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Impact of Service Ecology on Digital Trade Competitiveness - from Indurstrial Integration and Digital Absorptive Capacity Aspective

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A B S T R A C T

Based on the panel data of 28 manufacturing and 5 servicing sectors in China from 2010 to 2019, this paper uses the coupling coordination degree model to measure the digital absorption capacity of manufacturing sectors, and uses the mediation effect model to test the impact of producer services on competitiveness of digital trade and the mediated effects of manufacturing input servitization. Results show that the application of information technology effectively improves the service demand of manufacturing sectors and makes the impact of transportation service on digital export turn from negative to positive. For manufacturing sectors with weak digital absorption capacity, input servitization will float the impact of digital logistics and digital finance on digital export, but will strengthen the role of digital commerce and digital technology. The government should utilize information technology to build service ecology, mainly develop digital commerce around the manufacturing sectors with weak digital absorption capacity, mainly develop digital logistics around the manufacturing sectors with medium digital absorption capacity, primary develop digital finance and digital technology around the manufacturing sectors with strong digital absorption capacity.

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INTRODUCTION

China's producer servicing industry is growing at a higher rate than the industrial average (Liu et.al., 2020;Chen et.al.,2018),but there still problems such as insufficient supply of high-end services, low coupling degree between services and manufacturing, and small contribution of producer services to digital trade (Xu, 2020; Wei and Tang, 2020; Liu et. al., 2017; Sun and Han, 2019; Zhang and Han, 2019). Building a Digital China has been included in the national strategy since 2017. The National Development and Reform Commission issued the "Implementation Plan for Promoting the Action of 'Using data to Empower Enterprises With Wisdom In Cloud' to Cultivate New Economic Development", requiring the accelerating the development of digital trade, so as to enable industrial integration and manufacturing transformation with digital services. Therefore, digital trade, industrial digitization and producer servicing ecology are listed on regional development strategy. With more and more manufacturing enterprises investing in big data, artificial intelligence and cloud computing (Xu et. al., 2020), the increasingly complex digital application scenarios has led to the growth of high-end services and service outsourcing business, which has created conditions for the evolution of service industry cluster into service ecology. Cluster enterprises jointly carry out value sharing and value co-creation activities based on manufacturing needs, provide package solutions for manufacturing enterprises, and realize value added through digital output and trade. Leading enterprises opened the symbiotic technology platforms, magnetically attracted upstream and downstream enterprises to gather, opened up data streams of all links of manufacturing industry chain, continuously expanded the service ecology and amplified the scale effect (Yue and Li, 2020; Arnold, 2007), thus enhancing the correlation effect between different service industries and between service industries and manufacturing industries.

This paper studies the impact of producer service ecology on digital export and its mechanism through integration of two industries, aiming to solve three questions: what type of service ecology can best promote digital output? How to measure the digital absorption capacity of the manufacturing industry? For manufacturing in servitization with various digital absorption capacities, what kind of service ecology is more conducive to enhancing their digital export? The second part of the paper is a literature review. By searching CNKI, JOSTOR and other databases, the concepts of digital trade, manufacturing servitization and service ecology are clarified, and the business correlation and value transmission process among the three are analyzed to build a theoretical framework. The third part constructs the mechanism from producer service ecology → manufacturing input servitization → manufacturing producing servitization → manufacturing output servitization → digital export competitiveness, and puts forward the research hypothesis. The fourth part explains the data sources, economic connotation and processing methods, and establishes a moderated mediation model. The fifth part empirically examines the impact of producer service ecology on digital trade competitiveness and the mediating effect of digital absorption capacity and ICT technology application in this influence path, and draws research conclusions and political suggestions.

LITERATURE REVIEW

The Concept of Manufacturing Service Ecology

Build producer service ecology around demand of manufacturing servitization is an important path of industrial empowerment. Here producer service ecology refers to a self-constrained and self-adjusting service network around diverse demands of manufacturing scenarios, driven by technology, based on platforms,supported by resource integration, and committed to delivering and capturing value information, by gathering resources from various service providers (Baron and Kenny, 1986; Bond,1996). It aims to provide integrated service solutions for the high quality development of manufacturing. Integrating into producer service ecology can improve the ability of manufacturing to identify and use external knowledge to carry out innovative activities through organizational learning. Scientific and technological innovation, business service, logistics distribution, intellectual property transfer and other activities proceeds within a producer service ecology. Members in the ecology share and integrate resources, co-create and trade value abiding by certain arrangement. Take Greentown as an example, Its platform can provide one-stop services for enterprises, including business incubation, investment and financing, and other fundamental operation.

The rapid development of information and communication technology (ICT) has created conditions for the establishment of producer service ecology. The digital platform supported by ICT technology provides a cheap and efficient digital channel for the integration of services and manufacturing. More and more small and medium-sized service providers join this channel, and carry out value sharing, value co-creation and value exchange activities by opening data flow, so that the producer service ecology can be formed and expanded. The more resources the platform gathers, the lower the marginal cost of producer service ecology. Here, we define the producer service ecology as an organizational network to gather business entities such as manufacturers and service providers with the platform, open up the "data flow" between services and manufacturing through information interconnection, and carry out activities for business model innovation and value co-creation based on data mining technology. It aims to improve the digital absorption and digital marketing capabilities of manufacturing (Medase and Barasa, 2019). The process of producer service cluster evolving towards producer service ecology is also a process of dynamic capability enhancement.

Evolutionary Mechanism From Producer Service Cluster Towards Producer Service Ecology

A country's competitive advantage is closely related to its industrial advantage and enterprise competitiveness (Porter, 1991). In the era of digital economy, digital trade competitiveness is an significant manifestation of a country's competitive advantage, and cluster is an important source of industrial advantage. Within a specific geographic space, the same or similar service elements gather to form specialized clusters, while different service elements gather and integrate to form diversified clusters. When the service cluster merges into ecology to provide integrated service solution for manufacturing, it will greatly reduce the cost of element searching and price by increasing market concentration,, promote the collaboration between enterprises, accelerate product iteration and knowledge spillover through sharing and factor-flow mechanism, improve the operating efficiency, showing a positive externality for the manufacturing. When the cluster business model is effective to integrate superior resources and promote value co-creation and value exchange, more and more enterprises will be attracted to this process of value creation to continuously develop and expand the service ecology (Yan, 2017).

The application of digital technology further accelerates the formation of service ecology (Huang and Chen, 2021). Technological innovation shortens the product life cycle and makes consumers shift their focus from product to utility, and pursue personalized and customized value-added services (Gao et al., 2011), which forces manufacturing enterprises to increase service investment in R&D, design, digital marketing and others, and strengthen cooperation with advanced service providers (Timothy et.al

., 1994). Some service providers, relying on technology first-mover advantages, rapidly gather service resources and establish a service ecology in response to diversified manufacturing needs, and form a monopoly position, transforming the service market structure from scattered to oligopoly (Vandermerwe and Rada,1988). Service providers become technology tool providers, promote the interaction and integration of information, knowledge and other resources with users, and influence the process of value creation (Wieland et.al.,2016;Akhtar et.al.,2017). For example, around the purchase, consumption and after-sales service of automobiles, an automobile service ecology are quickly built by automobile trading, breakdown maintenance, automobile insurance and other service subjects (Vargo and Lusch, 2004). The emergence of shared car makes the car no longer a simple means of transportation, but a service of mobility.

Industrial digitalization strategy give birth to manufacturing service ecology. In order to improve their position in the value chain, manufacturing enterprises continue to invest knowledge and technology, and obtain external services by means of cooperative development and function outsourcing, which provides opportunities for the construction of producer service ecology. There are three ways to construct the service ecology: First, technology enterprises open the basic technology framework or reshape the business model to attract suppliers and service providers to gather and build the service ecology. For example, in the autonomous driving business, Didi Group relies on the advantages in big data algorithm, to realize precise portrait and matching, and launches services such as real-time carpooling, pooling before placing orders to improve the efficiency of vehicle configuration and utility, develop digital products such as sensors, Internet of vehicles, high-precision maps and edge computing to provide equipment and technical support for autonomous driving, establish a car charging and parking service network to facilitate autonomous driving. The second is to focus on the demand of manufacturing servitization, use digital technology to upgrade the service cluster into producer service ecology, by which integrated service solutions for the manufacturing will be provided. Third, leading manufacturing enterprises establish industrial Internet platforms to attract suppliers to open up the data flow by connecting industrial equipment, products, systems and services of all links, to collect massive data concerning to research and development, design, production, operation and maintenance services, and promote the optimal allocation of resources by data mining. For example, Halkaos Industrial Internet platform has gathered more than 4 million enterprises and 350 million users, covering 60 subdivided industries, connecting more than 26 million intelligent terminals and over 2,000 industrial applications (Apps), and providing services for nearly 70,000 enterprises[1]. It can be seen that digital transformation stimulates manufacturing' demand for high-end services, accelerates the agglomeration of service elements and the formation of producer service ecology (Tian and Zhang, 2010).

Path to promote digital trade competitiveness by producer service ecology

There are few studies on the impact of service ecology on the competitiveness of digital trade in academia, most of which focus on the single level, such as the impact of producer service cluster on the upgrading of manufacturing structure or the impact of trade on manufacturing servitization. Producer service clusters are major sources of inputted knowledge-intensive factors for manufacturing enterprises (Luo, 2020). Manufacturing industry is fostered and enjoy the benefit of large scale and technology spillover, which seems greater in the long-term than that

[1]data from: 2021 China Sharing Economy Development Report released by the State Information Center.

in the short-term (Han and Yang, 2020). Agglomeration of diversified service factors is more conducive to improving the domestic added value of manufactured products than specialized agglomeration (Yu et al., 2020). The specialized cluster of *ICT* or finance, and the diversified cluster of transportation and commerce are more conducive to the upgrading of manufacturing industrial structure. Support service[2] agglomeration indirectly improves the quality of manufacturing industry through intermediate factors inputs and labor sharing mechanism, while basic service agglomeration through knowledge sharing system.

Here servitization of manufacturing is regarded as an important path for service ecology to promote digital trade, because (1) there is a self-regulating function between service ecology and manufacturing servitization. knowledge intensive business service can customize and satisfy the needs of service-oriented manufacturing only in "face to face" contacts (Lundquist, 2008; Lafuente et al., 2017). (2) The digital coupling of service and manufacturing helps to improve their digital absorption capacity and thus promote their digital outputs. In regions where service industries are weak while manufacturing industry clusters are mature, digital strategy stimulates the demand for manufacturing servitization, promotes the formulation of service ecology dominated by start-ups (Wyrwich, 2019), by mass utilization of new technologies in various production scenarios, that leads to innovative business model, which can integrate service resources, open up data flow, promote digital innovation and technical commercialization. This type of "demand-induced" service ecology can not only greatly reduce the risk of technological innovation, but also transform potential demand into effective demand, forming a virtuous circle of "demand pulls supply and supply creates demand". (3) Service ecology directly promotes digital trade, while manufacturing servitization promotes digital trade indirectly. Digital trade is defined as e-commerce in the early days (Andrew,2019; Chryssolouris et.al.2009), later refers to the Digital Intermediation Platform, App Economy, Cloud Computing and other digital carriers and digital infrastructure, aiming to produce digital products and services, such as information communication, content entertainment, business and finance, and cross-border delivery activities (Lia, 2011; IMF,2017;OECD,2019; Sheng and Gao,2020) aiming at rights transfer (Teltscher, 2000) concerned to data and information. Manufacturing servitization refers to the process to improve the digital absorption capacity and digital outputs by melting into producer service ecology, increasing qualified service inputs, digital transformation of process and supply-chain management, leading service inputs towards service produce and outputs. Based on Chinese complete manufacturing system, Digital Strategy will be conductive to more application scenarios, that will optimize service supply and enlarge service ecology. For example, when quantities of manufacturing enterprises replace worker with machines, it will foster demands for functional robots and automated production lines, attract mass capital into the robot-made industry, drive the application and development of artificial intelligence, Big Data, industrial IoT and other technologies, and finally lead to exports of production and service standard. When more and more digital manufacturers appear, the applicable scenarios become complex to create more service demand[3]. The goal of manufacturing

[2]According to the definition and classification of producer services by Michael Porter (2002), basic productive services are defined as "transportation, postal and storage industries", and support services are defined as information transmission, computer and software services,finance, leasing and business services, scientific research, technical services and geological exploration.

[3]Data from 2021 China Sharing Economy Development Report released by the State Information Center.

servitization is to drive exports of digital products such as standards, patents, software, applications and service content. to drive exports of digital products such as standards, patents, software, applications and service content.

The application of *ICT* technologies represented by software, programming, telecommunications and artificial intelligence in service clusters has promoted manufacturing servitization and digital trade competitiveness, which is mainly manifested in the following aspects: (1) ecological driving effect. In the process of serving multiple application scenarios, cluster enterprises gradually build a service ecology to provide integrated service solution by data interaction at service nodes. (2) Technology spillover effect. By improving the quality and efficiency of the service sector, supply of quality services will be increased to reduce the cost of services inputted for the manufacturing sector. (3) Economies of scale. For an entity, the stronger digital service capability it has, it is more capable to integrate various service resources applicable for manufacturing scenes, open up data flows of production, marketing, circulation, research and development, adapt to provide a package of service solutions, and establish the underlying architecture and technical standards to attract more participants, enlarge and optimize the service ecology, and further reduce the marginal cost. (4) Capability evolution effect. Through data mining, user portrait and business model remodeling, digital service capabilities are transformed into marketing capabilities, innovation capabilities and commercialization capabilities, thus promote the transfer from value creation to value capture. In this way, the productive efficiency of service is improved, and more digital products are included in the scope of visual transactions, thus enhancing the competitiveness of digital trade. Under the condition of open economy, service ecology and manufacturing servitization mutually promote, and directly or indirectly promote digital export.

Research Ideas and hypotheses

To sum up, it is of positive significance to promote the competitiveness of digital trade by building service ecology for manufacturing servitization. The service cluster based on knowledge sharing, industry association and social network construction use ICT technology to construct service ecology surrounding different application scenarios will help to improve the efficiency of integrated service, stimulate service demand of the manufacturing, and provide integrated service solutions for the manufacturing industry through value sharing and value co-creation activities, finally promote the production of digital products and enhance the competitiveness of digital trade. In this study, digital trade competitiveness is used to reflect the manufacturing industry's ability to produce digital products and participate in international exchange, and the ICT professional agglomeration level is used to reflect the technical service ability. Three hypotheses are put forward:

H_1: The higher the *ICT* specialized concentration level is, the stronger the digital service capability will be, which will induce greater service demand of the manufacturing.

H2: The more intense application of *ICT* technology in the service cluster, the higher efficiency of value creation activities in The service ecology, which means more possibility to stimulate the service demand of the manufacturing, open up the data flow of manufacturing and service, transform the digital absorption capacity into digital innovation, digital producing and digital marketing capabilities, and promote the export of digital products.

H3: There is heterogeneous impact of service inputs on the production of digital products due to diverse digital absorption capacity in different manufacturing industries. The more capable to absorb digital information, the more easier for the manufacturing to absorb the service efficiency spillover, that will lead to digital innovation, production and marketing activities and finally promote digital output and export. If the manufacturing is weaker to absorb digital information, it will highly depend on external services, with little motivation for independent innovation.

Few studies have focused on the influence and mechanism of producer service ecology on the export competitiveness of digital products from the perspective of digital absorptive capacity. In this study, the application of *ICT* technology is regarded as a necessary condition for the transformation from productive service cluster to service ecology, and the action path of service ecology on digital trade competitiveness can be divided into tow types: (1) Direct effects within the industry. Leading enterprises within specialized or diversified service clusters establish resource sharing platform supported by *ICT* technology, aiming to formulate chained or net service ecosystem that will directly promote the production and export of digital content, digital software and other digital products. (2) Indirect effects between industries. By promoting manufacturing servitization, service clusters possibly sign outsourced contract and get the integrated data flow of service and manufacturing based on which to create automatic production and intelligent management, formulating a digital service ecology that can provide integrated service solutions for and empowering the manufacturing industry.

VARIABLE SELECTION AND MODEL SETTING

Variable selection and economic connotation

Explained Variable

Digital Trade Competitiveness related to manufacturing industry (DST). A powerful trading country can benefit greatly from international trade, including two aspects: one is the increased proportion of its export volume to the world's exports; the other is the greater efficiency of resource allocation through commodity or factor imports (Yao, 2019). The calculation formula is:

$$DST_{it} = \beta_{it} \times \frac{1}{6}\sum_{j=1}^{6} RCA_{jt}, \quad RCA_{jt} = \frac{E_{jt}}{E_{jt} + M_{jt}} RCA_{jt}^{e} + \frac{M_t}{E_t + M_t} RCA_{jt}^{m} \qquad \text{(Formula 1)}$$

$$RCA_{jt}^{e} = X_{jt}^{d}/X_{jt}^{w}; RCA_{jt}^{m} = M_{jt}^{d}/M_{jt}^{w} \qquad \text{(Formula 2)}$$

Where, *DSTit* represents the digital trade competitiveness related to manufacturing industry *i* in year *t*, reflecting the contribution of manufacturing servitization to digital trade competitiveness. β*it* is the penetration rate of digital service to the manufacturing industry under the intra-industry trade terms, which is used to reflect the complete consumption coefficient of manufacturing industry *i* for the digital service sector in year *t*, and calculated

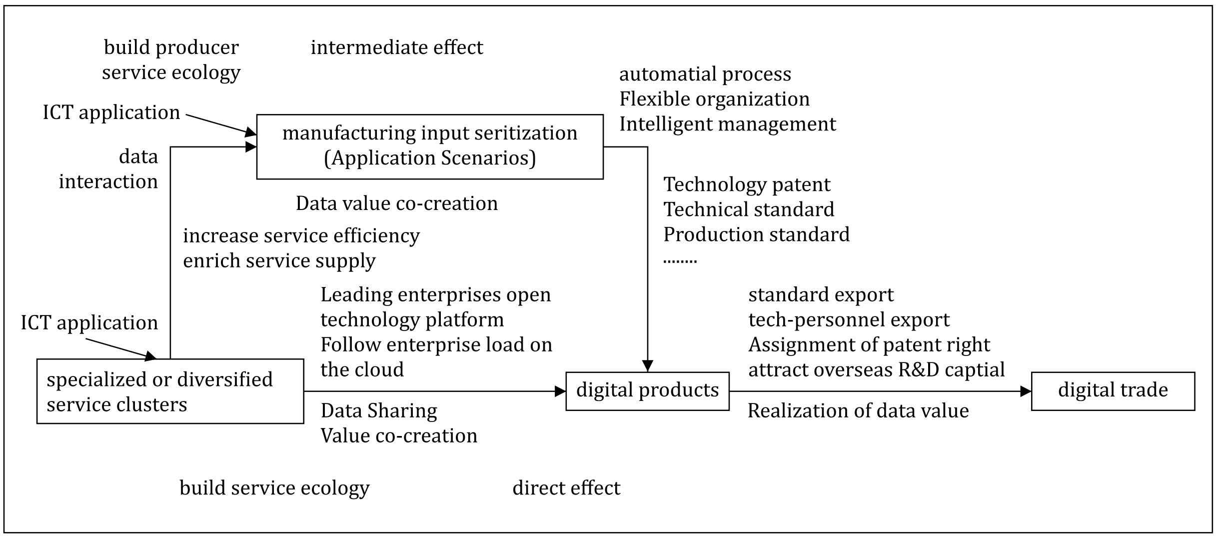

Figure 1. Influence path of service ecology on digital trade competitiveness

according to the data of the input-output table. represents the trade competitiveness index of digital service industry j in year t (j=1,2... , 6). E_{jt} and M_{jt} respectively represent the export volume and import volume of the world digital service industry j in year t. RCA_{ijt}^{e} represents the export comparative advantage index of digital service industry j in year t, X_{jt}^{d} （X_{jt}^{w}） represents the proportion of China's (world's) export volume of digital service industry j to China's (world's) export volume of total digital service. RCA_{jt}^{m} represents the import comparative advantage index, and M_{jt}^{d} （M_{jt}^{w}）represents the proportion of the import volume of China's (world's) digital service industry j to the import volume of China's (world's) total digital service. $DST_{it}>0$， The larger the value is, the stronger the competitiveness of digital trade, and the stronger the ability to participate in international value exchange for the relative producer ecology will be, which can cause significant "import for expanding export" circular effect.

Core Explanatory Variables

1. The specialized service cluster (SPE_{it}) and diversified service cluster (DIV_{it}) related to the manufacturing industry are respectively reflected by location entropy and Horsman-Herfindahl index. The relevant calculation formula is as follows:

$$SPE_{it} = \beta_{it} \text{ X,} \frac{\sum_{j=1}^{5} PS_{jt}}{5} PSj_{ijt} = L_{tdj}/L_{twj} \quad \text{(Formula 3)}$$

$$DIV_{it} = \beta_{it2} \times （1 - \sum_{j=1}^{5} {L_{tdj}}^{2}) \quad \text{(Formula 4)}$$

Where, SPE_{it} and DIV_{it} respectively reflect the specialized clusters and diversified clusters related to manufacturing industry i in year t, which are the bases for constructing chained and net service ecology by utilizing ICT technology. β_{it} is the complete consumption coefficient of manufacturing industry i for the digital service sector in year t, that is measured using data of the input-output table. PS_{ij} treflect the digital service industry j related to manufacturing industry i in year t, j= 1,2,3,4,5, respectively representing the five digital service industries of transportation, say, *ICT*, finance, business, scientific research and technology. L_{tdj} indicates the proportion of employment in Chinese service industry j to the total number of employment in the whole society in year t, L_{twj} indicates the proportion of employment in service industry j of the world to the total number of employment worldwide in year t.

2. Manufacturing-related service ecology can be reflected by the location entropy of the collaborative agglomeration of *ICT* and other producer services. The relevant calculation formula is as follows:

$$AGG_{it} = \beta_{it} \times \left[\left(1 - \frac{|PS_{2t} - PS_t|}{PS_{2t} + PS_t}\right) + |PS_{2t} + PS_t|\right], PS_t = L_{td}/L_{tw} \quad \text{(Formula 5)}$$

$$AGj_{it} = \beta_{it2} \times \left[\left(1 - \frac{|PS_{2t} - PS_{jt}|}{PS_{2t} + PS_{jt}}\right) + |PS_{2t} + PS_{jt}|\right] \quad \text{(Formula 6)}$$

Wherein, AGG_{it} reflects the net service ecology related to manufacturing industry i in year t. AGj_{it} refers to various chained service ecology formed by the application of *ICT* technology in specialized service cluster, j= 1,3,4,5, respectively representing service ecology, say, digital logistics, digital finance, digital commerce and digital technology. β_{it} is the complete consumption coefficient of manufacturing industry i on the productive service sector in year t measured with datus in the input-output table. PS_{2t} is the location entropy of *ICT* service industry in year t, and PS_t is the location entropy of non-information service industry in year t. L_{td} is the proportion of employment in the five categories of non-information service industry to the total number of employment in the whole society in year t. L_{tw} is the proportion of employment in the five categories of non-information service industry to the total number of employment in the world in year t.

Intermediate Variable

The level of manufacturing- input servitization (MOS_{it}). Based on the data of China's input-output table, the proportion of service products the input factors of manufacturing industry is calculated to reflect the input demand of manufacturing industry for service factors and map the level of manufacturing digitalization at input end. The defect value was replaced by the mean of the adjacent years.

$$MOS_{it}=\sum_{j=1}^{5} IS_{ijt}/INP_{it} \qquad \text{Formula 7}$$

Where, MOS_{it} is the input servitization level of manufacturing industry i in year t; IS_{ijt} reflects the inputted demand of manufacturing industry i for service industry j in year t, j= 1,2... 5; INP_{it} reflects the total input of intermediate products for manufacturing industry i in year t.

Variable of Control

Three control variables were selected in our study:

1. The attraction for foreign investment in manufacturing industry (INE)

$$INE = \frac{\text{Foreign capitals attracted in munufacturing industry}}{\text{real capital invested in manufacuring industry}}$$

2. The level of openness in the manufacturing (OPE)

$$OPE = \frac{\text{Number of foreign} - \text{invested enterprises in the munufactureing indurstry}}{\text{Number of enterprises above designated size in the munufacturing indurstry}}$$

3. (3) Energy consumption in manufacturing industries (COE),

$$COE=\frac{Energy\ consumption\ by\ sector}{Total\ energy\ consumption\ of\ manufacturing\ industry}$$

The definitions, data sources and economic connotations of each variable are shown in Table 1.

Table 1. Variable selection and economic connotation

Nature	Symbol	Economic connotation	Data source
Dependent variable	*DST*	Digital trade competitiveness related to manufacturing industry, reflecting the contribution of manufacturing service to digital trade.	Ministry of Commerce, State Administration of Foreign Exchange, International Trade Center (ITC)
Core independent variable	*SPE*	Specialized producer services clusters, reflecting the impact of chained clusters on digital output and exports	China Statistical Yearbook, ILO Statistics
	DIV	Diversify producer services clusters to reflect the impact of net clusters on digital output and exports	China Statistical Yearbook, ILO Statistics, China Input-Output Table
	PS1	Transport service cluster, reflecting the contribution of transport service to the manufacturing industry	Location entropy
	PS2	ICT service cluster, reflecting the contribution of information technology services to the manufacturing industry	Location entropy
	PS3	Financial service cluster, reflecting the contribution of financial services to the manufacturing industry	Location entropy
	PS4	Business service cluster, reflecting the contribution of business service to manufacturing industry	Location entropy
	PS5	Research and technology service cluster,reflecting the contribution of science and technology services to the manufacturing industry	Location entropy
	AGG	Coordinated agglomeration of ICT and other service industries,reflecting the contribution of network service ecology to the manufacturing industry	China Statistical Yearbook, ILO Statistics, China Input-Output Table
	AG1	Synergy of ICT and transport services,reflecting the contribution of digital logistics to the manufacturing industry	China Statistical Yearbook, ILO Statistics, China Input-Output Table
	AG3	Coordinated convergence of ICT and financial services, reflecting the contribution of digital finance to the manufacturing industry	China Statistical Yearbook, ILO Statistics, China Input-Output Table

	AG4	Coordinated convergence of ICT and business services, reflecting the contribution of digital commerce to the manufacturing industry	China Statistical Yearbook, ILO Statistics, China Input-Output Table
	AG5	Coordinated convergence of ICT and research and technology services, reflecting the contribution of digital technology services to the manufacturing industry	China Statistical Yearbook, ILO Statistics, China Input-Output Table
Intermediate variable	*MOS*	Input servitization Level of manufacturing, reflecting the investment for manufacturing digitalization. The larger this index is, the more conducive it is to improve the digital absorption capacity and promote digital output and export.	China Input-Output Table
Variable of control	*INE*	Openness of the manufacturing industry. If the competitive and knowledge spillover effect of foreign capital on local manufacturing are greater than market crowding-out effect, it is beneficial to digital production and export. Otherwise, it is not conducive to digital production and export.	China Statistical Yearbook
	OPE	Ratio of attracted foreign capital in manufacturing industry, reflecting potential technical innovation in manufacturing industry. The higher ratio means it's more likely to absorb know-how spillover and promote technological innovation, digital output and export.	China Statistical Yearbook
	COE	Ratio of energy consumption in manufacturing, reflecting the industrial capacity. Larger ratio means it's more likely to reduce the cost of digital production by scaled economy, and improve the competitiveness of digital trade.	China Statistical Yearbook

Model Setting

First, we establish an intermediary model that reflects the relationship between various producer service clusters and digital trade competitiveness.

$$DST_{it} = \beta_0 + \beta_1 PSj_{it} + \Theta CON_{it} + \epsilon_{it} \quad \text{Model 1-1}$$
$$MOS_{it} = \gamma_0 + \gamma_1 PSj_{it} + \Xi CON_{it} + \varpi_{it} \quad \text{Model 1-2}$$
$$DST_{it} = \tau_0 + \tau_1 PSj_{it} + \tau_2 MOS_{it} + \Psi CON_{it} + \pi_{it} \quad \text{Model 1-3}$$

Where, PSj_{it} reflects various producer service industry clusters, j=1,2,3,4,5, respectively reflects transportation ($PS1_{it}$), information communication ($PS2_{it}$), finance ($PS3_{it}$), business service ($PS4_{it}$), scientific research and technology ($PS4_{it}$) service.

Secondly, we establish an intermediary model reflecting the relationship between various digital services and digital trade competitiveness by considering the application of *ICT* in service clusters to build digital services.

$$DST_{it} = \beta_0 + \beta_1 AGj_{it} + \Theta CON_{it} + \epsilon_{it} \quad \text{Model 2-1}$$
$$MOS_{it} = \gamma_0 + \gamma_1 AGj_{it} + \Xi CON_{it} + \varpi_{it} \quad \text{Model 2-2}$$
$$DST_{it} = \tau_0 + \tau_1 AGj_{it} + \tau_2 MOS_{it} + \Psi CON_{it} + \pi_{it} \quad \text{Models 2-3}$$

Where, AGj_{it} (j=1,3,4,5) refers to digital logistics ($AG1_{it}$), digital finance ($AG3_{it}$), digital commerce ($AG4_{it}$) and digital technology ($AG5_{it}$) services formed by utilizing *ICT* technology.

EMPIRICALLY EXAMING THE IMPACT OF PRODUCER SERVICE ECOLOGY ON DIGITAL TRADE EOMPEITIVENESS

Descriptive Statistical Analysis

The standard deviation of digital trade competitiveness (*DST*) is 0.0639 and the range is 0.2515, indicating that diverse service industries have great differences in their ability to participate in international value exchange. The standard deviation (0.1014 vs.0.0244) and range (0.3699 vs.0.0941) of diversified producer service cluster (*DIV*) were larger than those of specialized cluster (*SPE*), indicating the dispersed degree is large, and that service network required by various manufacturing industries are significantly different. The large standard deviation (0.0008) and range (0.0034) of the digital absorptive capacity (MOS) indicate that

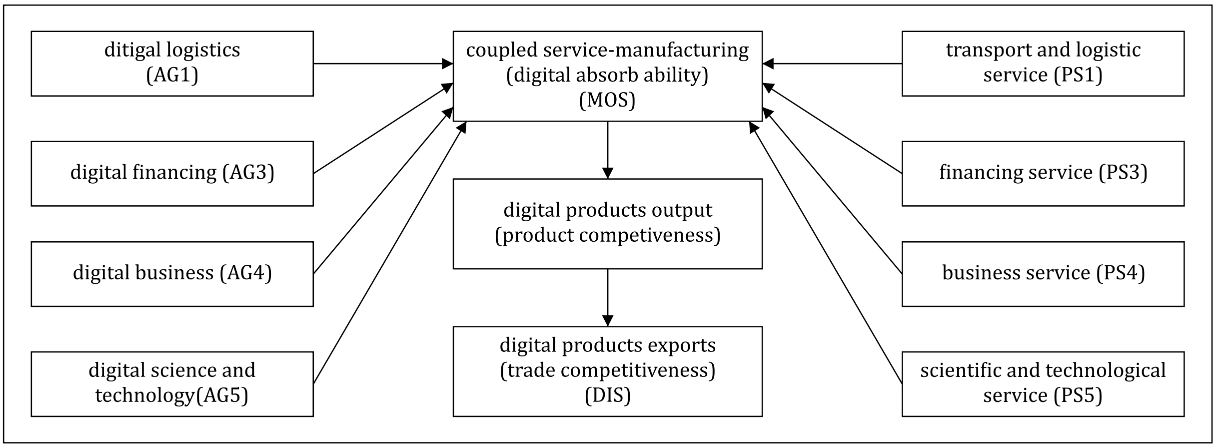

Figure 10. Impact of Service on of Digital Service Trade Competitiveness

Table 2. Descriptive statistics of variables

Variable	Mean value	Standard deviation	Minimum value	Maximum value
DST	0.0988	0.0639	0.0240	0.2755
SPE	0.0367	0.0244	0.0067	0.1008
DIV	0.1590	0.1014	0.0420	0.4119
MOS	0.0012	0.0008	0.0001	0.0035
PS1	0.0107	0.0086	0.0005	0.0380
PS2	0.0025	0.0024	0.0003	0.0125
PS3	0.0125	0.0127	0.0011	0.0527
PS4	0.0076	0.0058	0.0012	0.0227
PS5	0.0042	0.0035	0.0005	0.0145
AG1	0.0746	0.0604	0.0032	0.2676
AG2	0.0482	0.0514	0.0040	0.2081
AG3	0.0499	0.0350	0.0113	0.1398
AG4	0.0304	0.0237	0.0042	0.0963
AGG	0.2177	0.1435	0.0501	0.5927
INE	0.1307	0.0720	0.0004	0.3614
OPE	15.2093	7.9877	0.0000	48.4864
COE	3.5714	7.6052	0.0118	79.1428

different manufacturing industries have disparate ability for digital value-creation. The standard deviation and range of transport service (*PS1*), *ICT* service (*PS2*), financial service (*PS3*), business service (*PS4*), research and technical service (*PS5*) are (0.0086, 0.0375), (0.0024, 0.0122), (0.0127, 0.0516), (0.0058， 0.0215) and (0.0035，0.014) respectively. Among which, the standard deviation and range of financial service (*PS3*) and transportation service (*PS1*) are large, indicating that transportation and financial services required by manufacturing industries are obviously different. The standard deviation and range of digital logistics (*AG1*), digital finance (*AG3*), digital commerce (*AG4*), digital technology (*AG5*) and service ecology (*AGG*) are (0.0604, 0.264), (0.0514, 0.2041), (0.0350, 0.1285), (0.0237，0.0921) and (0.1435,0.5426) respectively, among which, the large standard deviation and range of service ecology (*AGG*), digital logistics (*AG1*) and digital finance (*AG3*) indicate that the service ecology built for various manufacturing industry differs, as well as their different contribution from digital logistics and digital finance.

Large range (0.3610 and 48.4864) for open degree (*INE*) and innovation potential (*OPE*) shows that manufacturing industries have different degree in openness and scientific and technological innovation capability. The largest range of *COE* (79.13.1) indicate that manufacturing industries differ in production capacity (see Table 2).

Unit Root Test

In order to avoid pseudo regression, we conducted HT test on short panel data. The results (see Table 3) show that all variables reject the null hypothesis at the 1% level, indicating that all variables are stable and integer of order 0.

Baseline Regression Results

According to the results of Hausman test, in order to eliminate heteroscedasticity, we used the fixed-effect model and cluster robust standard error to empirically test the influence of various services on the competitiveness of digital trade, and investigated the relative importance of services to manufacturing by utilizing relative importance analysis (*RI*) based on the *R2* method (Ye et.al.,2015).

Table 3. Unit root test results

Variable	Statistical value	Results	Variable	Statistical value	Results
DST	0.3652 ***	Stationary	Ag1	0.2386 ***	Stationary
SPE	0.3216 ***	Stationary	AG2	0.1838 ***	Stationary
DIV	0.3321 ***	Stationary	AG3	0.3225 ***	Stationary
MOS	0.4262 ***	Stationary	AG4	0.4351 ***	Stationary
PS1	0.2323 ***	Stationary	AGG	0.7232 ***	Stationary
PS2	0.4015 ***	Stationary	INE	-0.0414 ***	Stationary
PS3	0.1830 ***	Stationary	OPE	0.0882 ***	Stationary
PS4	0.2801 ***	Stationary	COE	-0.2457 ***	Stationary
PS5	0.4519 ***	Stationary			

Note: *** indicates stable at 1% level. All the results were calculated by utilizing Stata15.1.

Table 4. Results of mediating effect tests of services cluster on digital trade competitiveness

	Transportation Service Cluster (PS1)				Financial Service Cluster (PS3)		
	Model 1-1.1	Model 1-2.1	Model 1-3.1		Model 1-1.2	Model 1-2.2	Model 1-3.2
	DST	*MOS*	*DST*		*DST*	*MOS*	*DST*
MOS			26.2149****	*MOS*			11.7001****
			(3.7034)				(1.7558)
PS1	3.7499***	0.0512****	3.2863***	*PS3*	2.7934****	0.0395****	2.6394****
	(0.8514)	(0.0058)	(0.7436)		(0.3306)	(0.0042)	(0.3301)
INE	-0.0775	0.0035****	-0.0793	*INE*	-0.0690	0.0033****	-0.0703
	(0.0693)	(0.0008)	(0.0740)		(0.0610)	(0.0008)	(0.0639)
OPE	0.0010**	-0.0000*	0.0012***	*OPE*	0.0016***	-0.0000**	0.0016***
	(0.0004)	(0.0000)	(0.0003)		(0.0003)	(0.0000)	(0.0003)
COE	-0.0000	0.0000****	-0.0001	*COE*	-0.0000	0.0000****	-0.0001
Constant term	0.0148	0.0002**	-0.0056	Constant term	0.0141*	0.0004***	0.0050
	(0.0118)	(0.0001)	(0.0131)		(0.0073)	(0.0001)	(0.0081)
Time	Yes	Yes	Yes	*Time*	Yes	Yes	Yes
Industry	Yes	Yes	Yes	*Industry*	Yes	Yes	Yes
R2_a	0.912	0.329	0.916	*R2_a*	0.934	0.352	0.934
N	280	280	280	*N*	280	280	280

	Business Service Cluster (PS4)				Scientific Research & Technology Cluster (PS5)		
	Model 1-1.3	**Models 1-2.3**	**Models 1-3.3**		**Model 1-1.4**	**Model 1-2.4**	**Model 1-3.4**
	DST	*MOS*	*DST*		*DST*	*MOS*	*DST*
MOS			49.5808****	*MOS*			55.4031****
			(6.7691)				(6.8486)
PS4	5.0984***	0.0762****	4.8359****	*PS5*	6.2256***	0.1414****	6.4174***
	(1.5648)	(0.0082)	(0.5077)		(1.5920)	(0.0142)	(1.5084)
INE	-0.0045	0.0034****	-0.0168	*INE*	-0.0179	0.0026***	-0.0281
	(0.0575)	(0.0008)	(0.0683)		(0.0566)	(0.0008)	(0.0615)
OPE	0.0013***	-0.0000*	0.0015***	*OPE*	0.0020***	-0.0000*	0.0022****
	(0.0004)	(0.0000)	(0.0006)		(0.0004)	(0.0000)	(0.0002)
COE	0.0000	0.0000****	-0.0002	*COE*	-0.0001*	0.0000****	-0.0003***
	(0.0000)	(0.0000)	(0.0002)		(0.0000)	(0.0000)	(0.0001)
Constant term	0.0062	0.0002**	-0.0164	Constant term	0.0048	0.0003***	-0.0394**
	(0.0100)	(0.0001)	(0.0129)		(0.0108)	(0.0001)	(0.0128)
Time	Yes	Yes	Yes	*Time*	Yes	Yes	Yes
Industry	Yes	Yes	Yes	*Industry*	Yes	Yes	Yes
R2_a	0.895	0.347	0.919	*R2_a*	0.876	0.369	0.900
N	280	280	280	*N*	280	280	280

Note: ***, ** and * represent ρ<0.01,ρ<0.05 and ρ<0.1 separately.

Table 5. Results of mediation effect test of digital service on digital trade competitiveness

	Digital Logistics Service (AG1)				Digital Financial Service (AG3)		
	Model 2-1.1	**Model 2-2.1**	**Model 2-3.1**		**Model 2-1.2**	**Models 2-2.2**	**Model 2-3.2**
	DST	*MOS*	*DST*		*DST*	*MOS*	*DST*
MOS			30.3079***	*MOS*			12.7108***
			(4.1878)				(2.3541)
AG1	0.4900***	0.0022***	0.4167***	*AG3*	0.6736***	0.0026***	0.6338***
	(0.1240)	(0.0003)	(0.1014)		(0.0728)	(0.0002)	(0.0744)
INE	-0.0804	0.0002	-0.0818	*INE*	-0.0761	-0.0001	-0.0771
	(0.0709)	(0.0006)	(0.0759)		(0.0596)	(0.0005)	(0.0629)
OPE	0.0010**	-0.0000***	0.0012***	*OPE*	0.0016***	-0.0000	0.0016***
	(0.0004)	(0.0000)	(0.0004)		(0.0003)	(0.0000)	(0.0003)
COE	-0.0001	0.0000*	-0.0002	*COE*	-0.0000	0.0000*	-0.0001
	-0.0804	0.0002	-0.0818		(0.0001)	(0.0000)	(0.0001)
Constant term	0.0158	0.0012***	-0.0079	Constant term	0.0156**	0.0011***	0.0057
	(0.0125)	(0.0001)	(0.0141)		(0.0064)	(0.0001)	(0.0071)
Time	Yes	Yes	Yes	*Time*	Yes	Yes	Yes
Industry	Yes	Yes	Yes	*Industry*	Yes	Yes	Yes
R2_a	0.903	0.956	0.909	*R2_a*	0.933	0.963	0.934
N	280	280	280	*N*	280	280	280
	Digital Commerce Service (AG4)				**Digital Scientific Research & Technology Service (Ag5)**		
	Model 4-1.3	**Model 4-2.3**	**Models 4-3.3**		**Model 4-1.4**	**Model 4-2.4**	**Models 4-3.4**
	DST	*MOS*	*DST*		*DST*	*MOS*	*DST*
MOS			55.5665***	*MOS*			54.5489***
			(6.1897)				(7.1158)

AG4	1.2479***	0.0027***	1.0951***	*AG5*	1.1065***	0.0206****	1.1154***
	(0.0670)	(0.0006)	(0.0607)		(0.2449)	(0.0020)	(0.2508)
INE	0.1852***	0.0014**	0.1102*	*INE*	-0.0158	0.0026***	-0.0266
	(0.0682)	(0.0006)	(0.0599)		(0.0543)	(0.0008)	(0.0586)
OPE	0.0020***	0.0000	0.0018***	*OPE*	0.0019***	-0.0000*	0.0021***
	(0.0005)	(0.0000)	(0.0005)		(0.0003)	(0.0000)	(0.0003)
COE	0.0001	0.0000*	-0.0002	*COE*	-0.0001**	0.0000***	-0.0003***
	(0.0003)	(0.0000)	(0.0002)		(0.0000)	(0.0000)	(0.0001)
Constant term	-0.0191**	0.0008***	-0.0633***	Constant term	0.0026	0.0003***	-0.0406***
	(0.0091)	(0.0001)	(0.0093)		(0.0100)	(0.0001)	(0.0121)
Time	Yes	Yes	Yes	*Time*	Yes	Yes	Yes
Industry	Yes	Yes	Yes	*Industry*	Yes	Yes	Yes
R2_a	0.899	0.950	0.924	*R2_a*	0.881	0.387	0.904
N	280	280	280	*N*	280	280	280

Note: ***, ** and * represent $\rho<0.01$,$\rho<0.05$ and $\rho<0.1$ separately.

Results (see Table 3 and Table 4) show that all types of services significantly promote digital output and enhance digital trade competitiveness (*DST*) by promoting service and manufacturing coupling (*MOS*). Industrial Convergence (*MOS*) plays an active intermediary role in the influence path of promoting digital trade competitiveness with services.

Relative Importance Analysis

Results (see Table 5) show that digital services formed by utilizing *ICT* technology in service clusters have significantly improved the competitiveness of digital trade. The application of *ICT* makes the impact of transportation service on digital export (*PS1→AG1*) changed from negative effect to positive effect. The order of importance of digital services is: digital commerce (*AG3*, *RI*=30.28%) ,digital finance (*AG3*, *RI*=22.93%) ,digital technology (*AG5*, *RI*=17. 17%) ,digital logistics (*AG1*, *RI*=16.35%) , service ecology (*AGG*, *RI*=1.29%), This indicates that knowledge-intensive professional services are more conducive to promoting the coupling of the two industries and enhancing the competitiveness of digital trade.

The comparative study shows that digital transformation of service cluster increase its contribution to the competitiveness of digital trade significantly. The contribution of business service (*PS4→AG3*) jumps from 17.24% to 30.28%, and its importance ranks from the second to the first. The contribution of financial services (*PS3→AG2*) increased from 16.32% to 22.93%; The contribution of logistics service (*PS1→AG1*) increased from 13.45 percent to 16.35 percent. The contribution of science and technology service (*PS5→AG4*) increased from 9.35% to 17.17%, and its importance rose from the fifth to the third, indicating that the application of information technology (*ICT*) in the service cluster is conducive to constructing service network (Kolko, 2010), and improving efficiency of service-manufacturing coupling and digital absorption capacity (*MOS*). For a manufacturing industry with stronger digital absorptive capacity (*MOS*), stronger mediating role will happen to promoting digital export through producer services.

To sum up, both service clusters and digital services have effectively improved the competitiveness of digital trade. Digital services, especially digital commerce (*AG4*) and digital finance (*AG3*) have played a greater role.

Table 6. RI analysis of different mediation models

	Model 1-3	RI of Model 1-3		Models 2-3	RI of Models 2-3
	DST	DST		DST	DST
DIV	0.6056***	33.08% [1]	*AGG*	0.0127**	1.29% [8]
	(0.0125)			(0.0060)	
PS1	-0.8346***	13.61% [4]	*AG1*	0.2232***	16.35% [4]
	(0.1238)			(0.0243)	
PS3	0.1981**	4.53% [6]	*AG3*	0.4256***	22.93% [2]
	(0.0856)			(0.0331)	
PS4	0.4112**	16.32% [3]	*AG4*	0.5799***	30.28% [1]
	(0.2076)			(0.0620)	
PS5	1.2907***	17.24% [2]	*AG5*	0.7413***	17.17% [3]
	(0.3137)			(0.0946)	
MOS	2.5390***	10.73% [5]	*MOS*	10.2109**	5.73% [5]
	(0.5780)			(4.7110)	
INE	0.0003***	1.73% [8]	*OPE*	0.0006*	2.05% [7]
	(0.0001)			(0.0003)	
OPE	0.0162**	2.63% [7]	*INE*	-0.0071	4.01% [6]
	(0.0079)			(0.0399)	
COE	0.0000	0.13% [9]	*COE*	-0.0000	0.19% [9]
	(0.0001)			(0.0002)	
Time	Yes		*Time*	Yes	
Industry	Yes		*Industry*	Yes	
R2_adj	0.992		*R2_adj*	0.969	
N	280	280	*N*	280	280

Note: ***, ** and * represent ρ<0.01,ρ<0.05 and ρ<0.1separately. R2 decomposition method was adopted in RI analysis, and percentage represent contribution degree, that is, the variance contribution of each variable to the goodness of fit R2 for the dependent variable. and data in [ ] is the relative importance ranking of each variable. All results are calculated using Stata15.1.

EVALUATION OF DIGITAL ABSOPTIVE CAPACITY AND TEST BY GROUP

Digital absorptive capacity evaluation and grouping

We use the degree of coupled manufacturing and service to reflect the digital absorption capacity, and believe that the higher coupling degree of the two industries, the better for the service align to the manufacturing, the stronger the digital absorption capacity will be. Here, the Coupling Coordination Degree Model is used to measure the level of fit of 28 manufacturing industries and 5 producer services. The data are derived from China Statistical Yearbook, China Industrial Statistical Yearbook and Statistical Bulletin of National Economic and Social Development. Steps of measurement are as follows:

The first step is to build an evaluation system for industrial coordinated development from three dimensions: industrial scale, economic benefits and growth potential (see Table 6).

In the second step, a dimensionless processing are carried out for the data by using the range method. The relevant formula is as follows:

$$\chi_{ij} = \frac{(X_{ij}-Max_{ij})}{Max_{ij}-Min_{ij}} \times 0.99 + 0.01 \quad \text{(Formula 8)}$$

Where, X_{ij}, Max_{ij} and Min_{ij} respectively represent the order parameter, maximum value and minimum value of the jth index of subsystem *i*.

The third step is to design the index weight. The entropy weighting method was used to determine

Table 5. Evaluation system of industrial comprehensive development level

Subsystem (*i*)	Order parameter (*j*)	Measure	Unit
Manufacturing subsystem (i =1)	Industrial scale (j =1)	Number of Enterprise Units	individual
		Investment in fixed assets	100 million yuan
		Total profit	100 million yuan
	Economic benefit (j =2)	Total profit/employment	Yuan/person
		Total profit/(main business cost + three period expenses)	%
	Growth potential (j =3)	Growth rate of investment in fixed assets	%
		Profit rate of operating income	%
		Number of R&D projects	%
Service Subsystem (i = 2)	Industrial scale (j =1)	Number of Enterprise Units	individual
		Investment in fixed assets	100 million yuan
		Industry added value	100 million yuan
	Economic benefit (j =2)	Value added/employment	Yuan/person
	Growth potential (j =3)	Growth rate of investment in fixed assets	%
		Growth rate of industry added value	%

the entropy weight of each index (ε_{ij}), and the comprehensive development level of manufacturing industry (Um) and productive service industry (Us) was calculated.

$$U_i = \sum_{j=1}^{n} \varepsilon_{ij}\chi_{ij},\ i=m,\ s \quad \text{(Formula 9)}$$

Wherein, the entropy weight of the jth index is calculated as follows:

1. Specific gravity of the j^{th} index in subsystem i is transform $\rho_{ij} = \frac{\chi_{ij}}{\sum_{t=1}^{T} \chi_{ij}}$, t is the year, and the sample interval is 2010-2019, so T=10;
2. Calculate the entropy $\psi_j = -\frac{1}{ln(T)} \times \sum_{t=1}^{T} \rho_{ij}\, ln\rho_{ij}$ and difference coefficient $\phi_j = 1 - \psi_j$ of the j^{th} index;
3. Calculate entropy weight of the j^{th} index in subsystem i, $\varepsilon_{ij} = \frac{\phi_j}{\sum_{j=1}^{n} \phi_j}$

The fourth step is to calculate the coupling degree of manufacturing industry and productive service industry by using the coupling coordination degree model. The coupling degree is calculated as per $C = \frac{2\times\sqrt{U_m \times U_s}}{(U_m+U_s)}$, the coupling coordination degree model is $D_{ms} = \sqrt{C \times T}$, and the comprehensive coordination index of the two industries is $T = \alpha U_m + \beta U_s$ ($\alpha = 0.5$, $\beta = 0.5$).

The fifth step is to analyze the calculated results (see Table 7) according to the evaluation criteria for the coupling and coordinated development of the two industries (Tang et al., 2018).

Table 6. Evaluation criteria of the integrated development level and digital absorption capacity of the two industries.

Coupling coordination value (D_{ms})	Stage of Coupling development	Digital absorption capacity	Coupling coordination value (D_{ms})	Coupling development stage	Digital absorption capacity
D_{ms} ε (0.9, 1)	Superior coordinated development	perfect absorption	D_{ms} ε (0.4, 0.5)	Near disorder recession	weak absorption
D_{ms}ε (0.8, 0.9)	Favorable coordinated development	Strong absorption	D_{ms}ε (0.3, 0.4)	Slightly disorder recession	Mild weak absorption
D_{ms}ε (0.7, 0.8)	secondary coordinated development	Good absorption	D_{ms}ε (0.2, 0.3)	Moderate disorder decline	Moderate weak absorption
D_{ms}ε (0.6, 0.7)	Primary coordinated development	primary absorption	D_{ms}ε (0.1, 0.2)	Severe disorder recession	Severe weak absorption
D_{ms}ε (0.5, 0.6)	barely coordinated development	slightly absorb	D_{ms}ε (0, 0.1)	Extreme disorder recession	Extremely weak absorption

The coupling coordination degree model was used to calculate the integration level of manufacturing and services from 2010 to 2019 (see Figure 3), according to which the digital absorption capacity of different manufacturing industries could be judged.

From 2010 to 2019, the digital absorptive capacity of manufacturing sectors are rising (see Figure 7). From the average value, the coupling coordination degree of pharmaceutical and instrument manufacturing are superior (0.9< D_{ms}<1), which show perfect digital absorption ability. Eleven sectors, including food manufacturing, wine, beverage and refined tea manufacturing, leather, fur, feathers and their manufactured products, and furniture manufacturing, have entered a favorable coordinated stage (0.8<Dms<0.9), showing strong digital absorption capacity. Ten manufacturing sectors, including textiles, clothing, chemical raw materials and chemical products, are developed in the secondary coordinated stage (0.7<D_{ms}<0.8), indicating good digital absorption ability. The four manufacturing sectors, including tobacco products and textiles, are at the initial stage of coordinated development, showing a primary digital absorptive capacity. The coupled and coordinated level of the two industries of agricultural and sideline food processing is the lowest, just in barely coordinated development stage, and the digital absorption capacity is poor (see Table 8).

Therefore, 13 manufacturing sectors with superior or strong absorption capacity were classified into the Group A, 10 manufacturing sectors with good absorption capacity were classified into Group B, and 5 manufacturing sectors with primary or poor absorption capacity were classified into Group C. The impact of digital services on digital trade competitiveness and the mediating effect of manufacturing servitization will be grouped tested in order to determine which types of digital services are more conducive to enhancing the competitiveness of digital trade under various levels of absorption capacity.

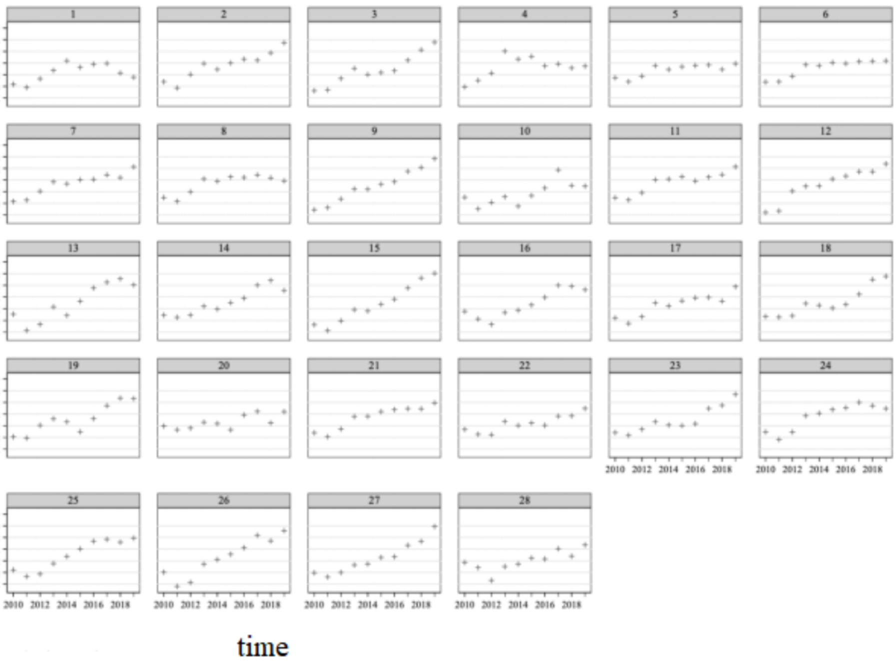

Figure 3. Level of Service-Manufacturing Coupling (2010-2019)

Note: Icons is the code m, m=1,2...28, representing the corresponding manufacturing sectors shown as Table 7.

Table 8. Calculation of coupling values of manufacturing and service sectors

Manufacturing sectors	Code (D_m)	Coupling Value	Manufacturing sectors	Code (D_m)	Coupling Value
Pharmaceutical manufacturing	D_{15}	0.903	Chemical raw materials and products	D_{14}	0.756
Instrument and meter manufacturing	D_{27}	0.894	Chemical fiber manufacturing	D_{16}	0.763
Food manufacturing	D_2	0.873	Rubber and plastic products	D_{17}	0.789
Alcoholic beverages and refined tea manufacturing	D_3	0.878	Non-ferrous metal smelting	D_{20}	0.720
Leather, fur, feathers and articles thereof	D_7	0.813	Articles of metal	D_{21}	0.795
Furniture manufacturing	D_9	0.883	Manufacture of special equipment	D_{22}	0.748
Printing and recording media reproduction	D_{11}	0.815	Transportation equipment manufacturing	D_{24}	0.747
Culture, education, beauty, sports and entertainment manufacturing products	D_{12}	0.813	Electrical machinery and equipment manufacturing	D_{25}	0.794
Oil processing	D_{13}	0.804	Other Manufacturing	D_{28}	0.737
Non-metallic mineral products	D_{18}	0.878	The tobacco industry	D_4	0.675
Ferrous metal smelting	D_{19}	0.832	textile	D_5	0.694
Manufacture of special equipment	D_{23}	0.867	Working of wood	D_8	0.693
Manufacture of computer communications and other electronic equipment	D_{26}	0.859	Paper and paper products	D_{10}	0.648
Textile clothing and apparel	D_6	0.719	Agricultural and sideline food processing	D_1	0.579

Table 8. Test results of Group A (with strong absorption capacity)

	Digital Logistics Service (AG1)				Digital Financial Service (AG3)		
	Model 2-1.1	**Model 2-2.1**	**Model 2-3.1**		**Model 2-1.2**	**Model 2-2.2**	**Model 2-3.2**
	DST	*MOS*	*DST*		*DST*	*MOS*	*DST*
MOS			11.8477***	*MOS*			7.1855*
			(4.0429)				(3.7929)
AG1	1.0566****	0.0068***	0.9757***	*AG2*	0.6316***	0.0093***	1.2955***
	(0.0560)	(0.0013)	(0.0608)		(0.0409)	(0.0015)	(0.0714)
INE	0.0326	0.0084***	-0.0675	*INE*	-0.2461**	0.0078***	-0.1128*
	(0.0660)	(0.0015)	(0.0724)		(0.1003)	(0.0015)	(0.0658)
OPE	0.0014***	-0.0000**	0.0017***	*OPE*	0.0002	-0.0000**	0.0014***
	(0.0005)	(0.0000)	(0.0005)		(0.0006)	(0.0000)	(0.0005)
COE	0.0006	0.0001***	-0.0002	*COE*	0.0010*	0.0001***	-0.0004
	(0.0004)	(0.0000)	(0.0005)		(0.0006)	(0.0000)	(0.0005)

Constant term	-0.0086	-0.0004**	-0.0043	Constant term	0.0943****	-0.0002	0.0201***
	(0.0078)	(0.0002)	(0.0077)		(0.0085)	(0.0002)	(0.0067)
Time	YES	YES	YES	*Time*	YES	YES	YES
Industry	YES	YES	YES	*Industry*	YES	YES	YES
R2_adj	0.800	0.483	0.813	*R2_adj*	0.925	0.508	0.843
N	128	128	128	*N*	128	128	128
	Digital Commerce Service (Ag4)				**Digital Scientific Research Technology (Ag5)**		
	Model 2-1.3	**Model 2-2.3**	**Model 2-3.3**		**Model 2-1.4**	**Model 2-2.4**	**Model 2-3.4**
	DST	*MOS*	*DST*		*DST*	*MOS*	*DST*
MOS			61.3916***	*MOS*			11.5471***
			(8.4222)				(3.4536)
AG3	1.2576***	0.0110***	1.1671****	*AG4*	2.5847***	0.0155***	2.4053***
	(0.0937)	(0.0019)	(0.0783)		(0.1149)	(0.0030)	(0.1225)
INE	0.3429***	0.0084***	0.2847***	*INE*	-0.0764	0.0078***	-0.1667***
	(0.1077)	(0.0015)	(0.0892)		(0.0579)	(0.0015)	(0.0617)
OPE	0.0007	-0.0000**	0.0006	*OPE*	0.0013***	-0.0000**	0.0016***
	(0.0007)	(0.0000)	(0.0006)		(0.0005)	(0.0000)	(0.0004)
COE	-0.0001	0.0001***	-0.0000	*COE*	0.0011***	0.0001***	0.0003
	(0.0007)	(0.0000)	(0.0006)		(0.0004)	(0.0000)	(0.0004)
Constant term	-0.0197	-0.0003**	-0.0786***	Constant term	0.0041	-0.0003	0.0072
	(0.0122)	(0.0002)	(0.0129)		(0.0067)	(0.0002)	(0.0065)
Time	YES	YES	YES	*Time*	YES	YES	YES
Industry	YES	YES	YES	*Industry*	YES	YES	YES
R2_adj	0.910	0.491	0.939	*R2_adj*	0.848	0.474	0.861
N	128	128	128	*N*	128	128	128

Note: ***, ** and * stand for ρ<0.01,ρ<0.05 and ρ<0.1 respectively.

Table 8. Test results of Group B (with moderate absorption capacity)

	Digital Logistics Service (AG1)				**Digital Financial Service (AG3)**		
	Model 2-1.1	**Model 2-2.1**	**Model 2-3.1**		**Model 2-1.2**	**Model 2-2.2**	**Model 2-3.2**
	DST	*MOS*	*DST*		*DST*	*MOS*	*DST*
MOS			22.2056**	*MOS*			19.6964***
			(10.0663)				(4.7039)
AG1	0.5205***	0.0043***	0.4809***	*AG2*	0.6934***	0.0046***	1.2630***
	(0.0710)	(0.0012)	(0.0716)		(0.0529)	(0.0016)	(0.0721)
INE	-0.2383**	0.0064***	-0.2392***	*INE*	-0.0858	0.0071***	0.0760
	(0.0914)	(0.0013)	(0.0892)		(0.0667)	(0.0013)	(0.0665)
OPE	0.0028**	-0.0001***	0.0029**	*OPE*	0.0023***	-0.0001***	0.0013*
	(0.0012)	(0.0000)	(0.0011)		(0.0008)	(0.0000)	(0.0007)
COE	-0.0001	0.0000	-0.0002	*COE*	-0.0001	0.0000	-0.0005*
	(0.0003)	(0.0000)	(0.0003)		(0.0002)	(0.0000)	(0.0003)
Constant term	0.0507**	0.0016***	0.0204	Constant term	0.0439***	0.0016***	-0.0204
	(0.0222)	(0.0003)	(0.0256)		(0.0160)	(0.0003)	(0.0148)
Time	YES	YES	YES	*Time*	YES	YES	YES
Industry	YES	YES	YES	*Industry*	YES	YES	YES
R2_adj	0.928	0.405	0.931	*R2_adj*	0.925	0.508	0.843
N	100	100	100	*N*	100	100	100

	Digital Commerce Service (AG4)				Digital Scientific Research Technology (Ag5)		
	Model 2-1.3	**Model 2-2.3**	**Model 2-3.3**		**Model 2-1.4**	**Model 2-2.4**	**Model 2-3.4**
	DST	*MOS*	*DST*		*DST*	*MOS*	*DST*
MOS			43.9282***	*MOS*			38.3700***
			(8.6113)				(11.5398)
AG3	1.2783***	0.0078***	1.0804***	*AG4*	0.8757***	0.0160***	0.8570***
	(0.0922)	(0.0018)	(0.0899)		(0.2818)	(0.0027)	(0.2651)
INE	0.2329**	0.0064***	0.1310	*INE*	-0.1214	0.0045***	-0.1302
	(0.0911)	(0.0013)	(0.0826)		(0.1145)	(0.0013)	(0.1077)
OPE	0.0037***	-0.0001***	0.0031***	*OPE*	0.0027*	-0.0001***	0.0028**
	(0.0009)	(0.0000)	(0.0008)		(0.0014)	(0.0000)	(0.0013)
COE	0.0001	0.0000	-0.0001	*COE*	-0.0001	0.0000	-0.0003
	(0.0003)	(0.0000)	(0.0002)		(0.0003)	(0.0000)	(0.0003)
Constant term	-0.0596***	0.0015***	-0.0893***	Constant term	0.0501*	0.0016***	-0.0060
	(0.0172)	(0.0003)	(0.0163)		(0.0289)	(0.0002)	(0.0320)
Time	YES	YES	YES	*Time*	YES	YES	YES
Industry	YES	YES	YES	*Industry*	YES	YES	YES
R2_adj	0.914	0.442	0.934	*R2_adj*	0.891	0.515	0.904
N	100	100	100	*N*	100	100	100

Note: ***, ** and * stand for ρ<0.01,ρ<0.05 and ρ<0.1 respectively.

Table 8. Test results of Group C (with weak absorption capacity)

	Digital Logistics Service (AG1)				Digital Financial Service (AG3)		
	Model 11.3-1	**Model 12.3-1**	**Model 13.3-1**		**Model 11.3-2**	**Model 12.3-2**	**Model 13.3-2**
	DST	*MOS*	*DST*		*DST*	*MOS*	*DST*
MOS			145.3333***	*MOS*			90.8173***
			(44.9863)				(24.7372)
AG1	0.0513***	-0.0041***	0.0190	*AG2*	0.1074***	-0.0019***	0.4862***
	(0.0184)	(0.0012)	(0.1514)		(0.0014)	(0.0003)	(0.1098)
INE	0.1157	-0.0031***	-0.2449	*INE*	-1.0513***	0.0017*	-1.4831***
	(0.1020)	(0.0007)	(0.2450)		(0.0127)	(0.0010)	(0.4350)
OPE	-0.0030***	0.0000*	-0.0034	*OPE*	0.0024***	0.0000***	0.0006
	(0.0006)	(0.0000)	(0.0032)		(0.0000)	(0.0000)	(0.0009)
COE	0.0005	0.0002***	-0.0082	*COE*	0.0026***	0.0000	-0.0036
	(0.0007)	(0.0001)	(0.0072)		(0.0000)	(0.0000)	(0.0031)
Constant term	0.0374***	0.0007***	0.0455	Constant term	0.1272***	0.0018	-1.8109
	(0.0080)	(0.0001)	(0.0350)		(0.0025)	(0.0079)	(1.9140)
R2	0.998	0.622	0.842	*R2*	0.999	0.996	0.994
N	50	50	50	*N*	50	50	50
	Digital Commerce Service (AG4)				**Digital Scientific Research Technology (Ag5)**		
	Model 11.3-3	**Model 12.3-3**	**Model 13.3-3**		**Model 11.3-4**	**Model 12.3-4**	**Model 13.3-4**
	DST	*MOS*	*DST*		*DST*	*MOS*	*DST*
MOS			111.9094***	*MOS*			180.6032***
			(39.8964)				(45.4100)
AG3	1.1920***	0.0044**	1.4337***	*AG4*	2.2362***	0.0051***	-0.7703**
	(0.3136)	(0.0018)	(0.4062)		(0.5138)	(0.0017)	(0.3784)

INE	0.1629	-0.0015	-0.3552	*INE*	0.1568*	-0.0006	-0.2943
	(0.1189)	(0.0010)	(0.2163)		(0.0912)	(0.0008)	(0.2346)
OPE	0.0050**	0.0000***	0.0061*	*OPE*	0.0079***	0.0000***	-0.0069**
	(0.0022)	(0.0000)	(0.0036)		(0.0026)	(0.0000)	(0.0033)
COE	0.0074	0.0000	-0.0063	*COE*	-0.0260***	0.0000*	-0.0065
Constant term	-0.0543**	0.0002	-0.0503	Constant term	-0.0169*	0.0432****	0.0718**
	(0.0253)	(0.0002)	(0.0392)		(0.0100)	(0.0100)	(0.0342)
	(0.0047)	(0.0000)	(0.0062)		(0.0090)	(0.0000)	(0.0068)
R2_adj	0.985	0.924	0.880	*R2_adj*	0.784	0.992	0.857
N	50	50	50	*N*	50	50	50

Note: ***, ** and * stand for ρ<0.01,ρ<0.05 and ρ<0.1 respectively.

Table 9. RI analysis of Model 2-3 tested in group

	RI value of Group C	**RI value of Group B**	**RI values of Group A**
	DST	*DST*	*DST*
Ag1	10.32% [4]	20.50% [3]	18.87% [4]
AG3	23.42% [2]	24.65% [2]	27.12% [2]
AG4	42.16% [1]	33.32% [1]	31.44% [1]
AG5	16.34% [3]	19.08% [4]	20.99% [3]
AGG	7.76% [5]	2.45% [5]	1.58% [5]

Note: ***, ** and * represent ρ<0.01,ρ<0.05 and ρ<0.1separately. R2 decomposition method was adopted in RI analysis, and percentage represent contribution degree, that is, the variance contribution of each variable to the goodness of fit R2 for the dependent variable. and data in [ ] is the relative importance ranking of each variable. All results are calculated using Stata15.1.

The three sets of regression results (see Table 9-Table 11) show that, by utilizing digital service to promote digital export, input servitization (*MOS*) will play different intermediary role due to various digital absorption capacity in manufacturing sectors: When the manufacturing sector has superior or strong digital absorption capacity, service inputs (*MOS*) plays a partial positive intermediary role, indicating that developing digital services (*AG1-AG5*) is helpful to promote digital output and enhance the competitiveness of digital trade by increasing digital inputs of manufacturing. When the manufacturing sector has weak digital absorption capacity, service inputs (*MOS*) plays a significant negative intermediary role initiated from digital logistics (*AG1*) and digital finance (*AG3*), while plays a partial positive intermediary role initiated path from digital commerce (AG4) and digital technology (*AG5*). This implies that for manufacturing sectors with weak digital absorption capacity, increasing service inputs will offset the impact of digital logistics (*AG1*) and digital finance (*AG3*) on digital export, but will intensify the promoting role of digital commerce (*AG4*) and digital technology (*AG5*) on digital export.

The relative importance analysis (*RI*) shows that, for the manufacturing sectors with weak digital absorption capacity, the contribution degree of digital services to the competitiveness of digital trade is ranked from largest to smallest as digital commerce (*AG4*), digital finance (*AG3*),digital technology (*AG5*),digital logistics (*AG1*) and digital service network (*AGG*); For manufacturing sectors with moderate digital absorption capacity, the contribution of digital services is ranked as digital commerce (*AG4*), digital finance (*AG3*), digital logistics (*AG1*), Digital technology (*AG5*) and Digital Service network (*AGG*); For manufacturing sectors with strong digital absorption capacity, the contribution of digital services is ranked as digital commerce (*AG4*), digital finance (*AG3*), Digital technology (*AG5*), digital logistics (*AG1*) and Digital Service network (*AGG*). Based on the existing infrastructure, the best way to promote digital output and export is to foster digital commerce (*AG3*) and digital finance (*AG2*) services and increase level of manufacturing input servitization.

In comparison, for manufacturing sectors with weak digital absorption capacity, digital commerce (*AG3*) and service ecology (*AGG*) contributed the most to digital output (42.16% > 33.32% > 31.44%; 7.76% > 2.45% > 1.58%); For manufacturing sectors with moderate digital absorption capacity, digital logistics (*AG1*) contributed the most to digital output (20.50% > 10.32% > 18.87%); For manufacturing sectors with strong digital absorption capacity, digital finance (*AG2*) and digital technology (*AG4*) contribute the most to digital output (27.12% > 23.42% > 24.63%, 20.99% > 16.34% > 19.08%), which indicates that in order to effectively promote digital export and enhance the competitiveness of digital trade under resource constraints, it is necessary to develop digital commerce (*AG3*) and building service ecology (*AGG*) agglomerated with diversified service factors around manufacturing sectors with weak digital absorption capacity, develop digital logistics (*AG5*) around manufacturing sectors with medium digital absorption capacity, and develop digital finance (*AG2*) and digital technology (*AG4*) around manufacturing sectors with strong digital absorption capacity.

Research Conclusions And Political Recommendations

Research conclusions

Based on China's 2010-2019 industrial panel data, this paper empirically examines the contribution of different types of service clusters to digital trade competitiveness before and after the application of *ICT* technology and the mediator effect of manufacturing input servitization, so as to determine which types of services are more conducive to promoting digital output and export through manufacturing with different digital absorption capacity. The results are as follows:

1. Building a producer servicing ecology is more conducive to promoting digital export, but this will be regulated and affected by the level of manufacturing input servitization and the application of information technology.
2. Developing digital services is conducive to increasing service demands by the manufacturing, and change the impact of transportation services on digital export from negative to positive. Developing digital commerce and digital finance can promote digital export through manufacturing servitization.
3. In order to promote digital output and export, we should emphatically develop digital finance and digital technology surrounding manufacturing sectors with superior or strong absorption capacity, develop digital commerce and formulate servicing ecology surrounding manufacturing sectors with primary or poor absorption capacity, and develop digital logistics surrounding manufacturing sectors with good absorption capacity.

Political recommendations

Based on the above research conclusions, relevant policy suggestions are put forward as follows:

1. Implement the integrated development strategy of service and manufacturing, that is, use information technology to improve the efficiency of digital services and the data coupling level between services and manufacturing, and based on which to co-create digital value and to produce and export digital products.
2. Accelerate the coupling of technology and service, technology and manufacturing, enrich application scenarios, and create more demands for digital products. We should

digitalize servicing clusters by utilizing information technology and give priority to developing digital commerce and digital finance so as to break financing bottlenecks and enhance commercialization capabilities. We should digitalize the manufacturing so as to expand the demand for digital products and promote the formation of a service ecosystem.

3. Considering the difference in digital absorption capacity, the service industry that should be mainly developed is different.Against manufacturing sectors with weak digital absorption capacity, the government should put the focuses on developing digital commerce and building a service ecology that provides integrated solutions. Against manufacturing sectors with medium digital absorption capacity, digital logistics will be mainly developed. Against manufacturing sectors with strong digital absorption capacity, the focus is on the development of digital finance and digital technology, to support manufacturing enterprises by financial product innovation to rebuild their business processes, introduce intelligent production lines, and accelerate digital output and export.
4. The government should guide leading manufacturing enterprises transformed into manufacturing service enterprises. Leading manufacturing enterprises should be encouraged to open their technology platforms to supply chain enterprises, through which they can pool resources, carry out data sharing and value co-creation activities, promote the production of technical standards, patents, software and other digital products, and at the same time improve the digital absorption capacity of platform enterprises, empower them with science and technology.

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