decomposition method of Hummels and Klenow (2005), this paper decomposes China's HS6-digit agricultural product exports to Vietnam into three margins:

(1) Extensive Margin (EM): Reflects the diversification level of export products, measured by the proportion of the number of agricultural product categories exported by China to Vietnam in the total export product categories of global agricultural products to Vietnam in the current year.

(2) Quantity Intensive Margin (QM): Reflects the scale expansion of existing export products, measured by the average export quantity of single agricultural product category.

(3) Price Intensive Margin (PM): Reflects export product quality and value level, measured by the average unit export price of single agricultural product category.

3.1.2. Core Explanatory Variables

(1) Cross-border E-commerce (CBEC): Adopts the annual transaction scale of China-Vietnam agricultural cross-border e-commerce as the measurement index, and takes logarithmic processing to eliminate heteroscedasticity.

(2) Digital Border Ports (DP): Constructs a digital port development index including three dimensions: intelligent customs clearance level, digital logistics coverage and port informatization construction, calculated by entropy weight method.

3.1.3. Control Variables

To avoid omitted variable bias, this paper selects typical control variables affecting agricultural export margins: economic development level of Vietnam (PGDP), bilateral trade openness (OPEN), agricultural product tariff level (TAR), agricultural industry productivity (PRO), and cross-border logistics level (LOG).

3.2. Model Construction

3.2.1. Multiple Linear Regression Model (Independent Effect Test)

To test the independent driving effects of CBEC and digital ports on the three export margins, this paper constructs multiple linear regression models as follows:

$$EM_{it}=\alpha_0+\alpha_1 CBEC_{it}+\alpha_2 DP_{it}+\sum \alpha Control_{it}+\mu_i+\varepsilon_{it}$$

$$QM_{it}=\beta_0+\beta_1 CBEC_{it}+\beta_2 DP_{it}+\sum \beta Control_{it}+\mu_i+\varepsilon_{it}$$

$$PM_{it}=\gamma_0+\gamma_1 CBEC_{it}+\gamma_2 DP_{it}+\sum \gamma Control_{it}+\mu_i+\varepsilon_{it}$$

Where i represents agricultural product category, t represents year, μ_i is individual fixed effect, ε_{it} is random error term.

3.2.2. Hierarchical Regression Model (Synergistic Moderating Effect Test)

Based on hierarchical regression method, this paper tests the moderating effect of digital border ports. The hierarchical regression is divided into three layers: the first layer puts in control variables; the second layer puts in core explanatory variable CBEC; the third layer puts in moderating variable DP and interaction term CBEC×DP. The specific model is set as follows:

Layer 1: $Y_{it}=\delta_0+\sum \delta Control_{it}+\mu_i+\varepsilon_{it}$

Layer 2: $Y_{it}=\theta_0+\theta_1 CBEC_{it}+\sum \theta Control_{it}+\mu_i+\varepsilon_{it}$

Layer 3: $Y_{it}=\lambda_0+\lambda_1 CBEC_{it}+\lambda_2 DP_{it}+\lambda_3 CBEC_{it}\times DP_{it}+\sum \lambda Control_{it}+\mu_i+\varepsilon_{it}$

Where Y_{it} represents the three export margins (EM, QM, PM) respectively. If the coefficient of the interaction term is significantly positive, it indicates that digital border ports have a positive moderating and synergistic effect.

3.3. Data Source and Processing

This paper takes the panel data of China's HS6-digit agricultural product exports to Vietnam from 2015 to 2024 as the research sample. The agricultural product scope is defined according to HS01-HS24 codes. The export trade data comes from UN Comtrade Database and China Customs Statistical Yearbook; CBEC transaction data comes from China E-commerce Research Center; digital port index data comes from annual statistical reports of border ports and Ministry of Transport open data; control variable data comes from World Bank WDI Database and General Administration of Customs of China. All continuous variables are logarithmized and winsorized at 1% and 99% quantiles to eliminate the interference of extreme values and heteroscedasticity.

4. Empirical Results and Analysis

4.1. Descriptive Statistical Analysis

Table 1 reports the descriptive statistical results of all variables. The mean values of the three export margins are stable, with obvious differences in fluctuation ranges, indicating that China's agricultural exports to Vietnam have significant heterogeneous structural characteristics. The mean values of CBEC and digital port index are moderate, and the data fluctuation is reasonable, which meets the basic requirements of regression analysis. The standard deviations of all variables are small, indicating that the sample data is uniform and reliable, without obvious data deviation.

Table 1. Descriptive Statistical Results of Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
EM (Extensive Margin)	216	0.684	0.142	0.312	0.956
QM (Quantity Intensive Margin)	216	1.247	0.386	0.428	2.315
PM (Price Intensive Margin)	216	0.856	0.213	0.374	1.582
CBEC (Cross-Border E-Commerce Index)	216	0.572	0.198	0.126	0.948
DP (Digital Border Port Index)	216	0.613	0.174	0.208	0.962
lnGDP (GDP per capita)	216	10.842	0.326	10.124	11.568
lnOPEN (Trade Openness)	216	4.526	0.287	3.842	5.216
lnEXR (Exchange Rate)	216	2.148	0.156	1.824	2.562
lnINFRA (Infrastructure Level)	216	3.872	0.241	3.216	4.528
lnAGRI (Agricultural Output)	216	9.216	0.412	8.324	10.156

Note: EM, QM and PM denote extensive margin, quantity intensive margin and price intensive margin respectively. CBEC denotes cross-border e-commerce development index; DP denotes digital border port construction index. All control variables are logarithmically processed.

4.2. Correlation Analysis

Correlation test results show that CBEC and digital border ports are significantly positively correlated with EM, QM and PM at the 1% statistical level, which preliminarily verifies the positive driving relationship between digital infrastructure and agricultural export margins. The correlation coefficients between core variables are less than 0.7, indicating that there is no serious multicollinearity problem, which ensures the validity of subsequent regression results.

4.3. Multiple Linear Regression Results (Independent Effect Test)

Table 2 reports the independent regression results of CBEC and digital border ports on the three export margins. The results show that both CBEC and DP have significant positive effects on EM, QM and PM, which fully verifies H1 and H2.

Table 2. Independent Effect Regression Results of CBEC and Digital Border Ports on Export Margins

Variables	EM	QM	PM
CBEC	0.428***	0.386***	0.453***
	(0.052)	(0.061)	(0.048)
DP	0.315***	0.512***	0.327***
	(0.047)	(0.058)	(0.044)
lnGDP	0.124**	0.186***	0.098*
	(0.058)	(0.062)	(0.053)
lnOPEN	0.086*	0.142**	0.072

Variables	EM	QM	PM
	(0.049)	(0.057)	(0.046)
lnEXR	-0.064	-0.118*	-0.052
	(0.051)	(0.063)	(0.048)
lnINFRA	0.156***	0.204***	0.132**
	(0.048)	(0.055)	(0.052)
lnAGRI	0.094*	0.128**	0.086*
	(0.050)	(0.056)	(0.049)
Constant	0.218***	0.342***	0.286***
	(0.062)	(0.074)	(0.058)
Observations	216	216	216
R^2	0.684	0.726	0.658
Adjusted R^2	0.672	0.716	0.645
F-statistic	58.42***	72.18***	52.36***

Note: Robust standard errors are in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels respectively. The dependent variables are EM, QM and PM in columns (1)–(3).

Specifically, in terms of extensive margin (EM), the regression coefficient of CBEC is 0.428 ($p<0.01$), and the coefficient of DP is 0.315 ($p<0.01$), indicating that CBEC has a stronger effect on promoting agricultural product diversification. CBEC platforms reduce market entry costs, help enterprises develop new product categories and expand market coverage, so as to significantly improve the extensive margin. In terms of quantity intensive margin (QM), the coefficient of DP is 0.512 ($p<0.01$), which is significantly higher than CBEC's coefficient of 0.386 ($p<0.01$), confirming that digital border ports have a more prominent driving effect on trade scale expansion. Intelligent customs clearance and efficient logistics of digital ports solve the pain points of low efficiency and high loss of agricultural product trade, and effectively expand the export scale of existing products. In terms of price intensive margin (PM), CBEC coefficient is 0.453 ($p<0.01$), DP coefficient is 0.327 ($p<0.01$), indicating that CBEC's brand promotion and quality display functions are more conducive to improving export product premium and upgrading export quality.

4.4. Hierarchical Regression Results (Synergistic Moderating Effect Test)

This paper adopts three-layer hierarchical regression to test the synergistic moderating effect, and the results are shown in Table 3. After adding control variables in the first layer, the model fitting degree is good. In the second layer, CBEC is added, and the regression coefficients of the three margins are significantly positive, and the R^2 of the model is significantly improved, indicating that CBEC can effectively explain the changes of agricultural export margins. In the third layer, digital port variable and interaction term are added, and the interaction term coefficients of CBEC×DP on EM, QM and PM are 0.216, 0.283 and 0.249 respectively, all significant at the 1% level.

Table 3. *Hierarchical Regression Results of Synergistic Moderating Effect*

Variables	EM-M1	EM-M2	EM-M3	QM-M1	QM-M2	QM-M3	PM-M1	PM-M2	PM-M3
CBEC	—	0.412***	0.386***	—	0.374***	0.352***	—	0.438***	0.412***
	—	(0.051)	(0.049)	—	(0.060)	(0.057)	—	(0.047)	(0.045)
DP	—	—	0.298***	—	—	0.486***	—	—	0.308***
	—	—	(0.045)	—	—	(0.056)	—	—	(0.042)
CBEC × DP	—	—	0.216***	—	—	0.283***	—	—	0.249***
	—	—	(0.052)	—	—	(0.061)	—	—	(0.048)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.342***	0.268***	0.224***	0.516***	0.408***	0.346***	0.418***	0.324***	0.282***
	(0.068)	(0.064)	(0.060)	(0.078)	(0.072)	(0.068)	(0.062)	(0.058)	(0.054)
Observations	216	216	216	216	216	216	216	216	216
R^2	0.426	0.612	0.708	0.458	0.634	0.752	0.402	0.586	0.684
Adjusted	0.410	0.598	0.694	0.443	0.621	0.740	0.386	0.571	0.669

Variables	EM-M1	EM-M2	EM-M3	QM-M1	QM-M2	QM-M3	PM-M1	PM-M2	PM-M3
R^2									
ΔR^2	—	0.186***	0.096***	—	0.176***	0.118***	—	0.184***	0.098***
F-statistic	26.84***	48.62***	62.18***	30.16***	52.48***	74.36***	24.52***	44.28***	56.84***

Note: M1, M2 and M3 denote the three-layer hierarchical regression models. M1 includes only control variables; M2 adds CBEC on the basis of M1; M3 adds DP and the interaction term CBEC×DP on the basis of M2. Robust standard errors are in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels respectively. ΔR^2 denotes the increment of R^2 compared with the previous layer.

The results confirm that digital border ports have a significant positive moderating effect, which verifies H3. The improvement of digital port infrastructure can significantly amplify the driving effect of CBEC on agricultural export margins. The synergistic mechanism is reflected in that digital ports provide efficient logistics and customs clearance support for CBEC online transactions, realize the effective transformation of online order flow to offline trade volume, further expand product diversification and trade scale, and rely on standardized digital supervision to improve export product quality, forming a benign interactive pattern of "platform empowerment + infrastructure guarantee".

4.5. Heterogeneity Analysis

To verify H4, this paper divides agricultural products into labor-intensive high-value-added products and bulk primary products for sub-sample regression. The results show that the synergistic driving effect of CBEC and digital ports on high-value-added agricultural products is extremely significant, with all interaction term coefficients greater than 0.25; while the synergistic effect on bulk primary products is weak, and the price margin effect is not significant. The reason is that high-value-added processed agricultural products have high digital matching demand and high logistics and customs clearance requirements, which are more sensitive to digital infrastructure upgrading; while bulk primary products have single product structure, low added value and low dependence on digital platforms and intelligent ports, resulting in insignificant marginal optimization effect.

4.6. Robustness Test

This paper adopts variable substitution method and sample truncation method for robustness test. First, replace the measurement index of CBEC with the number of cross-border e-commerce enterprises; second, truncate the sample data of the first and last years. The robustness test results show that the sign and significance of all core coefficients are consistent with the baseline regression results, indicating that the research conclusions are stable and reliable.

4.7. Independent Driving Mechanism of Digital Infrastructure

CBEC and digital border ports have differentiated independent driving effects on the three agricultural export margins, which is consistent with the functional attribute differences of the two digital infrastructures. As a virtual digital service platform, CBEC is oriented to market information optimization and transaction mode innovation, which can effectively reduce enterprise market development costs and product marketing costs, so it has stronger advantages in expanding product diversification (extensive margin) and improving product premium capacity (price intensive margin). Digital border ports, as physical digital infrastructure, focus on solving the bottlenecks of traditional agricultural trade such as slow customs clearance, low logistics efficiency and high product loss, and directly act on the trade circulation link, so they have the most significant promotion effect on the expansion of existing product trade scale (quantity intensive margin). This differential effect makes up for the homogeneous research conclusion of existing digital trade studies, and clarifies the targeted optimization value of different digital infrastructures for agricultural export structural upgrading.

4.8. Synergistic Moderating Logic of Virtual and Physical Digital Infrastructure

The hierarchical regression results verify the positive synergistic moderating mechanism between CBEC and digital border ports, which reveals the dual-dimensional driving logic of digital trade empowering agricultural export growth. Single CBEC platform empowerment is limited by offline logistics and customs clearance capacity, and it is difficult to realize large-scale transformation of online market advantages; single digital port infrastructure construction lacks online market demand docking, and the efficiency advantage cannot be fully released. The coordination of the two realizes the organic integration of online digital transaction and offline intelligent circulation, forms a full-chain digital trade service system from market matching, online transaction to intelligent customs clearance and efficient logistics, and comprehensively optimizes the three marginal levels of agricultural exports. This synergistic mechanism explains the rapid growth of China-Vietnam agricultural digital

trade in recent years, and provides a new perspective for understanding the structural optimization of cross-border agricultural trade under digital transformation.

4.9. Product Heterogeneity Differences and Theoretical Explanation

The significant product heterogeneity of the driving effect is determined by the product attribute differences of agricultural products. Labor-intensive and high-value-added processed agricultural products have the characteristics of rich product categories, high quality differentiation and strong market competition, which rely on digital platforms to expand market space and rely on intelligent ports to ensure product transportation quality and timeliness, so they can fully benefit from digital infrastructure upgrading. In contrast, bulk primary agricultural products have single product attributes, low quality differentiation and low trade profit margin, and their export growth mainly depends on price advantage and scale advantage, with low dependence on digital innovation, resulting in insignificant marginal optimization effect. This heterogeneity conclusion enriches the research on the boundary conditions of digital trade empowerment of agricultural exports.

5. Conclusion and Policy Implications

5.1. Core Conclusions

Based on the three-margin decomposition framework of export growth, this paper takes China-Vietnam agricultural trade panel data from 2015 to 2024 as research samples, and systematically tests the independent driving effect and synergistic moderating mechanism of cross-border e-commerce and digital border ports on agricultural export three margins by using multiple linear regression and hierarchical regression models. The core conclusions are as follows: First, both CBEC and digital border ports significantly promote the growth of extensive margin, quantity intensive margin and price intensive margin of China's agricultural exports to Vietnam, with obvious functional differentiation. CBEC dominates the optimization of extensive margin and price intensive margin, while digital border ports have the strongest driving effect on quantity intensive margin. Second, digital border ports have a significant positive moderating effect on the relationship between CBEC and agricultural export margins, and the two form a synergistic driving effect of virtual platform empowerment and physical infrastructure guarantee, which comprehensively improves the level of agricultural export marginal growth. Third, the digital-driven effect has significant product heterogeneity, and the synergistic optimization effect on high-value-added processed agricultural products is far better than that on bulk primary agricultural products. Fourth, the robustness test verifies that the above research conclusions are stable and reliable, and digital infrastructure is the core endogenous driving force for the high-quality growth of China-Vietnam agricultural exports.

5.2. Policy Implications

First, implement differentiated digital empowerment strategies based on marginal characteristics. Focus on expanding the coverage and service capacity of cross-border e-commerce platforms, enrich online display, transaction and brand promotion functions of agricultural products, and further release the optimization effect of CBEC on product diversification and export quality upgrading. Accelerate the intelligent upgrading of digital border ports, optimize the whole-process intelligent customs clearance and cold chain logistics system for agricultural products, and give full play to the scale expansion advantage of digital ports on agricultural exports.

Second, build a coordinated development system of CBEC and digital border ports. Break the information island between online e-commerce platforms and offline port supervision and logistics systems, realize data sharing, order docking and business collaboration between platforms and ports, amplify the synergistic driving effect of digital infrastructure, and build a full-chain digital trade service system for China-Vietnam agricultural products.

Third, implement classified digital transformation strategies for agricultural products. Focus on supporting the digital trade development of high-value-added processed agricultural products, encourage enterprises to carry out brand building and precision marketing through CBEC platforms, and rely on digital port intelligent supervision to improve product export quality standards. For bulk primary agricultural products, simplify digital trade processes and reduce digital transaction costs, so as to realize the coordinated development of different types of agricultural export trade.

Fourth, rely on the RCEP digital trade framework to expand regional digital cooperation. Promote the standard docking of digital ports and cross-border e-commerce rules between China and Vietnam, build a unified regional agricultural digital trade supervision system, and replicate the China-Vietnam digital agricultural trade cooperation model to more ASEAN countries, so as to drive the overall high-quality development of China's agricultural export trade.

5.3. Research Limitations and Future Prospects

This paper still has some research limitations. First, this paper only focuses on the empirical research of China-Vietnam bilateral agricultural trade, and does not expand to the multi-country sample of RCEP regions. Second, this paper mainly discusses the overall synergistic effect of digital infrastructure, and does not further decompose the internal transmission paths of digital trade cost reduction, market efficiency improvement and quality supervision optimization. Future research can expand the research sample to RCEP regional

countries, conduct comparative analysis of regional heterogeneity, and further adopt mediating effect models to decompose the multi-dimensional transmission mechanism of digital infrastructure driving agricultural export marginal growth, so as to enrich and improve the theoretical system of digital agricultural trade.

Conflicts of Interest

The authors declare no conflicts of interest.

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