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Digital Economy and the Upgrading of the Global Value Chain of China's Service Industry

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Abstract: China's service trade competitiveness is weak, and the service industry occupies a low position in the GVC (Global Value Chain); therefore, promoting the upgrade of the GVC of China's service industry is worth studying. Under the new situation of the continuous integration of the digital economy and the real economy, the digital economy has injected new momentum into the mid-to-high end of the GVC of China's service industry. Based on the panel data of the service industry sub-sectors, the mediating effect model is constructed, and the system GMM (Generalized Method of Moments) is used to empirically determine whether the digital economy can significantly improve the participation and position of China's service industry in the GVC, and promote the upgrading of the GVC of China's service industry. This conclusion still holds after replacing the independent variable measurement indicator, adding control variables, considering changes in industry trends, and using quantile regression and other robustness tests. The promotion effect of the digital economy on the upgrading of the GVC of China's service industry shows heterogeneity in different service objects and service industries with different factor intensities, indicating that the digital economy will affect the internal structure of the upgrading of the GVC of China's service industry. The results of the mediation test found that the service trade cost, multilateral resistance to service trade, service industry structure, financial development level, human capital and service export complexity are the mechanisms for the digital economy to enable the upgrading of the GVC of China's service industry. This study improves the analysis of the impact factors of the GVC in the service industry, enriches the theory of the GVC, and improves the research content of digital economy theory. This study also provides a reference for other developing countries similar to China on how to promote the upgrading of the GVC of the service industry in the process of digital economy development.



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Keywords: digital economy; service industry; GVC; participation; position

1. Introduction

With the accelerated development of global digitization and informatization, the digital economy represented by new-generation technologies such as mobile Internet, cloud computing, big data, the Internet of Things, blockchain, artificial intelligence, virtual reality, and augmented reality has increasingly become a new engine for high-quality economic development. In 2021, the scale of China's digital economy reached USD 7.1 trillion, accounting for 39.8% of the GDP, with a growth rate of 9.7% (data source: China Digital Economy Development Report) and continuing to maintain a high growth rate. With the rapid development of the digital economy, digital trade with data as the production factor, digital services as the core, and digital delivery as the feature is booming. In 2020, the scale of China's digitally deliverable service trade reached USD 294.76 billion, accounting for 44.5% of the total service trade, with a growth of 8.3% against the trend during the new crown pneumonia epidemic (data source: China Digital Economy Development Report). The digital economy has become a new driving force for the high-quality development of

China's service trade, which is of great strategic significance for building a new pattern of domestic and international dual circulation and mutual promotion. The outline of the "14th Five-Year Plan" and the long-range objectives through the year 2035 clearly state that it is necessary to accelerate digital development, promote the deep integration of the digital economy and the real economy, and accelerate the digitalization of the service industry. The "14th Five-Year Plan" for the digital economy development further requires that the digitalization of trade be accelerated and intensify the opening-up of the service industry. However, at present, China still has problems such as insufficient digital infrastructure construction, insufficient digital industrial foundation and technical support, low digital economy penetration rate, lagging behind in related system construction, and an incomplete digital economic ecosystem. China's service trade still shows a deficit, services export competitiveness is weak, and the service industry occupies a low position in the GVC. On the occasion of the rapid development of the digital economy and the high-quality development of service trade, this paper discusses the impact mechanism of the digital economy on the upgrading of the GVC of the service industry and clarifies the actual impact of the digital economy on the GVC of the Chinese service industry from the perspective of trade added value. It will not only help to deeply understand the service export effect of the digital economy but also provide a reference for solving the above problems and formulating concrete measures to promote the integration of the digital economy and the high-quality development of service exports.

2. Literature Review

The digital economy is the focus of research in the field of economic and social development. Research on the digital economy can be traced back to the 1990s. Since 2015, with the intensive introduction of policies and announcements by major countries in the world, the digital economy has been regarded as a strategy to strengthen the country, and the research interest in the digital economy has continued to rise in academic circles. At present, relevant literature mainly focuses on digital economy measurement and its driving factors: digital economy and innovation, economic growth, real economy integration, employment, digital divide, green development, manufacturing transformation, industrial chain, industrial structure upgrading, trade development, income distribution, consumption, etc. [1–3].

Closely related to this paper is the research on digital economy and manufacturing export, digital economy and service trade, and digital service export. The former mainly discusses the impact of the digital economy on the quality of manufacturing exports, the technical complexity of exports, and the upgrading of GVC. The results mostly found that the digital economy can promote the quality of China's manufacturing export products, the technical complexity of exports, and the upgrading of GVC; however, there is regional and industry heterogeneity [4–8]. The latter believes that the digital economy has improved the efficiency of the service industry, improved the tradability of services, and enabled service trade to accelerate the improvement of its international competitiveness [9–12]. Jiang, Chen, and Cui used the panel threshold model to empirically determine that the digital economy of trading partners promotes China's service exports, but the promotion effect weakens significantly when the cultural distance crosses the threshold [13]. Some scholars have found that in the era of digital trade, trade entities, trade mode, delivery mode, trade objects, and trade supervision policies will face all-round changes [14–17], and the scale of the service industry, RTA digital trade rules, market opening, data flow, data restriction policies, digital service trade restrictions, digital infrastructure, trust and risk management, etc. will all affect the export of digital services [18–23].

In summary, domestic and foreign literature provide rich and profound insights for an in-depth understanding of the impact of the digital economy on economic, social, and environmental development, laying a solid foundation for this research. These results either provide value for this research, provide a theoretical reference, or form a logical starting point, which is undoubtedly important and necessary. However, in terms of research content, there is little direct discussion on the impact of the digital economy on

the GVC of China's service industry. The upgrading of the GVC of the service industry is the key and focus of the implementation of high-level opening up of service trade and plays an important role in smoothing the dual circulation and building a new development pattern. The digital economy is an important way to promote the upgrading of the GVC of the service industry. Therefore, this paper analyzes the mechanism by which the digital economy promotes the upgrading of the GVC of the service industry. At the same time, in view of the background of the GVC, the traditional export volume cannot truly reflect the real gains of service trade. It is planned to pay attention to the actual impact of the digital economy on the upgrading of the GVC of China's service industry from the perspective of trade added value and provide policy suggestions.

3. Theoretical Analysis and Research Hypothesis

According to the existing literature on the impact of the digital economy and the impact of the digital economy on the upgrading of the GVC of the manufacturing industry, it can be seen that the digital economy mainly affects the upgrading of the GVC of a country's industries through mediator mechanisms such as trade costs, multilateral resistance, industrial structure, financial development, human capital, and export complexity.

(1) The digital economy is conducive to reducing service trade costs and accelerating the service industry's move to the mid-to-high end of the GVC. The digital economy reduces trade costs (information costs, transaction costs, search costs, communication costs, management costs, etc.) through economies of scope, economies of scale, and long tail effects, as well as eliminating information asymmetry [24–26], shortening the distance of service exports, improving the tradability of the service industry, helping to prolong the survival duration of service exports, enhancing the added value of service exports, and boosting the upgrading of GVC of the service industry.

(2) The digital economy will help to reduce multilateral resistance to service trade and expand the GVC of the service industry. The digital economy is conducive to reducing service trade barriers and trade frictions, effectively reducing multilateral resistance to service trade, lowering service trade access thresholds, broadening export market access, increasing service export market penetration, promoting the marginal growth of service exports, and promoting the continuous upgrading of the GVC of the service industry [27–30].

(3) The digital economy promotes the structural adjustment of the service industry, which is conducive to the optimization of the service export structure and accelerates the upgrading of the GVC of the service industry. In the era of the digital economy, the transformation of industrial digitalization has enhanced the application of digital technology in traditional service industries, which has accelerated the digitalization of traditional service industries. Digital industrialization breeds new business forms of the service industry, gives birth to new service models, and generates new service methods, bringing about the vigorous development of emerging service industries, promoting the structural upgrading of the service industry, promoting the advanced structure of service exports, increasing the complexity of service exports, and accelerating the service industry to move towards the mid-to-high end of the GVC [31–34].

(4) The digital economy is conducive to financial development and empowers the upgrading of the GVC of the service industry. The digital economy has promoted changes in financing modes, improved financing capabilities, and broadened financing channels, which can benefit those service export industries that have been excluded from traditional finance and traditional credit reporting, and help alleviate the difficulty and expensive financing of service export industries [35,36], while contributing to the innovation of financial technology products and services [37,38], implementing precise financial services, preventing and controlling financial risks, promoting the financial development level, and empowering the upgrading of the GVC of the service industry. In addition, as a new economic form leading the future, the digital economy is essentially the creation and sharing of data and information, which is conducive to promoting the development of

digital finance, improving the availability and inclusiveness of finance, and promoting the upgrading of the GVC of the service industry.

(5) The digital economy is conducive to improving the human capital level and helping to upgrade the GVC of the service industry. The digital economy will promote the continuous improvement of the training and education level of personnel in the service industry, and human capital plays a key role in the R&D of the service industry. Human capital can significantly promote the development of modern service industries and knowledge-intensive service industries, optimize the structure of service exports, and improve the technical content of service exports. At the same time, human capital can improve the quality and efficiency of service exports and promote the upgrading of the GVC of the service industry [39–41].

(6) The digital economy can help increase the complexity of service exports and promote the upgrading of the GVC of the service industry. The digital economy increases the intensity of R&D investment, optimizes the allocation of resources, promotes technological innovation [42–44], empowers the digital transformation and upgrading of the service industry, improves the productivity of the service industry, increases the complexity of service exports, and promotes the upgrading of the GVC of the service industry.

To sum up, the following hypothesis is proposed: the digital economy helps to upgrade the GVC of the service industry, which mainly promotes the upgrading of the GVC of the service industry by reducing service trade cost, reducing multilateral resistance to service trade, promoting the upgrading of service industry structure, helping financial development, improving the human capital level, and improving the service export complexity.

4. Model Construction, Variable Measurement and Data Description

4.1. Model Construction

In order to test the specific impact of the digital economy on the GVC of China's service industry, based on the existing literature on the impact factors of the GVC and the mediating variables (*MED*) [45–48], the following mediating effect model is constructed, in which Equation (1) is used to test the impact of the independent variable digital economy (*DIG*) on the dependent variable service GVC (*SGVC*); Equation (2) is used to test the impact of the independent variable digital economy on the mediating variables (*MED*), which include service trade cost (*SC*), multilateral resistance to service trade (*SR*), service industry structure (*SI*), financial development level (*IF*), human capital (*HC*), service export complexity (*SE*), service trade cost, multilateral resistance to service trade, service industry structure, and service export complexity are the mediating variables at the industry level, and financial development level and human capital are the mediating variables at the macro level; Equation (3) is used to test the impact of independent variable digital economy and mediating variables on the dependent variable service GVC.

$$\ln SGVC_{it} = \alpha_0 + \alpha_1 \ln SGVC_{it-1} + \alpha_2 \ln DIG_{it} + \alpha_3 CON_{it} + \varphi_i + \lambda_t + \varepsilon_{it}, \quad (1)$$

$$\ln MED_{it} = \beta_0 + \beta_1 \ln MED_{it-1} + \beta_2 \ln DIG_{it} + \beta_3 CON_{it} + \varphi_i + \lambda_t + \varepsilon_{it}, \quad (2)$$

$$\ln SGVC_{it} = \eta_0 + \eta_1 \ln SGVC_{it-1} + \eta_2 \ln DIG_{it} + \eta_3 \ln MED_{it} + \eta_4 CON_{it} + \varphi_i + \lambda_t + \varepsilon_{it}, \quad (3)$$

where i , t , φ , and λ represent the service industry sub-sector i , year t , industry fixed effect, and time fixed effect, respectively. *CON* is the control variable, including industry scale (*Sca*), industry foreign direct investment (*Ifd*), industry labor productivity (*Lab*), and industry factor endowment (*Fac*). Since there are many factors that affect the GVC and mediating variables of the service industry, the lagged terms of the dependent variables are added to the above models. To address the potential endogeneity bias, the system GMM method is used to estimate the models. According to the research of Arellano and Bond, Arellano and Bover, and Blundell and Bond [49–51], the GMM method can be divided into the differential GMM method and the system GMM method. The estimator of the system GMM method further uses the moment condition of the level equation on the basis of the estimator of the differential GMM method and takes the first-order difference of the

lagged variable as the instrumental variable for the corresponding level variable in the level equation [52]. Therefore, the system GMM method is used in this study to estimate the model.

4.2. Variable Measurement and Data Description

4.2.1. Dependent Variable

A multi-regional input–output model is constructed using the trade value-added method (KPWW) to decompose the total export value of China’s services and obtain the domestic value added IV of China’s service exports and the foreign value added FV contained in the service exports. Drawing on the indicators constructed by Koopman, Wang, and Wei to measure the participation and position in the GVC of a country (sector) [53], refer to the research of Zhang and Dai, Huang et al. and Zhang to calculate the participation degree in the GVC ($SGVCpar$) and position in the GVC ($SGVCpos$) of China’s service industry sub-sector i [54–56], as follows:

$$SGVCpar_{it} = IV_{it}/E_{it} + FV_{it}/E_{it}, \quad (4)$$

$$SGVCpos_{it} = \ln(1 + IV_{it}/E_{it}) - \ln(1 + FV_{it}/E_{it}). \quad (5)$$

Among them, E_{it} is the export scale of the service industry sub-sector i calculated from the perspective of added value. IV_{it}/E_{it} and FV_{it}/E_{it} are the forward participation and backward participation of the service industry sub-sector i in the global service industry value chain, respectively. The larger the forward participation, the more domestic added value of the service industry sub-sector i is exported to other countries in the form of intermediate products. The larger the backward participation, the more dependent the service industry sub-sector i is on foreign intermediate products in the GVC. The larger the measured value of $SGVCpar_{it}$, the deeper the service industry sub-sector i participates in the GVC and the deeper the degree of embedding in the GVC. The larger the measured value of $SGVCpos_{it}$, the larger the forward participation of service industry sub-sector i in the GVC compared to the backward participation, which indicates relative to the added value of imported intermediate products in service industry sub-sector i , the larger the added value of exported intermediate products, which indicates the higher the position of the service industry sub-sector i in the GVC, the higher the degree of embedding in the GVC. The original data were obtained from the World Input–Output Database (WIOD), developed by a consortium of 11 institutions supported by the European Union. The database mainly includes panel data of 56 industries in 42 economies from 2000 to 2014 (considering the availability of data, this is the latest data available at present). The industry classification standard is based on the one-digit and two-digit industry standards in ISIC Rev4.0, of which c24–c56 are service industries, including electricity, gas, steam, and air conditioning supply, water collection, treatment, and supply, construction, wholesale and retail trade, repair of motor vehicles and motorcycles, and another other 33 sub-service industries. See Table 1 for details.

Table 1. Industry classification of WIOD database.

ISIC Rev4.0 Industry Code	WIOD Industry Code	WIOD Industry Name	Factor Density
D	c24	Electricity, gas, steam, and air conditioning supply	Capital-intensive service
E36	c25	Water collection, treatment, and supply	Capital-intensive service
E37–39	c26	Sewerage waste collection, treatment and disposal activities, materials recovery, remediation activities, and other waste management	Labor-intensive service
F	c27	Construction	Labor-intensive service
G45	c28	Wholesale and retail trade and repair of motor vehicles and motorcycles	Labor-intensive service

Table 1. Cont.

ISIC Rev4.0 Industry Code	WIOD Industry Code	WIOD Industry Name	Factor Density
G46	c29	Wholesale trade, except for motor vehicles and motorcycles	Labor-intensive service
G47	c30	Retail trade, except for motor vehicles and motorcycles	Labor-intensive service
H49	c31	Land transport and transport via pipelines	Capital-intensive service
H50	c32	Water transport	Capital-intensive service
H51	c33	Air transport	Capital-intensive service
H52	c34	Warehousing and support activities for transportation	Capital-intensive service
H53	c35	Postal and courier activities	Capital-intensive service
I	c36	Accommodation and food service activities	Capital-intensive service
J58	c37	Publishing activities	Health, education and public service
J59-J60	c38	Motion picture, video, and television programme production, sound recording and music publishing activities, programming and broadcasting	Health, education and public service
J61	c39	Telecommunications	Capital-intensive service
J62-J63	c40	Computer programming, consultancy, and related information service activities	Knowledge-intensive service
K64	c41	Financial service activities, except insurance and pension funding	Knowledge-intensive service
K65	c42	Insurance, reinsurance, and pension funding, except for compulsory social security	Knowledge-intensive service
K66	c43	Activities auxiliary to financial services and insurance activities	Knowledge-intensive service
L68	c44	Real estate activities	Capital-intensive service
M69-M70	c45	Legal and accounting activities, activities of head offices, and management consultancy activities	Knowledge-intensive service
M71	c46	Architectural and engineering activities and technical testing and analysis	Knowledge-intensive service
M72	c47	Scientific research and development	Knowledge-intensive service
M73	c48	Advertising and market research	Knowledge-intensive service
M74-M75	c49	Other professional, scientific, technical, and veterinary activities	Knowledge-intensive service
N	c50	Administrative and support service activities	Knowledge-intensive service
O84	c51	Public administration and defence and compulsory social security	Health, education and public service
P85	c52	Education	Health, education and public service
Q	c53	Human health and social work activities	Health, education and public service
R-S	c54	Other service activities	Health, education and public service
T	c55	Activities of households as employers, and undifferentiated goods-and services-producing activities of households for own use	Labor-intensive service
U	c56	Activities of extraterritorial organizations and bodies	Health, education and public service

4.2.2. Independent Variables

The definition, statistical scope, statistical classification, and measurement methods of the digital economy have not yet been unified in the existing literature. Some scholars mainly build an index system from the aspects of digital infrastructure, industrial digitization, digital industrialization, digital environment, etc., and use the principal component method or entropy method to measure [57,58]. Other scholars have established indicator systems from the aspects of digital economic production, digital economic circulation, digital economic exchange, and digital economic consumption and draw on the calculation methods of the U.S. Bureau of Economic Analysis to measure [59–61]. Liu, Yang, and Zhang and Yao and Yao measured the development level of the digital economy from the dimensions of informatization development, internet development, digital technology, and digital transaction development [62,63]. The above studies are all from the national level, provincial level, city level, and manufacturing level; no one has studied the measurement of digital economy at the service level. According to the “White Paper on the Development of China’s Digital Economy (2021)”, the digital economy of China’s service industry will account for 40.7% of the industry’s added value in 2020, much higher than the proportion of the manufacturing and agricultural digital economy in the industry’s added value, which are 21.0% and 8.9%, respectively. Based on this, referring to the practice of Zhang and Yu [64], using the input–output method, the direct consumption coefficient m_{ij} and the complete consumption coefficient n_{ij} are used to measure the digitization degree of the service industry sub-sector i to reflect the development level of the digital economy in the service industry sub-sector. However, it is difficult for m_{ij} and n_{ij} to reflect the importance of

digital investment in total investment. Therefore, according to the research of Yang [65], the direct dependence $DIGd_{it}$ and the complete dependence $DIGc_{it}$ are used for improvement. The specific formula is as follows:

$$DIGd_{it} = m_{ij} / \sum_i m_{ij}, \quad (6)$$

$$DIGc_{it} = n_{ij} / \sum_i n_{ij}, \quad (7)$$

where m_{ij} represents the direct consumption of the service industry sub-sector i to the digital industry j , which is the total factor input by the digital industry j into the service industry sub-sector i divided by the total output of the service industry sub-sector i . $DIGd_{it}$ is the proportion of direct consumption of service industry sub-sector i to the digital industries set in all direct consumption. n_{ij} is the sum of all indirect consumption of service industry sub-sector i to digital industry j on the basis of direct consumption; that is, it also includes the amount of value that each digital industry invests in the service industry sub-sector through indirect means. $DIGc_{it}$ is the proportion of the complete consumption of the service industry sub-sector i to the digital industry set in all the complete consumption. Since $DIGd_{it}$ can more intuitively reflect the penetration of the digital industry to the service industry, $DIGc_{it}$ can more comprehensively reflect the impact of the digital industry on the service industry. Therefore, $DIGd_{it}$ is used for benchmark regression, and $DIGc_{it}$ is used for robustness tests. In order to use the above formula to measure the development level of the digital economy of the service industry sub-sector, referring to the practice of Xie and Wang to measure the development level of the digital economy in the manufacturing industry [48], select the computer, electronic and optical product manufacturing (C26), telecommunications (J61), computer programming, consulting and related activities (J62), and information services (J63) as digital industries according to the ISIC Rev4.0 industry classification standard. The original data were obtained from the WIOD database.

4.2.3. Control Variables

The value added of the service industry sub-sector, the actual use amount of foreign direct investment/value added, value added/number of employees, and total assets/number of employees are used to measure industry size, industry foreign direct investment, industry labor productivity, and industry factor endowment. The original data were obtained from the WIOD database, the World Bank database, the WTO database, the United Nations service trade database, the UNCTAD statistical database and the China Tertiary Industry Statistical Yearbook, etc.

4.2.4. Mediating Variables

Using Novy's model and referring to the practice of Tu, we can measure the service trade cost of the service industry sub-sector [66,67]. For the multilateral resistance to service trade in the service industry sub-sector, according to the practice of Kancs and Shi to measure the variable resistance to trade in goods [68,69], the reciprocal of the degree of foreign trade freedom of the service industry sub-sector is used to measure the multilateral resistance to service trade; the larger the value, the lower the degree of openness to foreign trade in the service industry sub-sector, and the greater the multilateral resistance to service trade. The formula for calculating the degree of foreign trade freedom of the service industry sub-sector is: $ST_{igh} = \sqrt{E_{igh}E_{ihg}/E_{igg}E_{ihh}}$, where the numerator is the product of bilateral exports of the service industry sub-sector i , the denominator is the product of the domestic trade volume of the service industry sub-sector i in bilateral countries (referring to the practice of Kan and Lv, 31 major service trade partner countries (regions) including the United States, the United Kingdom, France, Japan, Germany, South Korea, Italy, and Hong Kong, China) [70], and the domestic trade volume is the added value of service industry sub-sector i of a country minus the export value of this service industry. The larger the

ST value, the larger the product of bilateral exports of the service industry sub-sector i compared with the domestic trade volume of the service industry sub-sector i in bilateral countries; that is, the larger the degree of foreign trade freedom of the service industry sub-sector i . On the basis of the degree of foreign trade freedom of the service industry sub-sector i , the multilateral resistance to service trade of service industry sub-sector i is calculated using the formula $SR_i = (\sum_h V_h ST_{igh} / V)^{-1}$, which suggests the inverse of the weighted average of the degrees of bilateral trade freedom of the service industry sub-sector i in various countries, where the weight is the proportion of the added value of the corresponding service industry in the country, and V is the added value of the service industry. The original data were obtained from the WIOD database, the United Nations service trade database, and the UNCTAD statistical database.

Regarding the measurement of service industry structure, this paper first draws on the research of Sheng and Ma [71] and divides the service industry sub-sectors in the WIOD database into labor-intensive service industries (c26-c30, c36, c55), capital-intensive service industries (c24-c25, c31-c35, c39, c44), knowledge-intensive service industries (c40-c43, c45-c50), and health, education, and public services (c37-c38, c51-c54, c56), and then the ratio of the added value of the last three types of service industries to the added value of labor-intensive service industries is used to measure the service industry structure. The original data were obtained from the WIOD database, the World Bank database, and the China Tertiary Industry Statistical Yearbook.

The measurement of the financial development level is measured from the dimensions of the financial intermediary development level and financial market development level and is expressed by (private credit scale + stock market value)/GDP. This indicator can better reflect the importance of financial development in economic growth and reflects the support of financial development for the upgrading of the GVC of the service industry. Regarding the measurement of human capital, refer to the research of Kan [72], which is measured by the average years of education. As for the measurement of service export complexity, the formula for calculation is as follows:

$$SE_i = \sum_k \left[\frac{x_{ki} / X_k}{\sum_k (x_{ki} / X_k)} Y_k \right], \quad (8)$$

where x_{ki} is the export value of the service industry sub-sectors i of country k , and X_k and Y_k are the total service export value and per capita GDP of country k , respectively. The original data were obtained from the WIOD database, the UNCTAD statistical database, and the China Tertiary Industry Statistical Yearbook.

5. Results and Analysis

This part will first carry out benchmark regression and examine the impact of the digital economy on the GVC of China's service industry as a whole. Then, the robustness test is carried out from four aspects: replacing the independent variable measurement indicator, adding control variables, considering changes in industry trends, and using quantile regression. Further, a heterogeneity test is carried out on different types of service industries, and finally, the six mediating mechanisms of service trade cost, multilateral resistance to service trade, service industry structure, financial development level, human capital, and service export complexity are examined.

5.1. Benchmark Regression Results

According to the benchmark regression equation (1) in the model construction, the relationship between the digital economy and the GVC of China's service industry is estimated and analyzed. The specific results are shown in Table 2.

Table 2. Benchmark regression results.

	lnSGVC _{par}		lnSGVC _{pos}	
	(1)	(2)	(3)	(4)
Constant	3.645 ** (2.102)	3.103 * (1.847)	3.594 ** (2.001)	2.852 * (1.746)
the lag term of the dependent variable	0.386 * (1.839)	0.221 ** (2.214)	0.407 ** (2.118)	0.238 ** (2.095)
lnDIG _d	0.098 *** (4.721)	0.067 ** (2.056)	0.116 *** (3.769)	0.074 ** (2.107)
lnSca		0.152 ** (2.110)		0.127 * (1.834)
lnIfd		0.069 ** (2.008)		0.055 * (1.784)
lnLab		0.126 * (1.793)		0.109 ** (2.006)
lnFac		0.105 * (1.764)		0.113 (1.490)
ϕ	No	Yes	No	Yes
λ	No	Yes	No	Yes
Wald test	1280.462	1055.427	1262.850	964.854
Hansen test	0.705	0.561	0.698	0.526
Arellano–Bond AR(1)	0.006	0.006	0.006	0.005
Arellano–Bond AR(2)	0.273	0.224	0.267	0.201
Sargan	0.319	0.232	0.311	0.228

Note: *, **, and *** indicate that the variable is significant at the level of 10%, 5%, and 1%, respectively.

Columns (1)–(2) in Table 2 are the regression results of the dependent variable lnSGVC_{par}, and columns (3)–(4) in Table 2 are the regression results of the dependent variable lnSGVC_{pos}. From the estimation results of columns (1)–(2), it is found that the coefficient of the digital economy on participation of China's service industry is significantly positive. The regression results in column (2) show that after including relevant control variables and adding industry fixed effects and time fixed effects, the estimated coefficient of the variable lnDIG_d is 0.067, indicating that when the development level of the digital economy increased by 1 percentage point, the participation of China's service industry in the GVC increased by 0.067 percentage points, and the digital economy has a positive effect on the participation of China's service industry in the GVC. At the same time, from the estimation results of columns (3)–(4), it can be seen that the impact of the digital economy on the position of China's service industry in the GVC is also significantly positive. The regression results in column (4) show that the estimated coefficient of the variable lnDIG_d is 0.074, indicating that when the development level of the digital economy increased by 1 percentage point, the position of China's service industry in the GVC increased by 0.074 percentage points, indicating that the digital economy helps to improve the position of China's service industry in the GVC. Accordingly, the digital economy has promoted the upgrading of the GVC of China's service industry, and the digital economy has become a new driving force for the high-quality development of China's service trade. In terms of control variables, it is similar to the findings of the existing literature on the influencing factors of China's manufacturing GVC; that is, the regression coefficients of the industry scale, industry foreign direct investment, and industry labor productivity on the participation and position in GVC of China's service industry are significantly positive, which has promoted the upgrading of the GVC of China's service industry; however, the industry factor endowment has only significantly increased the participation of China's service industry in the GVC, but has not significantly improved the position of China's service industry in the GVC, indicating that the overall level of factor endowment in China's service industry is not high, and it still participates in the division of labor in the GVC of the service industry according to the theory of comparative advantage, with a high degree of participation, but more non-high-end factor-intensive service processes and links are provided in the GVC of the service industry. The technological progress and room for improvement of such service processes and links are relatively limited, which may lead to the so-called “low-end lock-in”.

5.2. Robustness Test

5.2.1. Replace the Independent Variable Measurement Indicator

The direct dependence DIG_{d_{it}} can more intuitively reflect the penetration of the digital industry to the service industry, and the complete dependence DIG_{c_{it}} can more comprehensively reflect the impact of the digital industry on the service industry. Therefore, DIG_{d_{it}} is used to measure the digital economy in the benchmark regression, which is

replaced by DIG_{it} to reflect the development level of the digital economy. Regression is carried out using the system GMM again to test whether the estimation results are reliable. From Table 3, we can see that the sign of the regression coefficients of $\ln DIG_{it}$ is consistent with the benchmark regression, only the size and significance level of the coefficients have changed, but no substantial changes have occurred, indicating that the empirical results of the benchmark regression pass the robustness test after replacing the independent variable measurement indicator.

Table 3. Results of robustness test (1).

	Replace the Independent Variable Measurement Indicator		Add Control Variables		Consider Changing Industry Trends	
	$\ln SGVC_{par}$	$\ln SGVC_{pos}$	$\ln SGVC_{par}$	$\ln SGVC_{pos}$	$\ln SGVC_{par}$	$\ln SGVC_{pos}$
Constant	3.006 ** (2.031)	3.048 * (1.813)	3.367 * (1.838)	3.415 ** (2.057)	3.163 * (1.806)	3.202 ** (2.049)
the lag term of the dependent variable	0.214 * (1.788)	0.231 * (1.862)	0.196 ** (2.067)	0.217 * (1.849)	0.210 ** (2.084)	0.228 ** (2.135)
$\ln DIG$	0.071 ** (2.123)	0.078 ** (2.027)	0.064 ** (2.042)	0.069 ** (2.161)	0.065 * (1.878)	0.073 * (1.796)
control variable	Yes	Yes	Yes	Yes	Yes	Yes
φ	Yes	Yes	Yes	Yes	Yes	Yes
λ	Yes	Yes	Yes	Yes	Yes	Yes
$\varphi \times \lambda$	No	No	No	No	Yes	Yes
Wald test	1022.498	992.642	1139.613	1110.306	1109.165	1066.714
Hansen test	0.543	0.541	0.628	0.614	0.597	0.589

Note: * and ** indicate that the variable is significant at the level of 10% and 5%, respectively.

5.2.2. Add Control Variables

In order to test whether the regression results are robust, this paper adds more control variables in the benchmark regression model for estimation. It mainly increases industry outward foreign direct investment and industry trade, which are measured by industry net outward foreign direct investment/added value and industry trade volume/added value. The original data were obtained from the WIOD database, the World Bank database, the United Nations service trade database, and the China Tertiary Industry Statistical Yearbook. From Table 3, we can see that the positive effect of the digital economy on the participation and the division of the service industry in the GVC is still significant and reliable.

5.2.3. Consider Changing Industry Trends

As time changes, the participation and the division of different service industries in the GVC may also change due to the impact of the digital economy. Therefore, the cross term of industry fixed effect and time fixed effect is added to the benchmark regression model for re-estimation. From Table 3, it is found that the regression coefficient of the digital economy is still robust.

5.2.4. Quantile Regression

The panel data model in benchmark regression is actually a mean regression, which is difficult to describe the effect of the digital economy on the overall distribution, and outliers in the sample can also lead to biased estimates [73]. Therefore, quantile regression is used here to further explain the relationship between the digital economy and the upgrading of the GVC in the service industry. The advantage of using quantile regression is that it can estimate the situation at different quantiles, the structural characteristics of the digital economy affecting the upgrading of the GVC of the service industry can be examined in detail, the use of quantile regression is not easily affected by extreme values, and the estimation results are more reliable. Table 4 presents the regression results of Stata software for the 25%, 50%, and 75% quantiles [74]. It is found that the estimated coefficients of the digital economy on the participation in GVC and division of the service industry are significantly positive, which is consistent with the benchmark regression

results. Additionally, it is further found that with the increase in quantiles, the regression coefficient of the digital economy at each quantile shows a gradually increasing trend. That is, the effect of the digital economy on the participation and division of the service industry in the GVC showed the nonlinear characteristics of “marginal effect” increasing, which may be due to the application of the network effects and Metcalfe’s law with increasing “marginal effects” of the digital economy in the GVC of the service industry [75].

Table 4. Results of robustness test (2).

	QR_25%		QR_50%		QR_75%	
	lnSGVCpar	lnSGVCpos	lnSGVCpar	lnSGVCpos	lnSGVCpar	lnSGVCpos
Constant	3.124 * (1.757)	3.165 ** (2.089)	3.028 ** (2.120)	3.070 * (1.763)	2.789 ** (2.045)	2.827 * (1.770)
the lag term of the dependent variable	0.201 ** (2.169)	0.223 * (1.729)	0.204 * (1.886)	0.219 * (1.805)	0.197 ** (2.136)	0.212 * (1.843)
lnDIG	0.062 ** (2.076)	0.068 *** (4.128)	0.069 ** (2.117)	0.075 ** (2.090)	0.070 ** (2.014)	0.078 ** (1.996)
control variable	Yes	Yes	Yes	Yes	Yes	Yes
φ	Yes	Yes	Yes	Yes	Yes	Yes
λ	Yes	Yes	Yes	Yes	Yes	Yes

Note: *, **, and *** indicate that the variable is significant at the level of 10%, 5%, and 1%, respectively.

5.3. Heterogeneity Analysis

From the benchmark regression results, it can be seen that the impact of the digital economy on the upgrading of China’s service industry in the GVC is significant. However, whether this effect will be different due to different sample classification standards is obviously worth further study, which is conducive to a deeper understanding of the potential connection between the digital economy and the GVC of China’s service industry. Therefore, according to different heterogeneity classification standards, the corresponding samples are classified and estimated.

5.3.1. Service Object Heterogeneity

Due to the large differences in the service objects of China’s service industry, the promotion effect of the digital economy may also be different for the service industries of different service objects. Based on this consideration, this paper divides the service industry sub-sectors in the WIOD database into producer services (c27-c35, c39-c43, c45-c50), living services (c24-c26, c36, c44, c54–55), and public services (c37-c38, c51-c53, c56), estimated separately. The results are shown in Table 5. We can see that the digital economy mainly promotes the participation and the division of China’s producer services and living services in the GVC but has not significantly improved the participation and the division of the public services in the GVC. The reason may be that the digital economy reduces the export cost of two types of services, improves the tradability of two types of services, effectively reduces the multilateral resistance to the export of two types of services, and increases the market penetration of the two types of services exports, whether it is producer services or life services; the digital economy has accelerated the R&D and application of digital technology, promoted the digital transformation of the two types of service industries, spawned new formats, new models and new methods of the two types of service industries, promoted the upgrading of the export structure and exports complexity of the two types of service industries, and accelerated the two types of service industries to move towards the mid-to-high end of the GVC. The digital economy has also broadened financing channels, improved the availability and inclusiveness of finance, improved the human capital level, promoted the quality and efficiency of service exports, and boosted the GVC of the service industry. In the public service industry, due to the high threshold for international market access, many market access conditions, discriminatory policy restrictions, institutional obstacles and trade barriers, and low degree of openness, it is difficult for the digital economy to play its role in the participation and division of the public service industry in

the GVC. Further, from Table 5, it is found that compared with the living service industry, the digital economy has a greater positive effect on the participation and the division of the producer service industry in the GVC. The reason may be that the export of living services is a relatively stable trade. Once a trade relationship is established, it will last for a long time. Therefore, both parties in the trade have a higher understanding of living services than producer services, and the uncertainty in the export process of producer services is greater. Therefore, the development of the digital economy can better eliminate the information asymmetry in the export process of producer services, reduce its uncertainty, and reduce the cost and multilateral resistance of trade in such services, thus playing a greater role participation and division of such services in the GVC. In addition, the living service industry mostly relies on labor resources, historical and cultural heritage, natural resources, traditional infrastructure, etc., to participate in the division of labor in the GVC. Compared with the producer service industry, the living service industry is in the middle and high-end position in the GVC, and the international market openness of this type of service industry is not high. The technological progress and room for improvement of such service processes and links in the GVC are relatively limited, resulting in a relatively low promotion effect of the digital economy on the GVC of this type of service industry.

Table 5. Results of heterogeneity test (1).

	Producer Service		Living Service		Public Service	
	lnSGVCpar	lnSGVCpos	lnSGVCpar	lnSGVCpos	lnSGVCpar	lnSGVCpos
Constant	2.893 ** (2.029)	2.936 * (1.859)	3.241 * (1.842)	3.283 ** (2.157)	3.140 ** (2.021)	3.184 * (1.768)
the lag term of dependent variable	0.206 * (1.853)	0.221 ** (2.134)	0.210 * (1.782)	0.232 ** (2.179)	0.247 *** (4.695)	0.259 *** (3.970)
lnDIGd	0.072 *** (4.005)	0.080 ** (2.107)	0.063 *** (3.874)	0.067 ** (2.048)	0.051 (1.223)	0.058 (1.436)
control variable	Yes	Yes	Yes	Yes	Yes	Yes
φ	Yes	Yes	Yes	Yes	Yes	Yes
λ	Yes	Yes	Yes	Yes	Yes	Yes
Wald test	916.699	889.932	1021.695	993.853	991.934	953.961
Hansen test	0.487	0.485	0.562	0.549	0.536	0.524

Note: *, **, and *** indicate that the variable is significant at the level of 10%, 5%, and 1%, respectively.

5.3.2. Factor Density Heterogeneity

In view of the large differences in factor intensity in China's service industry, the promotion effect of the digital economy may also be different for service industries with different factor intensities. Based on this consideration, according to the classification of the labor-intensive service industry, capital-intensive service industry, knowledge-intensive service industry, and health, education and public service industry, the sample is divided into four sub-samples for estimation, respectively. Since the service industry sub-sectors in the WIOD industry database included in the health, education, and public service industries are basically the same as the service industry sub-sectors included in the public service industry in the service object heterogeneity analysis, the regression results of this type of service industry sub-sector are not provided in Table 6, and will not be analyzed here. The specific results are shown in Table 6. We can see that the digital economy has promoted the participation and position of China's labor-intensive service industry, capital-intensive service industry, and knowledge-intensive service industry in the GVC. Compared with the labor-intensive service industry, the digital economy has a greater positive effect on the participation of the latter two types of service industry in the GVC and a less positive effect on the position of the latter two types of service industry in the GVC. The reason may be that capital-intensive and knowledge-intensive service industries tend to have more complex technical content, higher information costs, and greater uncertainty in the export process; therefore, the development of the digital economy can better reduce the uncertainty of the export of capital-intensive and knowledge-intensive service industries,

and thus play a greater role in the upgrading of the GVC of these two types of service industry, but it is limited to the role of the digital economy in the participation of the two types of service industry in the GVC. This is because some capital-intensive and knowledge-intensive service industries have long value chains, which are the key industries concerned by various countries, and are related to the national economy and people's livelihood. Therefore, various countries are cautious about opening up some of the processes and links in the value chain of these two types of service industries, and some developed countries have even imposed blockades and import restrictions on the processes and links of the two types of service exports enabled by digital technology in China, resulting in the limited role of the digital economy in enhancing the position of these two service industries in the GVC. In addition, the labor-intensive service industry mostly relies on traditional comparative advantages to participate in the division of labor in the GVC. Therefore, the digital economy has little positive effect on the participation of such a service industry in the GVC. In view of the low technical content of the labor-intensive service industry, the digital economy empowers the labor-intensive service industry with large space for digital transformation, the international market opening of such a service industry is relatively high, and the service processes and links provided in the GVC have large room for rise, resulting in the relatively high role of the digital economy in promoting the position in the GVC of such services.

Table 6. Results of heterogeneity test (2).

	Labor-Intensive Service Industry		Capital-Intensive Service Industry		Knowledge-Intensive Service Industry	
	lnSGVCpar	lnSGVCpos	lnSGVCpar	lnSGVCpos	lnSGVCpar	lnSGVCpos
Constant	2.925 * (1.744)	3.054 ** (2.135)	3.601 * (1.802)	3.328 * (1.780)	3.172 * (1.826)	3.856 ** (2.002)
the lag term of dependent variable	0.249 ** (2.156)	0.236 * (1.769)	0.213 * (1.747)	0.231 ** (2.092)	0.247 * (1.753)	0.227 ** (2.103)
lnDIGd	0.063 * (1.813)	0.082 ** (2.171)	0.068 *** (3.915)	0.072 ** (2.104)	0.071 *** (4.629)	0.069 ** (2.110)
control variable	Yes	Yes	Yes	Yes	Yes	Yes
φ	Yes	Yes	Yes	Yes	Yes	Yes
λ	Yes	Yes	Yes	Yes	Yes	Yes
Wald test	926.886	899.820	1033.047	1004.894	1002.953	964.561
Hansen test	0.494	0.491	0.569	0.553	0.542	0.530

Note: *, **, and *** indicate that the variable is significant at the level of 10%, 5%, and 1%, respectively.

5.4. Mediation Test

The empirical research shows that the digital economy has a significant role in promoting the upgrading of the service industry in the GVC. This paper further tests the specific influence mechanism. We use the mediating effect model to test whether service trade cost, multilateral resistance to service trade, service industry structure, financial development level, human capital, and service export complexity play a mediating role in the digital economy, affecting the upgrading of the GVC of the service industry. For the sake of robustness, the cross term of industry fixed effect and time fixed effect is included in the regression model to control the impact of different service industries over time.

The test results are shown in Table 7. Columns (1)–(2) of Table 7 are the regressions to the benchmark model. Columns (3)–(8) are the regressions of Equation (2), which are the regressions with service trade cost, multilateral resistance to service trade, service industry structure, financial development level, human capital, and service export complexity as dependent variables, respectively, reflecting the relationship between the digital economy and service trade costs, multilateral resistance to service trade, service industry structure, financial development level, human capital, and service export complexity. Finally, columns (9)–(10) of Table 7 are regressions of Equation (3); that is, six mediating variables are added to Equation (1) for estimation at the same time.

Table 7. Results of mediation test.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	lnSGVCpar	lnSGVCpos	lnSC	lnSR	lnSI	lnIF	lnHC	lnSE	lnSGVCpar	lnSGVCpos
Constant	3.163 * (1.847)	3.202 ** (2.119)	2.991 ** (2.153)	3.033 * (1.878)	2.782 * (1.764)	2.909 ** (2.012)	3.427 ** (2.069)	3.165 ** (2.108)	3.024 * (1.817)	3.673 ** (2.111)
the lag term of the dependent variable	0.210 ** (2.103)	0.228 ** (2.046)	0.206 * (1.758)	0.215 * (1.901)	0.234 ** (2.100)	0.231 ** (2.025)	0.203 ** (2.004)	0.226 * (1.802)	0.165 * (1.736)	0.157 * (1.892)
lnDIG	0.065 * (1.906)	0.073 * (1.827)	−0.087 *** (−3.895)	−0.082 *** (−4.506)	0.079 ** (2.083)	0.064 * (1.750)	0.058 * (1.812)	0.069 ** (2.015)	0.041 ** (2.121)	0.046 ** (2.048)
lnSC									−0.127 *** (−4.834)	−0.119 * (−1.835)
lnSR									−0.113 *** (−3.906)	−0.145 ** (−2.009)
lnSI									0.086 * (1.723)	0.104 ** (2.117)
lnIF									0.079 ** (2.085)	0.090 * (1.908)
lnHC									0.064 * (1.731)	0.092 *** (5.163)
lnSE									0.068 ** (2.029)	0.101 *** (4.336)
control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ϕ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
λ	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\phi \times \lambda$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald test	1109.165	1066.711	944.816	908.648	882.857	857.072	983.976	957.160	955.314	918.743
Hansen test	0.597	0.589	0.511	0.499	0.468	0.467	0.542	0.527	0.516	0.505

Note: *, **, and *** indicate that the variable is significant at the level of 10%, 5%, and 1%, respectively.

From the results in columns (3)–(8) of Table 7, we can see that the regression coefficient of the digital economy lnDIG is significantly positive or negative, indicating that the development of the digital economy significantly reduced service trade costs, reduced the multilateral resistance to service trade, promoted the optimization of service industry structure, and improved the financial development level. Further taking into account the role of digital finance development and drawing on the practice of Zhang et al. [76], the China Digital Inclusive Finance Index jointly compiled by the digital finance research center of Peking University and Ant Financial Group was used to measure the development level of digital finance and re-examine the impact of financial development level on participation and position of the service industry in the GVC, and the results did not change substantially, promoting the human capital level and the service export complexity. The results in columns (9)–(10) show that service trade cost and multilateral resistance to service trade have a significant negative impact on the participation and position in the GVC of the service industry, while service industry structure, financial development level, human capital, and service export complexity have a significant positive impact on service participation and position in the GVC; that is, the first two mediating variables are not conducive to the improvement of participation and position of the service industry in the GVC, while the last four mediating variables improve the participation and position of the service industry in the GVC. At the same time, compared with the results in columns (1)–(2), the regression coefficient of the digital economy lnDIG is still significant, but its size dropped significantly, which proves the mediating effects of service trade cost, multilateral resistance to service trade, service industry structure, financial development, human capital, and service export complexity. That is, service trade cost, multilateral resistance to service trade, service industry structure, financial development level, human capital, and service export complexity have played a significant mediating role, and service trade cost, multilateral resistance to service trade, service industry structure, financial development level, human capital, and service export complexity are all possible mechanisms for the digital economy to affect the upgrading of the GVC of the service industry.

6. Conclusions and Policy Recommendations

With the vigorous development of digital technology, the digital economy has become an important force in the transformation and upgrading of China's service trade, providing opportunities for the GVC of China's service industry to move towards the mid-to-high end. Based on the panel data of service industry sub-sectors, this paper empirically studies

the impact of the digital economy on the upgrading of China's service industry in the GVC using system GMM. The research conclusions are as follows:

First, the higher the development level of the digital economy in China's service industry, the more it can enhance the participation and position of the service industry in the GVC. That is, it can better promote the upgrading of the service industry in the GVC. After replacing the independent variable measurement indicator, adding control variables, considering changes in industry trends, and using quantile regression and other robustness tests, this conclusion still holds.

Second, the role of the digital economy in promoting the upgrading of China's service industry in the GVC has the heterogeneity of service objects and factor intensity. Specifically, the digital economy mainly promotes the upgrading of China's producer services and living services in the GVC but has not significantly promoted the upgrade of public services in the GVC. Compared with living services, the digital economy has a greater positive effect on the upgrading of producer services in the GVC. The digital economy has promoted the upgrading of China's labor-intensive service industry, capital-intensive service industry, and knowledge-intensive service industry in the GVC. Compared with the labor-intensive service industry, the digital economy has a positive effect on the participation of the latter two types of service industry in the GVC and a smaller positive effect on the position of the latter two types of service industry in the GVC. This means that the digital economy will affect the internal structure of the upgrading of China's service industry in the GVC.

Third, the results of the mediation test found that the mediating effects of service trade cost, multilateral resistance to service trade, service industry structure, financial development level, human capital, and service export complexity are significant.

There are three policy recommendations: First, actively implement the "14th Five-Year Plan" for the development of the digital economy, strengthen the construction of digital infrastructure, strive to break through key core technologies, innovate the governance mode of the digital economy, improve the information security of digital economy, and build a digital economy ecosystem, accelerate the development of the digital economy, cultivate new advantages, and inject new momentum into the upgrading of China's service industry in the GVC. Second, in the era of the digital economy, the service industry needs to adjust its service mode, giving full play to the innovative and empowering role of digital technologies such as mobile Internet, cloud computing, big data, Internet of Things, blockchain, artificial intelligence, virtual reality, and augmented reality, and use the productivity brought by digital technology to form a resource integration advantage in the whole process including demand information, R&D design, and intelligent services, to promote the upgrading of China's service industry in the GVC. Third, collaboratively promote the industrialization of digital services and the digital transformation of the service industry, deepen the application of digital technology in different service objects and different factor-intensive services, and promote the digital upgrading of various service industries, especially the public service industry, the capital-intensive service industry, and the knowledge-intensive service industry, to give full play to the role of digital technology in reducing service trade cost, reducing multilateral resistance to service trade, optimizing service industry structure, improving financial development level, increasing human capital and service export complexity, and enabling the upgrading of China's service industry in the GVC.

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