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The Impact of the Digital Economy on the High-Quality Development of Foreign Trade: Evidence from City-Level Panel Data in Anhui Province

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Abstract

The digital economy is reshaping global trade and creating new opportunities for the high-quality development of foreign trade.Taking the prefecture-level cities of Anhui Province during 2010–2023 as the empirical sample,this paper constructs a composite index of digital economy development along four dimensions—digital infrastructure,digital industrialisation,the digitalisation of industry,and digital talent—and an index of the high-quality development of foreign trade covering foreign trade volume,foreign trade structure and foreign trade competitiveness, both measured using the entropy weight method.A two-way fixed effects model is estimated to examine the effect of the digital economy on the high-quality development of foreign trade in Anhui.The results show that the digital economy exerts a significantly positive promoting effect on the high-quality development of foreign trade in the province,and that this effect displays pronounced regional and temporal heterogeneity. The findings carry practical implications for how Chinese provinces can seize the opportunities of the digital era to advance the high-quality development of foreign trade.

Keywords

Digital Economy; High-Quality Development of Foreign Trade; Two-Way Fixed Effects Model; Entropy Weight Method; Anhui Province

1. Introduction

Anhui is a major province for foreign trade development in central China,yet the high-quality development of its foreign trade currently confronts a number of problems.In the era of the digital economy, keeping pace with digital transformation helps promote high-quality growth of the province's foreign trade.This paper therefore explores how the digital economy empowers the high-quality development of foreign trade in Anhui,with a view to offering insights for the province's trade development in practice.

Before turning to the empirical analysis,the relevant concepts are delimited.Drawing on the literature on the connotation of the digital economy,Etemad[1] defines it as a new economic form that reshapes global business connectivity and international economic activity,whereas Rovenskaya etal.[2] treat it as a complex economic system encompassing technological innovation,industrial transformation and ecosystem coordination.Synthesising these contributions,this paper defines the digital economy as an economic system underpinned by digital infrastructure, centred on digital industrialisation and the digitalisation of industry,and supported intellectually by digital talent.

On measurement,Sang[3] builds an indicator system of digital infrastructure,the application of digital technology and the development of digital industries, and applies the entropy weight method to quantify the level of digital economy development; Xu and Bai[4] select Internet penetration and the value added of digital industries as core indicators and use principal component analysis to assess the development of the regional digital economy;Zheng and Zhang[5] measure the penetration of the digital economy directly through the digital inclusive finance index.Absorbing these studies while taking the availability of actual data into account, this paper adopts digital infrastructure,digital industrialisation,the digitalisation of industry and digital talent as its indicators, and measures the level of the digital economy with the entropy weight method.

The connotation of the high-quality development of foreign trade likewise requires delimitation. Etemad[1] argues that it is a development model in which digital technology drives innovation in the mode of trade and facilitates efficient matching with global markets. Wang and Zeng[6] hold that it is a model of foreign trade development that takes digital commerce as a key carrier and uses technological innovation to transform the mode of trade and optimise its structure. Combining the existing literature, this paper defines the high-quality development of foreign trade as a development model grounded in the steady growth of trade volume and centred on the optimisation of trade structure and the elevation of trade competitiveness.

With respect to measurement, Zhang etal[7] construct a system of four dimensions covering scale, structure, benefits and sustainability, while Cao[8] evaluates trade competitiveness through the trade competitiveness (TC) index and the revealed comparative advantage (RCA) index.This paper accordingly selects foreign trade volume, foreign trade structure and foreign trade competitiveness as its dimensions and again applies the entropy weight method.

Research on the determinants of foreign trade and on policies promoting its high-quality development has progressively focused on the digital economy. Analysing the European Union's "VAT in the Digital Age" package, Mikula[9] shows that optimising the tax regime can lower cross-border trade costs, and calls on the international community to harmonise digital trade rules so as to reduce barriers to cross-border data flows. Wang and Zeng[6] recommend improving the regulatory

framework for digital commerce and establishing mechanisms for the cross-border protection of intellectual property. Taking the Yangtze River Delta as an example, Chai[10] proposes diffusing the experience of digital transformation pilots in foreign trade through regional policy coordination, while Cao[8] advocates widening the coverage of cross-border e-commerce comprehensive pilot zones and exploring integrated "online plus offline" modes of trade.

The influence of the digital economy on the high-quality development of foreign trade thus represents a clear trend in academic research.Following this trend, the present study makes three advances relative to prior work. First, by taking Anhui as its entry point and constructing indicator systems for the digital economy and for high-quality trade development that are grounded in the region's industrial profile, it offers a transferable line of thinking for provincial-level research. Second, it estimates a two-way fixed effects model that systematically tests the relationship between the digital economy and the high-quality development of foreign trade. Third, it introduces heterogeneity analysis that is anchored in the timing of Anhui's digital economy policies and dynamically dissects the stage-specific features of this relationship, thereby providing a precise basis for decision making on regional trade transformation.

The remainder of the paper is organised as follows. Section 2 sets out the empirical design and the stylised facts,Section 3 reports and interprets the estimation results,and Section 4 derives policy implications,discusses the limitations and outlines directions for further research.

2. Empirical Design and Stylised Facts

2.1. Model Specification

To analyse the impact of the digital economy on the high-quality development of foreign trade in Anhui Province, this paper constructs the following model:

$$Tra_{it}=\alpha_0+\alpha_1 dig_{it}+\alpha_2 pgdp_{it}+\alpha_3 fdi_{it}+\alpha_4 gov_{it}+\alpha_5 indus_{it}+\varphi_i+\gamma_t+\mu_{it} \quad (1)$$

where Trait denotes the level of high-quality development of foreign trade and digit is the core explanatory variable,the level of digital economy development.The control variables are pgdpit (per-capita GDP), fdiit (dependence on foreign investment),govit (degree of government support) and indusit (level of industrial development).The subscript i indexes the prefecture-level city and t the year; φi captures unobserved city characteristics,γt captures unobserved year effects, and μit is the stochastic error term.

2.2. Variables

The level of high-quality development of foreign trade (Tra) is the dependent variable and the level of the digital economy (dig) is the core explanatory variable; both composite indices are evaluated with the entropy weight method.

Following Mao[11] and Zhang and Li,and considering data availability,four factors are selected as control variables.Per-capita GDP (pgdp) is measured as the ratio of regional gross domestic product to total regional population.Dependence on foreign investment (fdi) is measured as the ratio of actually utilised foreign capital to GDP.The degree of government support (gov) is measured as the ratio of fiscal expenditure to GDP in each prefecture-level city;government support can promote high-quality trade development directly or indirectly through capital injection,policy design and infrastructure provision.The level of industrial development (indus) is measured as the ratio of the value added of the secondary sector to gross output in each prefecture-level city.Industry is a major component of imports and exports in many countries, especially exports; as China is a leading exporting economy,the level of industrial development directly affects trade performance at the national and provincial levels.

Combining the preceding literature,the indicator systems for the level of the digital economy and for the high-quality development of foreign trade are constructed as shown in Tables 1 and 2.

Table 1. Indicator system for measuring the digital economy

First-level indicator	Second-level indicator	Unit	Attribute
Digital infrastructure	Number of international Internet users	10,000 households	+
	Number of mobile telephone users at year-end	10,000 households	+
Digital industrialisation	Total volume of telecommunications business	10,000 CNY	+
	Total volume of postal business	10,000 CNY	+
Digitalisation of industry	Digital inclusive finance index	/	+
Digital talent	Share of employment in information transmission,software and IT services	%	+

Note: All indicators are positive-direction indicators, as denoted by the"+"sign in the attribute column.

Table 2. Indicator system for the high-quality development of foreign trade

First-level indicator	Second-level indicator	Definition	Unit	Attribute
Foreign trade volume	Total value of imports and exports	Imports + exports	100 million CNY	+
	Foreign trade intensity	Total value of imports and exports / population size	/	+
Foreign trade structure	Degree of import–export balance	Import volume/export volume	/	+
Foreign trade competitiveness	Trade competitiveness (TC) index	|Exports –Imports| / total value of imports and exports	/	+
Foreign trade competitiveness	Dependence on foreign trade	Total value of imports and exports /GDP	/	+

2.3. Data Sources and Descriptive Statistics

The data for the indicators are drawn from the Statistical Yearbook of Anhui Province (2010–2023), the Statistical Communiqués on National Economic and Social Development of each prefecture-level city,the website of the Anhui Provincial Customs,and publicly released annual government work reports of the cities.Because the foreign trade statistics of individual cities are missing for certain years,missing values are filled using linear interpolation.

Table 3 reports the descriptive statistics. The dependent variable,the level of high-quality development of foreign trade, ranges from 0.0245 to 0.656;the digital economy index ranges from 0.0124 to 0.892; per-capita GDP ranges from 0.907 to 13.007;and the level of industrial development ranges from 0.323 to 0.747.The mean values indicate a comparatively high overall level of development for these variables.

Table 3. Descriptive statistics

Variable type	Variable definition	Symbol	N	Mean	SD	Min	Max
Dependent variable	Level of high-quality development of foreign trade	Tra	224	0.119	0.136	0.0245	0.656
Explanatory variable	Level of the digital economy	dig	224	0.169	0.135	0.0124	0.892
Control variable	Dependence on foreign investment	fdi	224	0.005	0.004	0.0001	0.027
Control variable	Per-capita GDP	pgdp	224	4.907	2.768	0.907	13.007
Control variable	Degree of government support	gov	224	0.200	0.055	0.107	0.355
Control variable	Level of industrial development	indus	224	0.475	0.093	0.323	0.747

Note: N is the number of city-year observations over 2010–2023; SD denotes the standard deviation.

3. Empirical Results

3.1. Baseline Regression Results

The model with two-way fixed effects for cities and years is estimated, and the results are reported in Table 4.

Table 4. Baseline regression results

	(1)	(2)	(3)
dig	0.256*** (3.93)	0.188*** (4.50)	0.192*** (4.71)
fdi			5.619*** (4.45)
pgdp			0.011*** (3.91)
gov			0.377*** (3.01)
indus			-0.142* (-1.89)
Constant	0.075*** (5.33)	0.026* (1.75)	0.015 (0.28)
Year/city fixed effects	No	Yes	Yes
Observations	224	224	224
R-squared	0.065	0.925	0.940

Note: t-statistics are in parentheses.***,** and * denote significance at the 1%, 5% and 10% levels,respectively;the same convention applies to Tables 5–7.

Column (1) of Table 4 imposes neither year nor city fixed effects and includes no

control variables; the coefficient on the digital economy is significantly positive at the 1% level,notwithstanding cross-city differences in dependence on foreign investment,per-capita GDP, government support and the level of industrial development. Column (2) adds year and city fixed effects without control variables,and the estimate remains significant. Column (3) adds the control variables together with the year and city fixed effects,and the coefficient is still significant at the 1% level. Taken together,the direct effect of the digital economy on the high-quality development of foreign trade is unaffected by whether control variables and fixed effects are included,indicating that the digital economy directly promotes the high-quality development of foreign trade in Anhui.

3.2. Robustness Checks

Table 5. Robustness test results

	(1) Shortened window	(2) Additional controls
dig	0.151*** (3.46)	0.207*** (4.30)
fdi	7.051*** (5.31)	6.000*** (4.69)
pgdp	0.011*** (3.65)	0.013*** (4.24)
gov	0.363*** (2.83)	0.248 (1.47)
indus	-0.260** (-2.58)	-0.135* (-1.67)
tech		-2.106 (-1.18)
edu		1.137 (1.28)
Constant	-0.006 (-0.10)	-0.006 (-0.10)
Year/city fixed effects	Yes	Yes
Observations	176	224
R-squared	0.950	0.941

First, the estimation window is shortened.The development of China's digital economy is generally regarded as having passed a nascent stage (1994–2002) and a stage of rapid expansion (2003–2012) before entering a mature stage from 2013 onwards.This paper therefore restricts the sample to 2013–2023 and re-estimates the model,with the results reported in column (1) of Table 5.The coefficient on the level of digital economy development remains positive and significant at the 1% level,so the conclusion holds once the time window is shortened,which supports the robustness of the findings.

Second, additional control variables are introduced to test robustness.Column (2) of Table 5 adds the level of science and technology (tech),measured as science expenditure divided by GDP,and the level of education (edu),measured as education expenditure divided by GDP.The coefficient on the level of digital economy development remains positive and significant at the 1% level,indicating that the results of this study still hold after further controls are included and that the robustness check is passed.

3.3. Heterogeneity Analysis

3.3.1. Regional Heterogeneity

To compare the relationship between the digital economy and the high-quality development of foreign trade across the regions of Anhui, this paper divides the province into southern Anhui (Wannan) and northern Anhui (Wanbei) following the regional classification set out above. The results are reported in Table 6.

The estimate for northern Anhui does not pass the significance test,indicating that the digital economy there has no positive effect on the high-quality development of foreign trade,whereas the coefficient for southern Anhui is 0.240 and significant at the 1% level (t = 4.10),indicating a pronounced positive promoting effect.The most plausible explanation is that northern Anhui remains dominated by traditional agriculture and resource-based industries,with low value added and a relatively single-track development model, which constrains the upgrading of its foreign trade,while southern Anhui enjoys a more diversified industrial structure and greater economic vitality. On the policy side,government support in industrial layout,fiscal resources and tax incentives has been concentrated in southern Anhui and in particular in Hefei, the provincial capital,accelerating the development of the digital economy there and allowing its positive trade effect to emerge,whereas northern Anhui has received comparatively little such support and its development has been constrained.Southern Anhui is also better endowed with educational resources,with universities and research institutions clustered locally and a favourable location close to the developed economies of the Yangtze River Delta,while northern Anhui is more peripheral, poorer in educational resources,and suffers a more severe out-migration of talent. The impact of the digital economy on the high-quality development of foreign trade therefore displays clear regional heterogeneity,with a markedly stronger positive effect in southern Anhui than in northern Anhui.

Table 6. Regional heterogeneity

	Northern Anhui	Southern Anhui
dig	-0.029 (-0.62)	0.240*** (4.10)
fdi	-0.030 (-0.05)	7.091*** (4.10)
pgdp	0.002 (0.93)	0.002 (0.63)
gov	0.126*** (2.68)	0.133 (0.56)
indus	-0.022 (-0.75)	-0.106 (-0.80)
Constant	0.038** (2.64)	0.044 (0.47)
Year /city fixed effects	Yes	Yes
Observations	84	140
R-squared	0.805	0.937

3.3.2. Temporal Heterogeneity

To explore how the development of the digital economy affected the high-quality development of Anhui's foreign trade in different periods,this paper takes 2013 as the time node and divides the development of the province's digital economy into two stages:an early stage from 2010 to 2013 and a mature stage from 2014 to 2023.

The results are reported in Table 7.For 2010–2013 the level of digital economy development does not pass the significance test and the coefficient is negative

(t=-0.12),indicating no positive effect on the high-quality development of foreign trade in that period,whereas for 2014–2023 the coefficient is 0.119 and significant at the 5% level (t = 2.53), indicating a significant positive promoting effect.The reason is that 2010–2013 corresponds to the formative phase of Anhui's digital economy,when digital infrastructure had not yet been deployed on a large scale and both digital industrialisation and the digitalisation of industry still required time to reach scale.From 2014 onwards, building on the earlier deployment and improvement of digital infrastructure, the province consolidated its foundations, expanded the scale of digital applications and deepened the integration of the digital economy with the real economy,so that digital technologies were applied ever more widely.A considerable number of firms enlarged the scale of their international trade through such integration, thereby driving industrial upgrading and promoting the high-quality development of Anhui's foreign trade.

Table 7. Temporal heterogeneity

	2010–2013	2014–2023
dig	-0.029 (-0.12)	0.119** (2.53)
fdi	-4.781 (-1.42)	7.077*** (5.15)
pgdp	0.006 (0.56)	0.006** (2.05)
gov	0.134*** (3.58)	-0.000 (-0.49)
indus	0.538* (1.98)	-0.401*** (-3.25)
Constant	-0.194 (-1.20)	0.172* (1.85)
Year /city fixed effects	Yes	Yes
Observations	64	160
R-squared	0.981	0.950

4. Policy Recommendations and Concluding Remarks

4.1. Policy Recommendations

4.1.1. Targeted recommendations for northern Anhui (Wanbei)

First, digital infrastructure in northern Anhui should be strengthened,with priority given to network communications and data centres,so as to broaden network coverage and improve network quality.Second,the transformation of traditional industries should be advanced, guiding them towards high value-added advanced manufacturing and modern services while reducing dependence on resource-based industries.Third,economic cooperation between northern and southern Anhui should be promoted so that foreign trade firms in the north can exploit the industrial and market advantages of the south to expand their business;links between northern Anhui's industries and the developed coastal regions should also be reinforced,so as to absorb industrial transfers and upgrade trade performance.

4.1.2. Targeted recommendations for southern Anhui (Wannan)

First, government policy support should help firms in southern Anhui cultivate their own brands,so that they can attract resources and innovate in technology,thereby raising the value added of their products and services.Second,policy incentives should guide firms to participate in the formulation of international

standards,strengthening their voice in international markets,and encourage foreign trade firms to attend renowned international exhibitions and establish overseas research centres in order to raise their international profile and expand into foreign markets.Third,firms in southern Anhui should build integrated online-and-offline international platforms to strengthen links with overseas markets, and in particular should exploit the advantages of the current era by seizing trade opportunities with countries along the Belt and Road.

4.2. Limitations and Future Research

This study has two limitations.The data cover a relatively short period (2010–2023) only,and the data sources and the selection of indicators may be incomplete,which bears on the generalisability of the conclusions.In addition,the analysis of the underlying mechanism is insufficient:although the promoting effect of the digital economy on Anhui's foreign trade is verified,the internal mechanism has not been explored in depth,and the specific paths through which digital technology affects the high-quality development of foreign trade have not been fully dissected.

Future research could broaden the data sample by incorporating more years and richer indicators,and benchmark the results against international data to strengthen their reliability.The moderating role of external environmental variables in the relationship between the digital economy and foreign trade could also be examined, and case studies combining qualitative and quantitative methods could be used to trace the paths through which the digital economy shapes the high-quality development of foreign trade. Finally, more operational and differentiated policy measures could be designed on the basis of regional heterogeneity and the stage of digital economy development, with policy outcomes tracked and adjusted dynamically,so as to provide a more precise basis for decision making on the coordinated development of the digital economy and foreign trade in Anhui Province.

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