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Research on the Impact of the Digital Economic Development Level of RCEP Member Countries on China's Export Trade of Mechanical and Electrical Products

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Abstract: Against the rapid growth of the global digital economy and deepened RCEP implementation, the mechanical and electrical (M&E) industry, a pillar of China's foreign trade, is crucial to China's high-quality regional trade development. Based on 2010-2024 balanced panel data of RCEP members, this paper employs an extended trade gravity model with country fixed-effects to investigate how host-country digital-economy development influences China's M&E exports and the synergistic mechanism of RCEP. The results show that RCEP members' digital-economy level is significantly positively associated with China's M&E exports. RCEP generates significant positive synergy with the digital economy, amplifying its export-empowering effect after the agreement takes effect. Heterogeneity analysis indicates that the main digital-economy effect holds for developed economies with no obvious RCEP synergy. For developing economies, the direct digital-economy effect is insignificant, whereas the RCEP-digital-economy interaction term is significant at the 1% level, suggesting RCEP institutional dividends effectively unlock the trade potential of the digital economy in developing member markets.

Keywords: Digital economy; Exports of mechanical and electrical products; RCEP; Trade gravity model

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1. Introduction

Driven by rapid technological progress, the digital economy has become a key force reshaping global economic activity. China has implemented policies to foster deeper integration between digital technologies and the real economy. Existing studies offer theoretical and empirical support for the trade-promoting role of the digital economy: Shi showed that the digital economy boosts trade by cutting transaction costs and optimizing resource allocation [1]. From a transaction-cost perspective, Yue and Li found that improved digital-economy technical

rules reduce regional trade costs and stimulate manufacturing exports [2]. Liu and Chen further verified positive cross-border trade effects of digital-economy development, establishing theoretical groundwork for research on digital-economy impacts on mechanical and electrical (M&E) exports [3].

As a cornerstone of China's exports, the M&E industry faces mounting pressures from slowing growth, low value-added output, and fierce global competition. This paper addresses research gaps concerning digital-economy-led export effects for this capital- and technology-intensive sector. It extends heterogeneous-firm trade theory to digital-trade contexts, clarifies transmission channels of digital factors on exports, and enriches the theoretical framework for digital-economy and foreign-trade research. The results inform M&E firms' overseas layout and product-mix adjustments according to host-country digital conditions. They also supply empirical evidence for governments designing coordinated digital-economy and trade policies within the RCEP framework, supporting high-end upgrading and sustained regional export competitiveness of China's M&E products.

2.Analysis of the current situation of China's mechanical and electrical product exports

From 2010 to 2024, China's exports of M&E products to RCEP members show phased steady growth. Since RCEP entered into force, policy dividends, together with China's sound industrial chains, technological upgrading, and new-form foreign trade, have further boosted regional M&E exports. In market distribution, an ASEAN-centered pattern of "one dominant market plus multiple key markets" has formed. Export focus has shifted from traditional markets including Japan and the Republic of Korea toward emerging ASEAN economies such as Vietnam. Declining market concentration reflects notable progress in market diversification and deepened intra-regional two-way M&E trade.

In commodity structure, electronic equipment remains dominant, while automobiles and auto parts—especially new-energy vehicles—act as major growth engines. M&E exports demonstrate growing technological intensity and an obvious high-end upgrading trend. Despite the differentiated competitive landscape across RCEP members, China still lacks core high-end technologies. Against regional digital-economy development, China's M&E exports face multiple constraints: digital technical barriers and intense competition in high-end markets from developed RCEP members; poor product adaptability caused by uneven digital infrastructure in developing members; substitution risks amid regional supply-chain restructuring; insufficient digital transformation of domestic firms; and high compliance costs arising from fragmented regional digital rules. These obstacles impede the high-quality growth of China's M&E exports within the RCEP market.

3. Level of digital-economy development

3.1. Measurement of digital-economy development level

A well-designed indicator system is critical for accurate digital-economy measurement. Following Zhao *et al.* and Liu *et al.*, this paper accounts for heterogeneous development levels and data limitations among RCEP and ASEAN developing members [4,5]. Guided by representativeness and data availability, we exclude heavily missing and redundant indicators. Nine secondary indicators covering digital infrastructure, digital industrial competitiveness, and digital innovation environment are selected to construct the evaluation system (**Table 1**). Principal Component Analysis (PCA) is adopted for objective weighting to calculate the composite digital-economy index.

Table 1. Evaluation indicator system for digital-economy development level

Primary indicator	Secondary indicator	Indicator description	Unit	Data source
Digital Infrastructure	Internet Penetration Rate	Internet users per 100 people	%	WDI
	Mobile-cellular Subscriptions	Mobilecellular subscriptions per 100 inhabitants	Subscription	WDI
	Fixed-broadband Subscriptions	Fixedbroadband subscriptions per 100 inhabitants	Subscription	WDI
Digital Industrial Competitiveness	Share of ICT Goods Exports	ICT exports / total manufactured exports	%	UNCTAD
	Share of High-tech Product Exports	Hightech product exports / total manufactured exports	%	UNCTAD
	Share of ICT-service Exports	ICT service exports / total service exports	%	UNCTAD
Digital Innovation Environment	R&D Expenditure Intensity	R&D expenditure as a percentage of GDP	%	WDI/ UNESCO
	Resident Patent-application Activity	Resident patent applications per million inhabitants	PCS	WIPO
	S&T Innovation Output	Scientific-technical journal articles per million inhabitants	Pt.	WDI

Data sources: World Bank WDI Database; United Nations Conference on Trade and Development (UNCTAD); United Nations Educational, Scientific and Cultural Organization (UNESCO); World Intellectual Property Organization (WIPO).

Principal Component Analysis (PCA) is applied to reduce dimensions and assign objective weights to indicators. We compute the panel dataset covering 14 RCEP member states (2010–2024) in SPSS. Given the cumulative variance contribution of the first three principal components is 81.7% (above the 80% empirical threshold), these three components are retained to generate the composite digital economy development index.

3.2. Analysis of digitaleconomy development level

According to the composite index scores, RCEP member states can be classified into three tiers in terms of digital economy development. The first tier consists of highly digitalized economies, including Republic of Korea, Japan, Singapore, and Australia, whose composite index scores exceed 0.4 and are significantly higher than those of other member states. The second tier represents moderately digitalized economies, covering New Zealand, Malaysia, Brunei, the Philippines, and Thailand, with index scores ranging from −0.2 to 0.4. The third tier comprises less digitalized economies, namely Vietnam, Indonesia, Laos, Myanmar, and Cambodia, whose index scores are below −0.2, indicating relatively underdeveloped digital economy growth.

4. Empirical analysis

4.1. Trade gravity model and estimation methodology

4.1.1. Trade gravity model

The gravity model is a classical empirical framework for international trade analysis, which posits that bilateral trade flows are positively related to economic scale and negatively related to geographic distance [6]. Based on

the standard gravity model, this study incorporates the digital economy level, RCEP policy dummy, and their interaction term, as well as per capita GDP and trade openness as control variables, to construct the following extended gravity model:

$$\ln EX_{it} = \beta_0 + \beta_1 DIG_{it} + \beta_2 RCEP_t + \beta_3 \left(DIG_{it} \times RCEP_t \right) + \gamma' X_{it} + \mu_i + \varepsilon_{it}$$

where i indexes RCEP member states excluding China and t is the year spanning 2010–2024. $\ln EX_{it}$ denotes the log value of China's M&E-product exports to country i. DIG_{it}, the core explanatory variable, is the composite digital-economy index for country i in year t. $RCEP_t$ is a policy dummy (1 for 2022 onwards, otherwise 0) acting as a proxy for policy roll-out. The model identifies correlations and synergistic linkages rather than strict causal effects. $DIG_{it} \times RCEP_t$ is the interaction term for testing policy-digital-economy synergy. X_{it} is the vector of time-varying controls; μ_i represents country fixed-effects absorbing time-invariant country attributes; ε_{it} is the random error term. Note that the time-only variation of the RCEP dummy produces perfect multicollinearity when time fixed-effects are added; hence, time fixed-effects are omitted from the baseline model.

4.1.2. Model estimation methodology

This study uses balanced-panel data covering 14 economies from 2010 to 2024 and employs the fixed-effects (FE) model for estimation. Clustered robust standard errors are applied to mitigate heteroskedasticity and within-group correlation. The core research hypotheses are presented as follows:

H1: The development level of the digital economy is positively associated with China's exports of mechanical and electrical products;

H2: There exists a positive synergistic effect between the RCEP policy and the digital economy.

4.2. Variable definition

Dependent variable: natural logarithm of China's export value of mechanical and electrical products to RCEP member states ($\ln EX$). Mechanical and electrical products cover machinery (Chapter HS84) and electrical equipment (Chapter HS85). Data are obtained from the World Bank WITS database.

Core explanatory variables: digital-economy development index (DIG), derived from the principal-component analysis in the previous section; RCEP policy dummy variable (RCEP), with 2022 as the policy effective year; and their interaction term (DIG×RCEP).

Control variables: natural logarithm of importer's per-capita GDP ($\ln GDPpc$), capturing market purchasing power; trade openness (OPEN), measuring the market openness of importing countries. All control-variable data come from the World Bank. Time-invariant variables such as geographic distance are absorbed by country fixed effects and thus not separately reported.

4.3. Baseline regression results

The RCEP dummy varies purely over time (equals 1 from 2022 onwards). Including year fixed-effects would cause perfect multicollinearity, rendering the RCEP main effect and its interaction term unidentifiable. Therefore, year fixed-effects are excluded from the baseline regression. Column (1) adopts country fixed-effects (FE) to account for cross-country heterogeneity, and Column (2) reports random-effects (RE) estimates for comparative reference. Baseline regression results are presented in **Table 2**.

Table 2. Baseline regression results

Variable	(1) FE	(2) RE
DIG	0.130**	0.254***
	(0.060)	(0.057)
RCEP	0.142	0.165
	(0.119)	(0.125)
DIG×RCEP	0.154***	0.167***
	(0.043)	(0.044)
ln(GDPpc)	0.082***	0.102***
	(0.024)	(0.038)
OPEN	0.003***	0.003**
	(0.001)	(0.001)
Constant	14.091***	13.736***
	(0.220)	(0.384)
R-squared	0.3469	0.3146
Observations	210	210
CountryFE	YES	NO
YearFE	NO	NO

Clustered-robust standard errors in parentheses; ***$P < 0.01$, **$P < 0.05$, *$P < 0.1$.

FE results show that the DIG coefficient is 0.130 and significant at the 5% level. A one-unit increase in host-country digital-economy level raises China's M&E exports by approximately 13.9%, supporting H1. Higher digitalization lowers cross-border transaction costs and boosts import demand for M&E products.

The RCEP direct-effect coefficient is 0.142 and insignificant, while the interaction term (DIG×RCEP) equals 0.154 and is significant at the 1%. This indicates RCEP generates little unconditional export stimulus; its value mainly comes from institutional coordination that amplifies the digital-economy export effect, bringing an extra 16.6% export elasticity gain and validating H2.

For controls, ln(GDPpc) is significantly positive at 1%, meaning stronger purchasing power increases demand for high-end M&E goods. OPEN also shows a significantly positive coefficient, implying higher openness facilitates absorption of China's M&E products. RE estimation yields similar coefficient signs and significance as FE.

4.4. Analysis of RCEP policy effects

To further examine the structural changes in the policy effect of RCEP, this study constructs nested models with progressively introduced variables (**Table 3**).

Table 3. Regression results for RCEP policy effects

Variable	Model 1	Model 2	Model 3
RCEP	0.630***	0.190	0.142
	(0.078)	(0.120)	(0.119)
DIG×RCEP	-	0.131***	0.154***
		(0.050)	(0.043)
DIG	-	0.159***	0.130**
		(0.058)	(0.060)

ln(GDPpc)	-	-	0.082***
			(0.024)
OPEN	-	-	0.003***
			(0.001)
Constant	15.168***	14.966***	14.091***
	(0.162)	(0.073)	(0.220)
R-squared	0.2366	0.3004	0.3469
Observations	210	210	210

Clustered-robust standard errors in parentheses; ***$P < 0.01$, **$P < 0.05$, *$P < 0.1$.

Step-wise outcomes from **Table 3** show that Model 1 (excluding digital-economy variables) yields a significantly positive RCEP coefficient of 0.630 at the 1% level, suggesting considerable trade-barrier-reduction dividends for China's M&E exports after RCEP entered into force.

When DIG and (DIG×RCEP)are sequentially incorporated in Model 2 and Model 3, the RCEP coefficient drops to 0.190 and 0.142 and becomes insignificant, while the interaction term remains strongly significant at the 1%.

This demonstrates that RCEP's trade promotion is not a universal tariff-reduction bonus but relies heavily on digital-economy conditions and institutional coordination. Tariff-related dividends are embodied in the synergy between digital-economy progress and rule harmonization. RCEP's origin-cumulation and paperless-trade provisions can generate full benefits only for importers with solid digital foundations, facilitating market penetration of China's high-quality, high-tech M&E products.

4.5. Heterogeneity analysis

This paper further explores heterogeneous characteristics of the synergistic effect between RCEP and the digital economy. **Table 4** presents heterogeneity regression results grouped according to economic development levels.

Table 4. Heterogeneity analysis results

Variable	Developed economies	Developing economies
RCEP	0.525	0.038
	(0.340)	(0.095)
DIG	0.183**	0.084
	(0.078)	(0.091)
DIG×RCEP	0.013	0.273***
	(0.084)	(0.059)
ln(GDPpc)	0.127***	0.050
	(0.027)	(0.032)
OPEN	0.003***	0.002**
	(0.001)	(0.001)
Constant	15.456***	13.327***
	(0.212)	(0.283)
R-squared	0.5032	0.2901
Observations	75	135
Country Num	5	9

Clustered-robust standard errors in parentheses; ***$P < 0.01$, **$P < 0.05$, *$P < 0.1$.

There exists evident heterogeneity in digital-economy effects and RCEP synergy across subsamples. For developed-economy subsamples, the main DIG effect is significant (β = 0.183, $P < 0.05$), while the interaction term (DIG×RCEP) is insignificant. Well-established digital infrastructure and industries in developed members generate endogenous demand for China's high-end M&E products. Substantial tariff reductions had already been achieved under prior bilateral FTAs, so RCEP produces little additional marginal synergy for these economies.

In the developing-economy group, the standalone digital-economy effect is insignificant, whereas (DIG×RCEP) reaches 0.273 and is significant at the 1%. Constrained by poor digital infrastructure and trade frictions, digital-economy growth alone could not drive M&E imports in developing RCEP members before RCEP. By virtue of origin-cumulation rules, cross-border e-commerce support and paperless-trade facilitation, RCEP provides institutional conditions for developing economies to integrate into regional industrial chains and unlock their digital-driven trade potential. Hence, the synergistic effect between RCEP and the digital economy is much more salient for developing members.

4.6. Robustness checks

To verify the reliability of the baseline regression outcomes, three robustnesscheck strategies are implemented: replacing the core explanatory variable, excluding pandemicperiod observations, and regressing on a recent subsample (**Table 5**).

Table 5. Robustness check results

Variable	(1) Variable replacement	(2) Excluding pandemic period	(3) Recent subsample
Internet Users	0.006*	-	-
	(0.003)		
DIG	-	0.192***	0.058
		(0.053)	(0.077)
DIG×RCEP	0.223***	0.171***	0.219***
	(0.028)	(0.030)	(0.038)
ln(GDPpc)	0.088***	0.099***	0.088***
	(0.024)	(0.026)	(0.029)
OPEN	0.003***	0.003**	0.003***
	(0.001)	(0.001)	(0.001)
Constant	13.861***	13.884***	14.156***
	(0.236)	(0.265)	(0.229)
R-squared	0.3397	0.4061	0.3759
Observations	210	182	140

Column (1) adopts internet penetration rate as an alternative proxy for the digital-economy index; Column (2) drops observations from 2020-2021. Clustered-robust standard errors in parentheses; ***$P < 0.01$, **$P < 0.05$, *$P < 0.1$.

In Column (1), internet penetration serves as an alternative measure. Its coefficient is significantly positive at the 10% level, and (DIG×RCEP) remains significant at 1%, confirming baseline findings are insensitive to variable measurement. Column (2) excludes pandemic-affected years 2020–2021; both DIG and (DIG×RCEP) stay highly significant, indicating exogenous public-health shocks do not alter core conclusions. Column (3)

uses the 2015–2024 subsample for temporal-stability testing. While the main DIG effect loses significance in this shorter sample window, the interaction term (DIG×RCEP) is still significant at 1%.

Overall, despite fluctuations of the standalone digital-economy effect across subsamples, the positive synergistic interaction between digital-economy development and RCEP policy proves highly robust under different settings. Hence, Hypothesis H2 is strongly supported.

5. Conclusion

Empirically, RCEP members' digital-economy development positively correlates with China's M&E exports and creates notable synergy with RCEP policies. Governments should construct a differentiated regional support system: develop a digital-economy monitoring and early-warning platform; advance digital-infrastructure connectivity and digital-trade rule recognition under RCEP; roll out tailored fiscal, financial, and certification policies for members at different digital-development stages; and enhance public services covering cross-border e-commerce, IP protection, and talent training to cut export costs.

Enterprises need to adjust export strategies for RCEP's digital markets. They should upgrade products locally to boost digital, intelligent, and green performance, integrate into regional digital supply chains, and utilize origin-cumulation rules to shift toward comprehensive digital-solution supply. By adopting tiered market positioning and regional digital-trade platforms, firms can improve long-term export competitiveness and market stability.

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Disclosure statement

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