Digital Economy's Contribution to Sustainable Trade in Services: Empirical Evidence from China

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Abstract: The digital economy has injected new momentum into the sustainable development of trade in services. Based on China's provincial panel data from 2011 to 2022, this study empirically examines the impact of the digital economy on trade in services. The study finds that the digital economy has a significant impact on the development of trade in services, a finding that remains robust after addressing endogeneity and conducting robustness tests. Mechanism analysis reveals that the digital economy facilitates trade in services through two primary channels: promoting industrial structure upgrading and fostering new quality productive forces. Heterogeneity analysis indicates that the positive effect is more pronounced in eastern coastal regions and economically developed areas. Further research reveals that the impact of the digital economy on trade in services follows a nonlinear pattern, with its effect closely related to the threshold range of new quality productive forces. To promote the sustainable development of trade in services, policymakers should strengthen digital infrastructure to consolidate the foundation of the digital economy, accelerate industrial transformation to cultivate new competitive advantages, prioritize the development of new quality productive forces as an innovation engine, and implement regionally differentiated strategies to promote coordinated growth.

Keywords: Digital Economy; Empirical Evidence from China

0. Introduction

The digital economy has become a core driver of global economic development. The rapid advancement of cutting-edge digital technologies such as the Internet of Things, cloud computing, and artificial intelligence is profoundly reshaping the global economic landscape. In this process, the widespread application of digital technologies across industries and their deep integration with traditional sectors are leading unprecedented transformations. Trade, as a key engine of economic growth, is of undeniable significance. With the rise of the digital economy, China's trade structure is undergoing a profound transformation. Against the backdrop of the booming global digital economy, trade in services, as a vital component of international trade, is at a critical stage of digital transformation. According to data from the United Nations Conference on Trade and Development (UNCTAD), global trade in services grew by 7% in 2024, accounting for approximately half of the total global trade growth, highlighting its increasingly prominent role in global trade. Consequently, China is actively promoting the development of trade in services. The "14th Five-Year Plan for High-Quality Development of Foreign Trade" explicitly proposes deepening the integration of digital technologies with trade in services, upgrading traditional service trade toward higher-quality development, and exploring diversified models of digital trade.

As the world's second-largest economy, China leverages its significant advantages in the digital economy and the vigorous growth of new quality productive forces to inject fresh momentum into the sustainable development of trade in services. Taking China as a representative developing economy, this study conducts an empirical analysis of data from 30 Chinese provinces to explore the relationship between the digital economy and the sustainable development of trade in services. It delves into the underlying mechanisms between the two, aiming to provide theoretical support for China's sustainable trade in services while offering valuable insights for other developing countries in formulating policies to facilitate their own service trade transformation.

1. Literature review

The development of the digital economy is reshaping the landscape of international trade. Current academic research on the digital economy and trade has yielded substantial findings, primarily focusing on the following two aspects.

First, academic research on the relationship between the digital economy and trade has yielded rich and multidimensional insights. Primarily, the development of the digital economy is driving paradigm innovation in global trade. By optimizing resource allocation and enhancing trade efficiency, it has significantly strengthened the competitiveness of export-oriented enterprises while fostering high-quality growth in international trade [1]. More specifically, the advancement of the digital economy has significantly enhanced agricultural trade efficiency. It has not only exerted a positive and substantial impact on a nation's export performance but has also demonstrated remarkable spatial spillover effects [2][3]. Furthermore, the digital economy has exerted multidimensional impacts on trade in developing regions, particularly in Africa, where the improvement of digital infrastructure plays a pivotal role in facilitating trade development [4]. Consequently, developing nations must prioritize substantial investments in digital infrastructure development to foster the growth of their digital economies [5]. Simultaneously, the digital economy has catalyzed green transformation in trade [6,7]. Empirical studies reveal that digital economic development has not only significantly reduced China's adjusted carbon emissions and enhanced the competitiveness of low-carbon manufacturing trade [8][9], but also optimized industrial structures while diminishing regional trade dependency [10]. A study examining the relationship between the digital economy and carbon emissions in G7 countries revealed that, within the context of trade liberalization, digital economic development has facilitated cross-border energy trade, effectively reduced per capita carbon emissions, and thereby contributed to sustainable development [11]. Globally, the digital economy has also exerted profound impacts on trade in services. It has enhanced the competitiveness of service exports and increased service trade volumes [12]. Notably, in high-income countries, the advancement of digitalization demonstrates more pronounced positive effects on service trade [13], thereby further accelerating the growth of global services trade [14].

Academic research on promoting the development of trade in services has primarily focused on the following dimensions: First, trade agreements exert significant influence on services trade. Deep trade agreements effectively reduce trade costs by eliminating barriers and optimizing terms [15] [16]. Particularly, provisions governing data flows play a pivotal role in facilitating the development of services trade [17]. Secondly, economic freedom exerts a profound impact on international services trade. Enhanced economic freedom typically correlates with bilateral services trade growth [18], as enterprises demonstrate greater propensity to export services to destinations with fewer restrictions [19]. However, the constraining effects of services trade barriers prove relatively weaker for large-scale enterprises, suggesting that firm size plays a critical moderating role in overcoming international trade obstacles. Furthermore, firm heterogeneity demonstrates significant correlations with the development of international services trade. Empirical studies reveal that enterprises engaged in services trade typically exhibit higher production efficiency compared to their merchandise trade counterparts [20]. Meanwhile, religious factors have been empirically identified as exerting significant influence on international services trade, underscoring the crucial role of cultural and social contexts in shaping global trade patterns [21]. An analysis of services trade in the Common Market for Eastern and Southern Africa found that national GDP, trade distance, and time differences all significantly affect services trade. Advances in digital information technology are expected to drive further growth in services trade [22]. A study on services trade in the Association of Southeast Asian Nations region found that restrictions on services trade create obstacles for participating in global value chains, negatively impacting member countries. This makes reducing services trade restrictions particularly necessary to strengthen the region's competitiveness in the global economy [23].

Based on the analysis of the existing literature, we note that there is a considerable amount of research on the digital economy and its impact on trade, however, academic explorations focusing on the specific mechanisms of the digital economy's effect on trade in services are relatively scarce and lack in-depth analysis. Given that China is both the world's largest digital economy and is vigorously promoting the development of the country's trade in services, this study takes China as an example and aims to explore in depth the intrinsic links between the digital economy and trade in services. Based on data information from 30 provinces in China between 2011 and 2022, this paper attempts to shed light on how the development of the digital economy in each province has an impact on regional trade in services. Through this study, it not only enriches the current research on digital economy and trade in services, but also has a practical guiding significance in promoting the development of trade in services, and provides theoretical significance and practical guidance for understanding the change and development of trade in services in the context of the development of digital economy.

2. Analysis of the mechanism of the digital economy to promote the development of trade in services

2.1. The direct impact of the digital economy on the development of trade in services

According to the Global Digital Economy White Paper 2024 released by the China Academy of Information and Communications Technology in July 2024, China's digital industry revenue reached 31.7 trillion yuan in 2024, marking a year-on-year growth of 5.4%. As the world's second-largest economy, China holds a pivotal position in global trade in services. Simultaneously, the digital economy has emerged as a key focus across sectors and a research hotspot in international economics and trade. Specifically, digital technologies significantly reduce information costs in trade, boost trade growth, and enhance supply chain management [24], thereby improving access to services trade information. Second, the digital economy, driven by modern information technologies, facilitates knowledge spillovers, as well as the clustering of technology and talent within a country. By elevating informatization levels, it attracts high-tech industries and digital service agglomerations while providing support for diverse sectors. Third, analyses using the International Market Share (IMS) index, Revealed Comparative Advantage (RCA) index, and Trade Competitiveness (TC) index indicate that the digital economy gradually enhances China's international competitiveness in trade in services, improves quality [25], restructures industrial frameworks, and steers industries toward higher-value transformation. Fourth, amid profound shifts in the global economic structure, economic models are transitioning from traditional manufacturing to a service-oriented paradigm, revolutionizing conventional trade practices. Scholars widely agree that the digital economy has spurred the rapid rise of digital trade, driven the digital transformation of traditional industries and reshaped global trade dynamics. Through technological innovation and information automation, the digital economy further boosts productivity in the services sector.

Based on the aforementioned research analysis, scholars posit that the digital economy can facilitate the development of trade in services through four key dimensions: technological advancement, information infrastructure, enhancement of international competitiveness, and promotion of industrial transformation. These findings establish a foundational framework for studying the digital economy's role in advancing services trade. Consequently, investigating the pathways through which digital economic development influences services trade growth carries significant theoretical and practical implications. Building upon this research foundation, this study proposes the following hypothesis:

2.2. The mediating effect of industrial structure upgrading in the relationship between the digital economy and trade in services development

Industrial structure upgrading refers to the transformation process from low-value-added, labor-

intensive industries to high-value-added, technology-intensive, and knowledge-intensive industries. This transition is typically measured using the ratio of tertiary to secondary industry output as a proxy for industrial advancement, reflecting the economic impact of structural transformation [26]. Such upgrading not only enhances overall industrial competitiveness but also establishes a higher-quality industrial foundation for the development of trade in services.

The rapid development of the digital economy and its integration with the real economy play a pivotal role in enhancing corporate digital capabilities. Digital technologies significantly boost production efficiency, drive innovation, and optimize organizational structures, providing crucial technical support to overcome transformation challenges faced by traditional enterprises. By improving resource allocation efficiency and accelerating factor mobility, the digital economy facilitates both rationalization and advancement of industrial structures [27]. Moreover, it redefines inter-industry equilibrium, further promoting structural optimization. Industrial structure upgrading, as a key manifestation of this optimization, holds substantial practical significance for fostering services trade development. On one hand, industrial structure upgrading reflects technological progress that enables: (1) digital cross-border delivery of traditional services, (2) spatiotemporal constraint breakthroughs through digital platforms, and (3) emergence of new trade forms like data analytics and AI solutions. The rise of these high-value-added service sectors enhances productivity and creates superior industrial foundations for services trade by reallocating resources from traditional industries to more innovative, higher-value-added sectors. On the other hand, industrial structure upgrading improves cost efficiency within value chains, integrates global industrial resources, and expands green models like R&D outsourcing and remote collaboration, thereby deepening the embeddedness of services trade in global value chains. Essentially, industrial structure upgrading serves as a critical bridge that translates the digital economy's technological advantages into competitive advantages in services trade. Based on this mechanism, we propose the following hypothesis:

2.3. The mediating effect of new quality productive forces in the relationship between the digital economy and trade in services development

The digital economy directly drives the development of trade in services while also indirectly empowering it through the creation of new quality productive forces. As an emerging economic form, the digital economy enhances productivity via technological innovation and digital infrastructure, accelerating the transformation from traditional production factors to advanced ones and promoting the development of higher-level productive forces. Following Marxist principles, digitalization reshapes the three core components of the labor process, namely workers, tools, and subjects, leading to systematic reorganization of traditional productivity elements. First, new quality productive forces upgrade workers' digital capabilities, enabling service trade professionals to develop new service competencies with an emphasis on cultivating interdisciplinary digital talent. Second, intelligent upgrades to tools expand their applications and strengthen the international competitiveness of services trade. Third, this development greatly diversifies the types and forms of labor subjects. Big data analytics helps businesses better understand customer needs, implement targeted marketing, provide personalized services, and innovate service models, offering technical support for cross-border delivery [28]. By enhancing new quality productive forces, the digital economy significantly improves service efficiency and quality in digital platforms, cross-border outsourcing, and e-commerce, thereby advancing the digital transformation and global expansion of trade in services. This creates a positive transmission mechanism from the digital economy to new quality productive forces to trade in services. Based on this analysis, we propose the following hypothesis:

2.4. Threshold effects of the digital economy on trade in services development

The development of new quality productive forces constitutes a gradual yet nonlinear dynamic process. Its evolutionary trajectory demonstrates distinctive phased transition characteristics—

neither instantaneous linear leaps nor uniformly distributed progression.

During the initial phase, the productivity system requires sustained absorption of high-quality human capital, cutting-edge R&D investments, and iterative infrastructure upgrades. These elements typically undergo extended accumulation periods where marginal output effects of innovation factors remain latent. While digitalization and intelligentization begin emerging in services trade, the overall upgrading momentum remains in quantitative accumulation.

Upon transitioning to the advanced phase, general-purpose technologies (e.g., big data, AI) deeply penetrate all service trade segments. This not only restructures traditional service delivery models but also spawns new formats like cross-border data services and cloud platform solutions. Trade in services exhibits pronounced nonlinear acceleration during this stage, where technology spillover effects trigger industrial chain synergies, and combined economies of scale and scope drive nonlinear value creation growth. Crucially, qualitative breakthroughs in productivity's enabling effects on services trade only occur when institutional environments, market ecosystems, and technological innovation achieve resonance. This threshold effect necessitates that policymakers to accurately identify phase-specific bottlenecks and implement differentiated factor allocation strategies. Based on this framework, we propose:

3. Model setting and variable description

3.1. Variable description

3.1.1 Explained variables

The explained variable of this study is trade in services (TS). Concerning related studies [26][30], the total import and export volume of trade in services published in the China Commerce Yearbook is selected as the indicator to measure the development level of China's trade in services. For missing data portions, the linear interpolation method is adopted for supplementation to enhance data completeness and consistency.

3.1.2 Core explanatory variables

This study employs the development level of the digital economy (DE) as the core explanatory variable. Drawing on existing literature [31][32][33], we construct a comprehensive indicator system spanning three key dimensions: digital users, digital industries, and digital transactions. The digital users dimension measures the infrastructure development of the digital economy across provinces, incorporating four specific indicators: fiber-optic cable density, number of internet access ports, mobile telephone exchange capacity, and internet penetration rate. The digital industries dimension focuses on the advancement of information technology and telecommunications, assessed through three sub-indicators: the proportion of urban employment in information transmission, software, and IT services; mobile phone penetration rate; and total telecommunications business volume. Lastly, the digital transactions dimension evaluates the application of digital technologies in market transactions, encompassing four metrics: e-commerce procurement value, coverage breadth of digital finance, usage depth of digital finance, and the digitalization level of financial services.

Table 1. Digital economy indicator system.

Level 1 indicators	Secondary indicators	Tertiary indicators	Indicators nature
Digital economy	Digital users	Fiber–optic cable density (kilometer/ ten thousand people)	+
		Number of internet access ports (ten thousand units)	+
		Mobile telephone exchange capacity (ten thousand subscriber units)	+
		Internet penetration rate	+
	Digital industries	The proportion of urban employment in information transmission, software, and IT services (%)	+
		Mobile phone penetration rate (units per people)	+
		Total telecommunications business volume (hundred million yuan)	+
	Digital transactions	E–commerce procurement value (hundred million yuan)	+
		Coverage breadth of digital finance	+
		Usage depth of digital finance	+
		Digitalization level of financial services	+

3.1.3 Control variables

The development of China's trade in services is influenced by multiple factors, and therefore, this study controls for several relevant variables that may affect trade in services. Drawing on existing literature [1][30], key control variables include: economic development level (GDP), financial development level (Fdl), local fiscal expenditure ($Expenditure$), tertiary industry employment ($Employment$), and foreign capital inflow ($Investment$). Specifically, the economic development level may shape the scale, structure, and foundational conditions of trade, thereby impacting trade in services growth. Regional financial development can facilitate trade in services expansion by improving financing access and optimizing resource allocation. Local fiscal expenditure influences trade in services potential through infrastructure investment, business environment improvements, policy incentives, and government guidance. An increase in tertiary industry employment reflects labor force expansion in the service sector, providing essential human capital to support industry growth and market expansion. Meanwhile, foreign capital inflow enhances the overall competitiveness of trade in services by introducing capital, advanced technologies, and management expertise.

3.1.4. Mediating variables

Based on the previous theoretical analysis, this study selects industrial structure upgrading and the development level of new quality productive forces as mediating variables. For industrial structure upgrading, drawing on Luo's [34] research, it is measured by the ratio of the output value of the tertiary industry to that of the secondary industry. Regarding new quality productive forces, drawing on existing literature [35][36][37], this study constructs an indicator system from three dimensions: new quality laborers, new quality means of labor, and new quality objects of labor. The specific indicator selections are detailed in Table 2.

Table 2. New quality productive forces indicator system.

Level 1 indicators	Secondary indicators	Tertiary indicators	Indicators nature
New quality laborers	New−type human capital investment	Fiscal expenditure on science and technology (hundred million yuan)	+
		Local fiscal expenditure on education (hundred million yuan)	+
	New−type human capital output	Average years of schooling (years)	+
		Number of R&D personnel (full−time equivalent, person−years)	+
New quality means of labor	Tangible means of production	Number of internet domain names (ten thousand units)	+
		Patents per capita	+
	Intangible means of production	Technology market transaction value (ten thousand yuan)	+
New quality objects of labor	Green sustainability	Forest coverage rate (%)	+
		Investment in pollution treatment (ten thousand yuan)	+
	Pollutant emissions	Waste generation/GDP	−
		Wastewater discharge/GDP	−
		SO_2 emission in waste gas/GDP	−

3.2. Data sources

This study selects panel data from 30 provincial−level administrative units in China spanning 2011−2022 as the sample. This selection aims to comprehensively and thoroughly investigate the relevant economic phenomena while excluding regions constrained by data availability or special circumstances − specifically excluding Tibet, Hong Kong, Macau, and Taiwan of China. Regarding data sources: the key indicator of services trade volume comes from the China Commerce Yearbook; the digital financial inclusion index, usage depth index, and digitization level index are sourced from the research outcomes of the Institute of Digital Finance Peking University. The remaining data primarily originate from authoritative economic information platforms, including the China Statistical Yearbook, China Statistical Yearbook on Science and Technology, Wind Database, and CEIC Database. To address the limited missing values, present in the dataset, this study employs linear interpolation for data imputation. For data analysis tools, Stata 16.0 software was utilized for data processing and empirical analysis. The detailed indicators are presented in Table 3.

Table 3. Variable selection.

Variable Type	Variable Name	Measurement Method
Dependent Variable	Trade in services (TS)	Total import and export volume of trade in services (trillion USD)
Independent Variable	Digital economy (DE)	Composite index calculated from the digital economy indicator system
Control Variables	Economic development level (GDP)	Per capita regional GDP (ten thousand yuan)
	Financial development level (Fdl)	(Year-end deposit balance of financial institutions + loan balance of financial institutions)/regional GDP
	Local fiscal expenditure ($Expenditure$)	Local government general budget expenditure (hundred million yuan), log-transformed
	Tertiary industry employment ($Employment$)	Employment in tertiary sector (people), log-transformed
	Foreign capital inflow ($Investment$)	Actual utilized FDI (ten billion USD)
	Industrial structure upgrading ($Upgrade$)	Tertiary sector output value/secondary sector output value
Mediating Variables	New quality productive forces ($Nqpf$)	Composite index calculated from the new quality productive forces indicator system

3.3. Descriptive Statistical Analysis

Table 4 displays the descriptive statistical analysis results of key variables in this study. The trade in services variable shows a mean value of 0.0253 with a standard deviation of 0.0466, indicating moderate fluctuations in total services trade volume across provinces. For the digital economy indicator, the mean value of 0.1881 and standard deviation of 0.1031 suggest relatively balanced development levels among Chinese provinces, while the significant gap between maximum and minimum values reveals pronounced regional disparities. The dataset constitutes a balanced panel with complete observations for all variables (N=360).

Table 4. Summary statistics.

Variable	N	Mean	S.D.	Min	Max
TS	360	0.0253	0.0466	0.0000	0.2496
DE	360	0.1881	0.1031	0.0372	0.6788
GDP	360	5.8719	3.0661	1.6024	19.0313
Fdl	360	3.4321	1.0963	1.6776	7.6095
$Expenditure$	360	8.4352	0.5989	6.5595	9.8273
$Employment$	360	6.7265	0.7560	4.7095	8.2306
$Investment$	360	1.0132	2.0105	0.0003	18.4002

3.4. Model setting

3.4.1. Baseline regression model

Based on theoretical analysis, the following baseline regression model is employed to examine the impact of the digital economy on the development level of trade in services:

$$TS_{i,t} = \alpha_0 + \alpha_1 DE_{i,t} + \alpha_2 Controls_{i,t} + \sum id + \sum year + \varepsilon_{i,t} \quad (1)$$

In Equation (1), $TS_{i,t}$ represents the development level of trade in services for province i in year t ; $DE_{i,t}$ denotes the digital economy development level for province i in year t ; α_0 is the constant term; α_1 and α_2 are parameters to be estimated; $Controls_{i,t}$ stands for the control variables; id captures province fixed effects; $year$ accounts for time fixed effects; $\varepsilon_{i,t}$ is the random error term.

3.4.2. Mediation effects model

The traditional mediation effect model often fails to ensure the exogeneity of mediating variables in practice, potentially leading to endogeneity bias and reduced statistical test power. To address these limitations, this study adopts the mediation effect testing approach proposed by Jiang [38], constructing separate linear regression equations where the explanatory variable digital economy is regressed on industrial structure upgrading and new quality productive forces. In equation (2) and (3), $Upgrade_{i,t}$ denotes industrial structure upgrading for province i in year t ; $Nqpf_{i,t}$ denotes the new quality productive forces development level for province i in year t ; β_0 and λ_0 are constant term; β_1 , β_2 , λ_1 and λ_2 are parameters to be estimated.

$$Upgrade_{i,t} = \beta_0 + \beta_1 DE_{i,t} + \beta_2 Controls_{i,t} + \sum id + \sum year + \varepsilon_{i,t} \quad (2)$$

$$Nqpf_{i,t} = \lambda_0 + \lambda_1 DE_{i,t} + \lambda_2 Controls_{i,t} + \sum id + \sum year + \varepsilon_{i,t} \quad (3)$$

3.4.3. Threshold effect model

To thoroughly analyze the heterogeneous effects of the digital economy on trade in services across varying levels of new quality productive forces development, this study employs a threshold regression model for empirical testing, constructing the following single−threshold model:

$$TS_{i,t} = \gamma_0 + \gamma_1 DE_{i,t} \times I(Nqpf_{i,t} \leq \theta_1) + \gamma_2 DE_{i,t} \times I(Nqpf_{i,t} > \theta_1) + \quad (4)$$
$$\gamma_3 Controls_{i,t} + \sum id + \sum year + \varepsilon_{i,t}$$

In equation (4), γ_1 and γ_2 represent the impact coefficients of the digital economy on trade in services development when the threshold variable falls within different ranges; θ_1 denotes the estimated threshold value; $I(\cdot)$ is the indicator function that takes the value 1 if the condition in parentheses is satisfied, and 0 otherwise. All other variable symbols maintain the same definitions as in Equations (1) − (3).

4. Empirical results and analysis

4.1. Baseline regression results

Table 5 presents the results of the baseline regression using a two−way fixed effects model to examine how the digital economy affects trade in services. The findings consistently show that digital economy development significantly boosts services trade at the 1% significance level, with or without control variables. This robust effect stems from multiple channels: the thriving digital economy has effectively reduced trade barriers through technological innovations, enabling businesses to connect with global buyers more easily through digital platforms, facilitating faster information exchange and international market expansion, thereby increasing trade volumes. Simultaneously, digital advancements in finance have streamlined cross−border payments by cutting transaction costs and exchange rate risks, creating a more stable and efficient payment environment for global services trade. Furthermore, the rapid growth of the digital economy has given rise to new industries and service formats like digital finance, remote education, and

telemedicine, generating fresh growth opportunities for China's services trade sector.

Regarding the control variables, the level of local economic development demonstrates a statistically significant positive impact on trade in services, which aligns well with observed realities. Typically, regions with more advanced economies exhibit greater vibrancy in their services trade sectors. The expansion of China's services trade volume has been fundamentally underpinned by sustained economic growth. Consequently, fostering regional economic development constitutes a prerequisite for promoting services trade growth. Local fiscal expenditure also shows a markedly positive correlation with services trade performance. The advancement of trade inevitably requires governmental support, particularly in areas like infrastructure development that demand proactive investment and commitment from public authorities. Government fiscal allocations provide essential material foundations and policy backing for the flourishing of services trade, thereby creating favorable conditions for its continued expansion.

Table 5. Benchmark regression results.

Variable	(1)	(2)
	TS	*TS*
DE	0.1778***	0.1172***
	(0.0385)	(0.0409)
GDP		0.0030**
		(0.0013)
Fdl		0.0034
		(0.0026)
Expenditure		0.0191***
		(0.0071)
Employment		0.0043
		(0.0041)
Investment		0.0004
		(0.0009)
Control variables	NO	YES
Province FE	YES	YES
Year FE	YES	YES
Constant	0.0782***	−0.1476**
	(0.0112)	(0.0604)
Observation	360	360
	0.9705	0.9728

Note: ***, **, * denote 1%, 5%, and 10% significance levels, respectively. The standard errors are reported in parentheses.

4.2. Robustness tests

To verify the robustness of our findings, we conducted a series of robustness tests. First, considering the potential impact of the COVID-19 pandemic on global services trade in 2020, we restricted the sample period to 2011–2019 for re-estimation to isolate our results from this exogenous shock. Second, acknowledging the unique administrative status of China's four direct-controlled municipalities (Beijing, Shanghai, Tianjin, and Chongqing), we excluded these observations to prevent their disproportionate influence on the results. Third, we implemented a 1% winsorization treatment to mitigate potential distortions from outliers before re-running the regressions. As demonstrated in Table 6, all robustness checks yield results consistent with our baseline estimates, confirming the reliability of our conclusions.

Table 6. Robustness tests.

Variable	2011-2019	Excluding the direct-controlled municipalities	Winsorize
	(1)	(2)	(3)
	TS	*TS*	*TS*
DE	0.1455***	0.0982**	0.1103***
	(0.0477)	(0.0429)	(0.0307)
Control variable	YES	YES	YES
Province FE	YES	YES	YES
Year FE	YES	YES	YES
Constant	−0.1051	−0.1811**	−0.1068*
	(0.0806)	(0.0734)	(0.0568)
Observation	270	312	360
R^2	0.9812	0.9541	0.9763

Note: ***, **, * denote 1%, 5%, and 10% significance levels, respectively. The standard errors are reported in parentheses.

4.3. Endogeneity tests

Due to limitations in data availability and the authors' comprehension, it was challenging to incorporate all potential factors influencing the development level of trade in services into the model variables. Consequently, this study may be subject to omitted variable bias. To mitigate this concern, we adopted the approach proposed by Lei [39] by applying a one-period lag to all explanatory variables except the digital economy, followed by re-estimation. As presented in Table 7, the regression results demonstrate that the digital economy continues to exert a statistically significant positive effect on the advancement of trade in services even after addressing endogeneity concerns. This finding further corroborates the robustness and reliability of previous conclusions.

Table 7. Endogeneity test results.

Variable	(1)
	TS
DE	0.1305***
	(0.0483)
L.GDP	0.0017
	(0.0016)
L.Fdl	0.0048
	(0.0030)
L.Expenditure	0.0229***
	(0.0081)
L.Employment	0.0044
	(0.0045)
L.Investment	−0.0011
	(0.0010)
Control variables	YES
Province FE	YES
Year FE	YES
Constant	−0.1736**
	(0.0702)

Observation	330
R^2	0.9757

Note: ***, **, * denote 1%, 5%, and 10% significance levels, respectively. The standard errors are reported in parentheses.

4.4. Mediation effects

To investigate the mechanisms through which the digital economy influences trade in services, this study selects industrial structure upgrading and new quality productive forces as mediating variables based on the theoretical framework, with regression results presented in Table 8. The findings reveal that the digital economy significantly promotes industrial structure upgrading, likely because widespread adoption of digital technologies accelerates the transformation of traditional service sectors and facilitates the shift toward higher value−added activities, thereby indirectly expanding services trade. Furthermore, the digital economy demonstrates a statistically significant positive effect on China's new quality productive forces. Through technologies such as artificial intelligence, big data, and blockchain, digitalization enhances total factor productivity across industries, elevating overall societal productivity and providing robust support for services trade growth. Consequently, policymakers should intensify efforts to digitally empower traditional service industries, reallocate resources toward technology−intensive services, and expedite industrial structure upgrading. Simultaneously, increased fiscal investment in new quality productive forces development is essential to sustain innovation−driven expansion of trade in services.

Table 8. Results of mediation effect tests.

Variable	(1)	(2)
	Upgrade	*Nqpf*
DE	0.7063**	0.2552***
	(0.3585)	(0.0568)
Control variable	YES	YES
Province FE	YES	YES
Year FE	YES	YES
Constant	2.3618**	−0.2515*
	(0.9335)	(0.1295)
Observation	360	360
R^2	0.9716	0.9753

Note: ***, **, * denote 1%, 5%, and 10% significance levels, respectively. The standard errors are reported in parentheses.

4.5. Heterogeneity analysis

Given the pronounced heterogeneity across regions, conducting a heterogeneity analysis holds significant importance. This study first divides China into eastern, central, and western regions for comparative analysis. The empirical results demonstrate that while the digital economy has a positive impact on trade in services nationwide, the degree of influence varies substantially across regions. The regression coefficient for eastern China is significantly higher than those for central and western regions, likely attributable to the eastern region's more advanced economy and mature industrial structure, which enables stronger digital economy−driven trade facilitation. Furthermore, drawing on existing literature [40], we categorize China's 30 provinces into economically developed and less−developed regions. As expected, the regression coefficients show markedly greater digital economy effects in developed regions, reflecting their superior infrastructure, technological innovation capabilities, and policy environments that collectively

enhance digital trade synergies. These findings suggest that to promote the balanced regional development of China's trade in services, policymakers should strengthen digital economy support policies for central, western, and less-developed regions while leveraging the demonstration effects of eastern and developed regions to drive coordinated growth across all territories.

Table 9. Results of heterogeneity analysis.

Variable	Eastern China	Central China	Western China	Developed regions	Less developed regions
	(1)	(2)	(3)	(4)	(5)
	TS	TS	TS	TS	TS
DE	0.1379**	0.0263***	0.0487***	0.1520**	0.0396***
	(0.0544)	(0.0086)	(0.0110)	(0.0631)	(0.0075)
Control variable	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Constant	−0.2872***	−0.0582**	−0.0175	−0.4878***	0.0072
	(0.0923)	(0.0250)	(0.0303)	(0.1637)	(0.0179)
Observation	156	72	132	96	264
R^2	0.9717	0.9321	0.8382	0.9687	0.8550

Note: ***, **, * denote 1%, 5%, and 10% significance levels, respectively. The standard errors are reported in parentheses.

4.6. Further analysis

To investigate the nonlinear relationship between the digital economy and trade in services, this study employs new quality productive forces as the threshold variable and conducts bootstrap testing to verify the existence of threshold effects. As shown in Table 10, the test results demonstrate statistically significant evidence for a single threshold effect, while double and triple threshold effects fail to achieve statistical significance. These findings conclusively establish the presence of a single-threshold effect of the digital economy on trade in services with new quality productive forces serving as the threshold variable.

Table 10. Threshold effect test.

Number of thresholds	F value	P value	10% critical value	5% critical value	1% critical value
Single threshold	58.76	0.0000	19.7584	25.6997	32.5529
Double threshold	17.77	0.1000	17.5396	22.0183	32.5589
Triple threshold	8.68	0.6467	28.1328	36.5739	66.5521

Table 11 presents the threshold regression results using new quality productive forces as the threshold variable. The findings reveal a significant threshold effect at the estimated value of 0.5027. When new quality productive forces levels are below this threshold, the digital economy shows a negative impact on trade in services. However, when new quality productive forces exceed 0.5027, the digital economy demonstrates a significantly positive effect on services trade growth. This nonlinear relationship can be attributed to two key factors. In regions with lower new quality productive forces development levels, inadequate digital infrastructure and shortages of skilled technical personnel may hinder the effective transformation of digital advantages into trade growth momentum. Conversely, in higher new quality productive forces development level regions, the combination of stronger innovation capacity, more complete industrial chains, and advanced technological ecosystems enables digital technologies to significantly reduce transaction costs

and expand market reach. Moreover, regions with higher levels of new quality productive forces development typically benefit from more open economic policies and robust legal environments, which provide institutional safeguards for digital economy applications and further propel services trade development.

Table 11. Threshold model parameter estimates.

	Coefficient
$Nqpf \leq 0.5027$	−0.0026
	(0.0216)
$Nqpf > 0.5027$	0.0534*
	(0.0275)

Note: ***, **, * denote 1%, 5%, and 10% significance levels, respectively. The standard errors are reported in parentheses.

5. Conclusion and policy recommendations

Based on panel data covering 30 provinces in China from 2011 to 2022, this study thoroughly examines the impact of the digital economy on trade in services and draws the following conclusions. Firstly, the development of the digital economy has a positive effect on trade in services, a finding that remains robust after a series of robustness tests and consideration of endogeneity issues. Secondly, industrial structure upgrading and new quality productive forces play significant mediating roles in the process through which the digital economy promotes the growth of trade in services. Thirdly, the impact of the digital economy on trade in services exhibits notable heterogeneity, with its positive effect being more pronounced in eastern coastal regions and economically more developed areas. Finally, the threshold effect model tests, using new quality productive forces as the threshold variable, reveal that the promoting effect of the digital economy on trade in services demonstrates a nonlinear relationship.

Based on the aforementioned research findings, this study proposes the following targeted policy recommendations. First, it is essential to strengthen the foundational support system of the digital economy to ensure the sustained and healthy development of trade in services. The government should increase investment in digital economy infrastructure to comprehensively enhance its development at the national level. Specifically, priority should be given to deploying 5G networks in the economically advanced eastern regions of China while accelerating efforts to bridge gaps in digital infrastructure in the central and western regions, thereby narrowing development disparities and preventing the emergence of a "digital divide". Additionally, policies and regulations should be refined to incentivize service trade–related enterprises to actively adopt digital technologies, enhancing their international competitiveness and fostering sustainable growth in China's trade in services.

Second, accelerating industrial restructuring and upgrading will help increase service trade exports. Promoting the digital, intelligent, and green transformation of traditional industries will strengthen their global competitiveness while providing high–quality products and services to support trade in services. Furthermore, vigorous support should be given to emerging industries, particularly those closely linked to the digital economy, such as IT services, education services, and financial services, injecting new momentum into the sustainable development of trade in services.

Lastly, cultivating and applying new quality productive forces is crucial for fostering coordinated regional development in trade in services. By advancing new quality productive forces, a

conducive economic environment for service trade growth can be established. At the same time, efforts should be intensified to cultivate high-caliber talent, improving workers' professional skills to supply the digital economy and service trade sectors with high-quality human resources. Tailored strategies should be formulated based on the characteristics of different regions and industries, leveraging the leading role of the eastern and more developed regions while accelerating development in the central, western, and less-developed areas to achieve balanced nationwide progress in trade in services.

To ensure the effective implementation of these strategies, institutional and policy innovations must serve as key enablers. Relevant national departments should provide critical support and actively participate in shaping global digital trade rules, thereby facilitating China's transition from scale expansion to quality enhancement in trade in services and achieving leapfrog sustainable development.

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