The Impact of Digital Economy Embedding on Trade and Export——Empirical Analysis Based on Transnational Panel

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Abstract. with the advent of the digital economy era, digital embedding has brought significant improvements to enterprise exports. This paper adopts the input-output table of 56 departments between countries in the world database, the social and economic account sea, the annual report of the Wall Street Journal and the American Heritage Foundation, the global information technology report and other data. From the theoretical level, this paper expounds that digital embedding can improve total factor productivity and promote enterprise exports by promoting technological progress, and also demonstrates the impact of digital embedding on enterprise exports from an empirical perspective. After considering the endogeneity, this paper finds that the digital economy can improve the total factor productivity and increase the export of enterprises. After considering the robustness, it is still established. Based on the heterogeneity test of countries with different economic levels, national digital economy development levels, and different industries, digital embedding has a differential impact on the export promotion of enterprises. This study provides empirical evidence for promoting the digitalization of investment and promoting the rise of trade exports, and broadens the policy connotation of theoretical research.

Keywords: Digital economy; total factor productivity enterprise; trade export

1. Introduction

With the advance of the fourth industrial revolution and the advent of the era of digital economy, digital economy is an economic form brought by information technology and communication technology, and has gradually become an important driving force for international economic development. Digital company is composed of Internet, digitization, company production mode and information innovation. Internet and other technologies have completely changed the characteristics of low efficiency and non trade of traditional service industry, making the trend of enterprise internationalization irreversible (Jiang Xiaojuan et al., 2020). According to the data released by the China Institute of information technology, the overall scale of the added value of China's digital economy has reached 32.6 trillion, accounting for 43.7% of GDP, an increase of 3.0% in nominal terms. Digital economy enables service transactions to be carried out through digital ordering or digital interaction, and realizes service transactions, cross-border data circulation transactions and goods trade (Yu miaojie et al., 2022). First, the rise of digital technology has achieved disintermediation, enabling consumers and producers to exchange information directly, and the number of cross-border trade in services and goods has increased. Secondly, data assets have the characteristics of increasing returns to scale, which leads to the reduction of the marginal cost of digital products, the improvement of their quality and the substantial increase of the scale of consumers, thus greatly improving trade exports (Chen Ling et al., 2022). Finally, the development of digital economy also realizes the accurate matching of consumer demand and producer supply, and reduces the information friction in economic activities. (Li Sanxi et al., 2021).

Under the complex situation of the COVID-19, the rising international trade protectionism and the stagnation of the development of the global industrial chain, the establishment of a new development pattern led by the domestic and international cycle and complementary to the domestic and global economic cycle has become the key task of China at this stage. (Wen Jun et al., 2021) the development of digital economy can not only effectively promote domestic and foreign market demand, but also promote the benign interaction between domestic demand and industry. It can also gradually spread and penetrate this international competitive advantage into foreign markets through the cooperation of multinational enterprise groups, so as to promote China's domestic economy to deeply integrate

into the global economic cycle. It is mainly reflected in the following aspects: firstly, the innovation and application of digital technology has established a timely and fast information interaction channel for small and medium-sized enterprises, reduced the mismatch between search cost and information technology through cost saving effect, effectively improved the information communication efficiency of small and medium-sized enterprises worldwide, and effectively reduced the communication and cooperation costs between small and medium-sized enterprises, information transaction costs, payment costs and transportation costs of trade links. Second, the use of digital economy technology reduces the time complexity of the connection of the value chain of small and medium-sized enterprises through effective information connection function, which not only increases the length of domestic manufacturing in the manufacturing link of the world value chain, but also helps to form a regional value chain dominated by China and the layout of China's economic innovation and development. Third, the domestic and international market effect is an important way to use digital economy technology to promote enterprises to form a domestic and international market cycle and two wheel drive development. The integration of digital economy and socio-economic activities not only promotes knowledge and innovation spillover, but also reduces the status of labor factors, so that the domestic market effect can be brought into full play, so as to promote the domestic and international cycle (Zhao Chunming et al., 2021).

With the advent of the new era of the development of China's digital economy, there are more and more discussions on digital economy and "digital dividend" in academic circles, which can be roughly divided into two levels. First, from the theoretical level, this paper analyzes the digital effect. Now many scholars begin to study the impact of digital effect on exports. For example, it is proposed that digital business technology can promote the development process of production management of small and medium-sized enterprises, so as to improve the number of enterprise network connections, save time and space costs, standardize value chain management, and enable small and medium-sized enterprises to climb to the high end of the value chain (Qiu Ying, Guo Zhouming, 2019). (Jiang Xiaojuan, Luo Libin, 2019) proposed that the development trend of digital service transaction can significantly improve the manufacturing and transaction efficiency of the world service industry, so as to reduce the manufacturing and transaction costs of the world service industry, promote the transaction development of the world service industry, and improve the export technology complexity of the world manufacturing industry. (Tan Donghua et al., 2022) from the perspective and theoretical level of the development of China's open market economy, this paper explores the four links of commodity production, sharing, trading and consumption in the process of social production development and expanding market reproduction cycle under the condition of trade digitization. The domestic and foreign boundaries are increasingly blurred and show the characteristics of "global integration", so that the domestic and international cycles have the objective conditions and foundation of "linkage". The second is to analyze the investment of digital effect from the empirical level. (Yi Jingtao, Wang Yuehao, 2021) according to the world bank's research data on global economy and other macro aspects in 2012, it can be concluded that digital development is conducive to the expansion of exports of small and medium-sized enterprises; Industrial development is coordinating the effective combination of digital production and export; The market competition environment also has a positive regulatory effect; The policy environment has a negative regulatory effect. Through wiod input and output information database, China's largest industrial enterprise information database and customs import and export information database, China has verified the micro impact of the digitization of input to different resources and the division level of industrial value chain (represented by export domestic added value rate edvar) (Zhang Qing, Yu Jinping, 2021). The data show that large digital investment has a very important improvement effect on enterprise edvar. By comparing China's industrial enterprise information and customs statistics from 2004 to 2009, this paper empirically investigates the combined impact of information network technology on industrial export and production level (Yue Yunsong et al., 2021). The survey shows that the Internet application has generally promoted the improvement of the production technology level of small and medium-sized enterprises. From the micro level, the digital index at the micro level of enterprises is

established, and it is concluded that the digital transformation of foreign trade enterprises has important positive significance for improving export efficiency (Hong Junjie et al., 2022). Based on the China customs database, the export quality of 5850 products in 31 provinces in China from 2013 to 2019 is estimated. The research shows that the digital economy can significantly improve the export quality, and after reverse causality It is still valid after selecting historical data as instrumental variables and adding "broadband China" as endogenous tests such as exogenous policy shocks (Li Yabo et al., 2022).

The defects faced in the existing literature are as follows: first, at present, few articles specifically study the digital effect and impact mechanism of investment from the perspective of the new development pattern of "double cycle", while more abundant research is needed to deeply grasp the impact of digital operation on modern service industry and foreign trade export. Second, most of the studies on the effect of digital input and the export of trade products are at the macro level, and the empirical evidence at the enterprise level is also very scarce. Only a few micro effect studies are limited to the individual perspectives of networking and artificial intelligence. Third, because the quantitative research and empirical test of most scientific research need to be filled, the scientific research on the effect of digital investment is still in the exploratory stage. Based on the above analysis, the most possible theoretical marginal contribution of the paper lies in: first, from the perspective of scientific research, on the digital effect of investment, based on the perspective of China's "double cycle" new development pattern, it not only puts forward strong opinions for "enjoying the growth dividend of Internet digitization and seizing the high position of the global value chain", but also helps to further clarify the impact mechanism of investing in Internet digitization on China's foreign trade and exports. Second, in terms of analysis content, it mainly analyzes the heterogeneity effect of digital economy from the development trend of digital economy in various developed countries, dividing the development level of digital economy in various countries, and distinguishing the development of manufacturing industry and service industry in various fields. At the same time, it also analyzes that data economy affects the export level through all factor output, so as to provide an empirical basis for promoting the digitization of enterprise investment and promoting the growth of foreign trade and export, Further expand the policy content of policy analysis.

2. Theoretical mechanism

The following mainly studies the specific mechanism that the development of digital economy is conducive to increasing foreign trade exports. First, digital economy can improve all factor productivity by promoting science and technology. On the other hand, due to the utilization of digital economy and society and the externality of the Internet, this cost structure has been gradually expanded, which has established a framework with high fixed cost and low inter edge value in the production and operation of enterprises, resulting in the gradual decline of the overall benefits of enterprise production and operation, thus forming the effect of small-scale operation (Yue Yunsong, 2021). In addition, the company also uses the multilateral network platform to accumulate the number of users, so as to reduce the operating cost, diversify the production of goods or businesses, and realize the scope operation under the situation of parallel development of various business models. In addition, using modern information technology and network technology to improve the matching effect of market supply and demand can not only improve the information redundancy in the operation of the market economic system, but also efficiently integrate the information resources at the two ends of market supply and demand, so that all effective information of both market supply and demand in the same space and time period can be integrated on the network platform, which greatly reduces the market transaction cost and improves the total factor productivity (Li Haijian et al., 2014). Secondly, total factor productivity is also the main factor of trade and export. The improvement of total factor productivity means the increase of the contribution of foreign technology to economic growth. Not only because Chinese digital products have opened up domestic and foreign markets, retained a large number of Chinese entrepreneurs, but also obtained more foreign-funded enterprises.

Therefore, the introduction of foreign technology is not only a channel of trade and export, Moreover, it helps to improve the market competitiveness and manufacturing quality of China's domestic digital products by means of international competition and product spillover. At the same time, the improvement of digital technology also provides a strong guarantee for the digital economy industry to participate in international competition, breaks the constraints of time and space, weakens the transaction risks and costs caused by information asymmetry, accurately matches the supply and demand sides, and drives the number of transactions of services and goods in the digital economy, It can promote the expansion of trade export scale (long Xiaoning, 2018). In addition, foreign direct investment enables enterprises to avoid the cognitive bias of a single domestic investor when making production and operation decisions, and brings rich resources and a broader perspective, which is conducive to the improvement of productivity. Hypothesis: digital economy can improve trade and export through total factor productivity.

3. Measurement model setting

1. Model setting

Based on the above theoretical calculation and existing research results, we determine the basic calculation mode as follows:

$$TRADE_{ijt} = A_0 + A_1 Dig_{ijt} + A_2 X + \alpha_i + \alpha_j + \alpha_t + \varepsilon_{ijt} \quad (1)$$

（1）Where: I, J and t respectively represent the country name, industry and time. Is the total amount of foreign trade exports, which is used to measure the amount of national foreign trade exports. Invest in digital level for industrial development. The focus of modeling is to estimate the coefficient, and the expected symbol is positive. Is the control variable, including: ① industrial scale (GO), expressed by total business output; ② Industrial capital intensity, (capital)expressed by the ratio of asset reserves of each industry to the number of employees; ③ Labor output of the service industry, (Labor)expressed by the ratio of the total output of the service industry to the number of employees in the industry; ④ Foreign capital inflow, the proportion of foreign capital inflow in GDP (FDI) ⑤ a country's economic development level, expressed in per capita GDP (nfba) ⑥ number of fixed broadband access (PCG) ⑦ added value of service industry / GDP (avi). α_i、α_j、α_t It provides a fixed effect for individual space, time and industry. ε_{ijt} Is a random error term. In order to avoid the problem of heteroscedasticity coefficient between control variables, this paper adopts natural logarithm treatment for each control variable.

(1) Explained variable

Trade export (): the data is from the 56 sector inter country input-output table in the wiod database. The data from 2000 to 2014 were selected as the explanatory variables. In the subsequent regression analysis, in order to alleviate the influence of heteroscedasticity, some variables were processed by natural logarithm.

(2) Core explanatory variable

Digitization of investment: the division of the category of numerical economy has always been an important cornerstone for measuring the digitization of investment. In fact, the digitization of investment measurement has always been a difficult problem to be solved by academic circles and statistical institutions. Due to the problems existing in the understanding and preparation of China's numerical economic and social satellite account system, it has not been completely solved, and it is still unable to clearly divide the accounting category and data type. Therefore, based on the global standard industrial division (ISIC rev4.0), this paper attempts to define the core basic elements of the digital economy, selects the supporting industries of the basic elements of the digital economy and society one by one in combination with the actual development of China's digital economy and society, and refers to the statistical institutions of some countries in the Development Conference (UNCTAD, 2019), OECD and other foreign institutions, as well as the accounting framework of the United

Nations Trade Commission for the digital economy and society as the definition criteria. Figure 1 shows the basic elements of digital economy and society and the main supporting industries of manufacturing this industry. Table 1 lists the elements of digital economy and the supporting industries for the production of this product.

Table 1. Division of digital economy 1

Core elements	Content	Relying on industry (ISIC rev4.0 classification)
Digital infrastructure	Telecommunication device research and service	J-61 wired, wireless, satellite and other telecommunications activities J-62 computer software research, consultation and implementation management
	Computer software	J-63 business activities such as data storage and management, and other information business activities not otherwise classified
	Computer hardware	C-26 design and manufacturing of electronic components, design and production of computers and peripheral products, mobile communication devices, electronic consumer goods, and production of detection, navigation and monitoring devices
Digital media	Online publishing and webcast	Creation and recording of j-59 video, video and Film Festival projects and release of music works
	Data flow service	J-60 network broadcasting, program creation and other activities

From the modern electronic measurement of industry, this paper summarizes the calculation method of "service" according to the absolute value index "complete energy consumption coefficient" proposed by Xu Helian et al. (2017) and the corresponding index "direct consumption coefficient" proposed by Yang Ling (2015). NRI_{ijt} Represents the direct consumption coefficient, which is used by manufacturing sector J for the direct consumption coefficient of digital economy supporting sector d . a_{dj} said that the complete energy consumption coefficient is estimated according to law, which is the vertical energy consumption coefficient of the manufacturing product unit part to the digital economy utilization part. The statistics are derived from the input-output table of 56 departments in the wiod database. The proportion of industrial electronization estimated by the complete energy consumption coefficient method is the total investment of "medium and high digital industry" required by a production department to produce a unit of output in a single national economy. The formula of calculation result is as follows: $D\text{igitization}_{ij}^{direct} = D_{ij} / O\text{utput}_j$ (2) Where, $D\text{igitization}_{ij}^{direct}$ represents the electronic penetration of the industry estimated by the complete energy consumption coefficient; Said that "intermediate investment of medium and high digital degree industry" in industry i "intermediate investment of industry i" : D_{ij} ;Output of industry J: $O\text{utput}_j$.

(3) Control variable

Industry scale: expressed by the total output of the industry (GO), it is generally believed that the total output of the industry is positively correlated with trade exports. The larger the industrial output, the larger the trade export. The data comes from the social and economic account sea. Industrial capital intensity: expressed by the ratio of capital storage volume of each industry to the number of employees. It is generally pointed out that there is a positive correlation between industrial capital storage volume and trade export. The greater the capital stock of the industry, the greater the trade

export. The data comes from the social and economic account sea. The data are from the socio-economic account sea. Industrial labor productivity (Labor), expressed by the ratio of total industry output to industry employees, is generally considered to be positively correlated with trade exports. The greater the labor productivity of the industry, the greater the trade export. The data comes from the social and economic account sea. Foreign direct investment (FDI): there is great uncertainty in the direct impact of foreign direct investment on the scientific and technological complexity of export commodities. On the one hand, driven by science and technology spillover and innovation effect, foreign direct investment can create resources for the host country to attract external leading science and technology, and improve the scientific and technological complexity of China's goods leaving the country; At the same time, the increase of foreign direct investment will cause greater international competition oppression to local small and medium-sized enterprises in a country, have a negative impact on their original resource advantages of export commodities and the positive role of scientific and technological innovation development, and finally reduce the scientific and technological complexity of China's export commodities. We use the financing amount of foreign-invested companies to measure foreign direct investment. Statistical source: WDI database, world commercial bank. Per capita GDP (nfba): GDP at home and abroad is the most intuitive reflection of a country's overall economic scale. Therefore, we choose to represent the per capita GDP by the ratio of regional GDP to population. A country's economic development scale has a positive impact on its scientific and technological output complexity. The higher the per capita GDP, the larger the country's economic development scale and the higher the scientific and technological output complexity. (Liu Zhijian, 2021) data source: WDI database, world bank. The number of fixed broadband access (PCG) generally believes that the number of fixed broadband access is positively correlated with trade exports. The greater the access of fixed broadband, the greater the trade export. The following information is from WDI database. The data of added value / GDP (AVI) of service industry is from WDI database. Economic freedom(freedom). The higher the degree of economic freedom of a country, the output of high-quality services can be driven by reducing trade barriers. Therefore, this paper mainly takes the international economic freedom index as the characterization variable. The higher the index, the higher the degree of economic freedom of a country. The data analysis is mainly from the annual statements published by the Wall Street newspaper and the American National Heritage Foundation. The overall measurement framework of network readiness index (NRI_{ijt}) is mainly composed of three-level indexes. In terms of dynamic factors, the readiness, application and external environmental factors of informatization jointly form the main driving force for the development of digital economy and society, and on this basis, it has a far-reaching impact on the whole economic and social Development (Dang Lin et al., 2021). The data comes from the global information technology report and is also processed logarithmically in the subsequent empirical analysis.

(4) Description of data source

The original data of trade and investment output are from the input-output table of the 2016 version of the wiod database, while the original data of digital business input are from the WDI database, the World Economic Forum (WEF database), the International Telecommunication Association (ITU), and the global commercial bank database (WDI). The original data information of industrial scale, industrial investment intensity and industrial average labor productivity are from the 2016 edition of wiod database. The original data information of sea, per capita GDP, total fixed broadband access, service industry added value / GDP and foreign direct investment are from the WDI database. The sample time range is 2000-2014. It must be noted that although there are 43 countries (regions) in the data of wiod2016, the data of control variables exclude the data of Taiwan, China, and the number of countries (regions) in the sample reaches 42, while the core analytic variables and explained variables delete the external doors and institutions. In this industry, there are 55 in the construction industry, 26 in the industry and 29 in the service industry. The statistical framework of regression in this paper is "region industry year", so our observation value is 33435.

4. Estimation results and analysis

1. Benchmark regression

Results Figure 2 shows the reported baseline regression results. In this paper, the stepwise regression method is used to show that column (1) is only the core explanation. The regression coefficients found in the results are negative, which can not preliminarily verify that the impact of digital economy input on trade output is positive. However, from the regression conclusions listed in (2) - (8) to further expand the control variables, it can be seen that the significance and symbol of the statistical relationship have fundamentally changed, and the measurement conclusion is also significantly positive. According to the analysis of the complete results of series (8), the lndiginput estimation coefficient is positive at the significance level of 1%, which shows that the input of digital economy and technology can improve trade and export, and it is confirmed that the input of digital economy can promote trade and export. The foundation of data economy is the electronization of trade, communication and transaction based on ICT. Firstly, digital technology widens the use field of commercial data, makes it easier for traders in trade to find the required data, reduces the data matching time of buyers and sellers, and reduces the data asymmetry; Secondly, the application of the network breaks through the limitations of time and space in the general business process. The use of communication methods such as website display, e-mail and digital marketing can reduce the human and material resources consumption of transnational business negotiation, reduce the communication, effectively reduce the overseas extra marketing cost and reduce the export risk of enterprises. Finally, the rapid development of information technology will enhance the modern management level of the company's product operation by enhancing the company's technological innovation, algorithm optimization, innovation and scientific and technological application. The transformation from data to information technology will improve the company's trade and export by improving efficiency and realizing data-driven information matching analysis, inventory control and production optimization, and then using the advantages of information technology.

Table 2 benchmark regression

variable	（1）	（2）	（3）	（4）	（5）	（6）	（7）	（8）
lndiginput	-0.021	0.054***	0.051***	0.051***	0.054***	0.053***	0.053***	0.054***
	(-0.916)	(2.844)	(2.672)	(2.726)	(2.855)	(2.833)	(2.832)	(2.858)
lngo		1.221***	1.262***	1.269***	1.272***	1.273***	1.273***	1.274***
		(74.805)	(66.149)	(66.081)	(66.350)	(66.387)	(66.693)	(66.724)
lncapital			-0.169***	-0.228***	-0.226***	-0.223***	-0.223***	-0.223***
			(-6.364)	(-7.561)	(-7.518)	(-7.406)	(-7.371)	(-7.374)
lnlabor				0.067***	0.068***	0.068***	0.068***	0.068***
				(3.206)	(3.268)	(3.268)	(3.265)	(3.276)
lnnfba					-0.066***	-0.070***	-0.070***	-0.072***
					(-6.146)	(-6.475)	(-6.275)	(-6.447)
lnavi						1.489***	1.491***	1.568***
						(3.362)	(3.382)	(3.554)
lnpcg							-0.015	0.002
							(-0.098)	(0.015)
lnfdi								-0.027***
								(-3.011)
Constant term	6.115***	-5.716***	-5.121***	-5.217***	-4.331***	-10.404***	-10.247***	-10.696***
	(80.776)	(-32.869)	(-30.146)	(-29.243)	(-18.616)	(-5.692)	(-3.975)	(-4.149)
National fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observed value	33,435	33,435	33,435	33,435	33,435	33,435	33,435	33,435
R^2	0.552	0.662	0.663	0.663	0.664	0.664	0.664	0.664

Remarks: * * *, * *, * represent significant at the level of 1%, 5% and 10%. The figures in brackets are t statistical values, the same below.

2. Robustness test

(1) Substitution variable test

This paper uses substitution variable regression to verify the robustness of the results. The world information technology research bulletin 2001 first proposed the definition of "network readiness index", which evaluates the requirements for the use of information and communication technology and the perfection of the development working environment from the perspectives of Internet infrastructure, the whole business and regulatory departments (Zhang Bochao, Shen Kaiyan, 2018). So we use "network readiness index" （NRI_{ijt}） replace estimated digital economy input level （$\mathrm{diginput}_{ijt}$）, taking the network employment index as a substitute factor for the data economy development level at the national level and replacing it with the core explanatory variable, the prediction results show that the estimation coefficient of digital economy investment is obviously positive at the level of 5%, which is consistent with the benchmark regression conclusion, which verifies that the comprehensive digital economy development of trading partner countries has significantly promoted the improvement of trade exports, and the conclusion is basically consistent with the above.

(2) Endogenous problem

Lag lndiginput for one period and replace the nuclear explanatory variable with (lndiginput_l),The calculation results show that the estimation coefficient of digital economic investment is obviously positive at the level of 5%, which is consistent with the benchmark regression results. It is also used as an instrumental variable to replace the kernel to explain the estimation coefficient of digital economic investment is obviously positive at the level of 1%, which is consistent with the basic regression results, which proves the authenticity of the research results of this paper. Therefore, it is highly possible that the questions of this paper are caused by the analysis of the core variables of the country. The variables that make the trade output lag by one period are regarded as instrumental variables and solved by two-stage least squares estimation (2SLS). At the same time, item (2) of Table 3 shows that the basic conclusion is still stable after investigating potential endogenous problems. At the same time, we also refer to the selection method of tool variables by Huang Qunhui et al. (2019) and select the total number of fixed phones in 1984 in the world's major developed countries as the main tool variable of digital economy investment. The internal logical reason is that the historical telecommunications infrastructure and industrial communication application habits of the modern Internet on which the social communication of the digital economy depends are constantly developing, and the regions with more stable telephone penetration in history are also very likely to be the regions with more current digital economy development level, and the number and frequency of fixed phones have little direct impact on the current trade output level, which meets the requirements of relevance and exclusivity of instrumental variables. In order to avoid the practical application of instrumental variables that do not change with the times in the panel data model, according to the processing method of Nunn & Qian (2014), the interactive term between the number of fixed telephones in 1984 and the industrial digital R & D investment of the previous year is constructed for 2SLS regression. The industrial digital R & D investment is based on the photoelectric technology The investment proportion of digital industrialization departments such as post and Telecommunications (Yang Huimei, Jiang Lu, 2021) is expressed by the product of the proportion of overall research investment of various countries. The specific tool variable structure is as follows:

$$IV_{cit} = N\mathrm{um\_p1984} \times \sum_j \mathrm{dig\_input}_{cj,\ t-1} \tag{2}$$

(3) Where, $N\mathrm{um\_p1984}$ the number of fixed line telephones in 1984, $\sum_j \mathrm{dig\_input}_{cj,\ t-1}$ it shows the variable effectiveness of intermediate investment tools in the industrialization sector of digital economy. The test results show that it is effective and feasible to select the interactive term composed of the number of fixed phones in history and the data R & D investment between industries in the previous year as the intermediate tool variable of digital economy penetration. After solving the endogenous problem, there is still a high degree of consistency between the regression results of digital economy investment on foreign trade output and the international benchmark regression

results, and continues to prove the improvement effect of digital economy investment on foreign trade output.

Table 3 robustness analysis

variable	（1） lnexport	（2） lnnri	（3） lndiginput_1	（4） iv
lnnri		0.027**		
		(2.036)		
lndiginput	0.055***		0.048**	0.063***
	(2.738)		(2.431)	(2.983)
lngo	1.264***	1.228***	1.257***	1.257***
	(62.230)	(74.047)	(65.635)	(65.662)
lngoempe	-0.238***		-0.212***	-0.212***
	(-7.388)		(-6.828)	(-6.813)
lnkempe	0.077***	-0.009	0.074***	0.074***
	(3.472)	(-0.461)	(3.393)	(3.404)
lnnfba	-0.068***	-0.071***	-0.089***	-0.090***
	(-6.068)	(-6.328)	(-5.544)	(-5.569)
lnavi	1.462***	1.697***	1.557***	1.558***
	(3.185)	(3.855)	(3.426)	(3.427)
lnpcg	0.030	-0.036	0.228	0.230
	(0.189)	(-0.233)	(1.232)	(1.242)
lnfdi	-0.030***	-0.026***	-0.016*	-0.016*
	(-3.131)	(-2.875)	(-1.779)	(-1.786)
Constant term	-10.517***	-11.369***	-13.394***	-13.345***
	(-3.946)	(-4.418)	(-4.871)	(-4.853)
National fixed effect	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes
Observed value	33,435	28,977	31,345	31,345
R^2	0.667	0.663	0.664	0.664

Note: the data in parentheses in column (1) is the statistical value of T; Column (2) Z statistics in parentheses.

3. This paper spans from 2000 to 2014, but considering the impact of the European financial crisis in 2008 and 2009, the historical data fluctuated greatly, which had a great impact on the stability of the regression results. In view of this, excluding the data of 2008 and 2009, there is no significant change in the estimation coefficient of digital economy investment after regression again, and the regression conclusion has good stability, as shown in Figure 3.

3. Scalability analysis

(1) Heterogeneity test based on countries with different economic levels

This paper explores the impact of cultural heterogeneity of countries with different economic levels on Trade and export. The regression conclusion is shown in columns (1) and (2) of Table 4 below. The estimation relationship of lndiginput is significantly positive in uneven, significantly positive in column (1) and not significantly positive in column ②. It is divided by taking logarithm according to the median of economic freedom. In column (1), the country with logarithm greater than

or equal to the median of economic freedom is the country with higher degree of economic freedom, and the country with logarithm less than the median of economic freedom in column (2) is the country with lower degree of economic freedom. It can be seen that the digital economy of countries with high economic freedom has a great impact on Trade and export. Countries with low degree of economic freedom, digital economy has little impact on trade exports. The degree of economic freedom reflects the degree of openness. The higher the degree of economic freedom, the higher the degree of economic openness and the completeness of its cooperation mechanism, which is conducive to the small and medium-sized enterprises of exporting countries to expand the scale of service export trade. First, the continuous rise of economic openness will promote the continuous expansion of the variety and total amount of digital commodity imports, and form a higher variety effect and science and technology spillover effect, so as to further improve the science and technology concentration of the output products of the home country and improve the output structure. Second, more high-tech service inputs will continue to reduce the production costs of small and medium-sized enterprises and improve the output efficiency of enterprises, so as to increase the openness of enterprises and introduce more high-tech digital intermediaries, so as to enhance the scientific and technological concentration of small and medium-sized enterprises' output services, so as to promote the growth of service exports. Third, the expansion of foreign markets, the subsequent expansion of demand and fierce international competition will inevitably continue to stimulate the national strength of home country companies to increase development investment, so as to improve trade exports.

Table 4 heterogeneity test based on countries with different economic levels

variable	（1）	（2）
lndiginput	0.079***	0.036
	(3.194)	(1.289)
lngo	1.165***	1.346***
	(69.729)	(41.089)
lngoempe	-0.073**	-0.267***
	(-1.971)	(-6.366)
lnkempe	0.117***	0.024
	(5.310)	(0.769)
lnnfba	-0.004	-0.095***
	(-0.185)	(-6.848)
lnavi	0.817	2.191***
	(1.157)	(3.753)
lnpcg	0.780***	-0.193
	(3.059)	(-0.959)
lnfdi	0.006	-0.045***
	(0.462)	(-3.209)
Constant term	-16.879***	-11.550***
	(-3.585)	(-3.536)
National fixed effect	Yes	Yes
Time fixed effect	Yes	Yes
Industry fixed effect	Yes	Yes
Observed value	16,688	16,747
R^2	0.751	0.600

(2) Heterogeneity test based on the development level of National Digital Economy

This paper studies the various effects of digital economy on foreign trade export under the development level of national digital economy. See columns (1) and (2) of table 5 for the return

conclusion. The estimated coefficient of lndiginput is significantly positive in column (2) and not significantly positive in column (1). It is divided by taking logarithm according to the median of online employment index (2009-2014). The countries with logarithm greater than the median of national digital economy development level in column (1) are countries with higher national digital economy development level, and the countries with logarithm less than the median of national digital economy development level in column (2) are countries with lower national digital economy development level. It can be seen that among the developed countries with relatively more development levels of digital economy in China, the impact of digital economy investment on Trade and export is relatively small. While China's digital economy development level is relatively small, China's digital economy investment has a great impact on Trade and export. The reason may be that digital economy investment has different marginal effects on the trade and exports of developed countries with different levels of digital economy development. Due to the higher development level of digital economy, the construction of digital infrastructure in developed countries starts earlier, and the coverage and popularity are generally higher. Therefore, the impact of digital economy investment on the trade and export of developed countries with higher development level of digital economy will be minimal or not obvious. However, for developed countries with low level of digital economy and social development, there are generally some characteristics, such as lagging speed of digital infrastructure construction, less information coverage, slow broadband speed and so on, which also shows that there is a large development space in the construction of digital infrastructure in these countries.

Table 5 heterogeneity test based on national digital economy development level

variable	（1）	（2）
lndiginput	0.034	0.142***
	(1.599)	(3.640)
lngo	1.284***	1.261***
	(62.355)	(24.639)
lngoempe	-0.239***	-0.091
	(-7.118)	(-1.240)
lnkempe	0.084***	0.036
	(3.738)	(0.708)
lnnfba	-0.047***	0.131
	(-4.172)	(0.266)
lnavi	1.219**	0.599
	(2.146)	(0.503)
lnpcg	-0.026	0.447
	(-0.127)	(0.555)
lnfdi	-0.006	-0.012
	(-0.576)	(-0.628)
Constant term	-9.394***	-15.527
	(-2.649)	(-1.435)
National fixed effect	Yes	Yes
Time fixed effect	Yes	Yes
Industry fixed effect	Yes	Yes
Observed value	17,165	16,270
R^2	0.683	0.610

3) Heterogeneity test based on different industries

This paper studies the impact of the development level of digital economy on foreign trade export in various industries. The regression conclusion is shown in columns (1) and (2) of table 6 below.

The statistical coefficients of lndiginput are significantly positive in both. By dividing different industries, the manufacturing industry is given a value of 0 and the service industry is given a value of 1. Item (1) lists the direct impact of the development level of digital economy on trade exports in the manufacturing industry, and item (2) lists the direct impact of the development level of digital economy on the quantity of trade exports in the service industry. It can be seen that the development level of digital economy in industry has a great negative impact on foreign trade exports, and the development level of digital economy in service industry has a great negative impact on foreign trade exports. Among them, it has a significant impact on the export of service industry. In the past, because of the immediacy of production and consumption process, the service industry has a series of characteristic attributes such as indivisibility, non storability and non tradability in space and time, which makes the traditional service industry unable to improve productivity with the help of large-scale operation. The rapid development and wide application of digital economy bring new opportunities to realize a large number of production transactions and optimize the allocation of resources in the value chain of the whole service industry, It also promotes the development of the global production and service system, resulting in the increasingly prominent problems of the decomposability of important links in the value chain and the tradability of intermediate industries. At the same time, the utilization quality and decentralization level of resources are also improving. At the same time, the electronization of financial services and the realization of online payment by using the advantages of computer technology have greatly enhanced the tradability of financial services, greatly promoted the transnational transaction of financial services, and promoted the growth of high value-added service industry in the world value chain (Yang Xiao et al., 2020). With the gradual embedding of China's digital economy, compared with the manufacturing industry, modern service industry is gradually becoming a hot spot for entrepreneurship and employment, which objectively shows that China is transforming from a power with demographic dividend to a power with human resources. Second, under the new situation of the development of the socialist market economy, there is a new demand for the technology of employees. Employees learn to apply modern technology to the service industry and can better grasp their advantages in international competition.

Table 6 heterogeneity test based on different industries

variable	(1)	(2)
lndiginput	0.065*	0.059***
	(1.785)	(2.593)
lngo	1.209***	1.282***
	(31.255)	(56.369)
lngoempe	0.025	-0.307***
	(0.422)	(-8.585)
lnkempe	0.080**	0.075***
	(2.255)	(2.808)
lnnfba	-0.090***	-0.066***
	(-4.179)	(-5.290)
lnavi	0.797	1.774***
	(1.086)	(3.342)
lnfdi	-0.022	-0.030***
	(-1.311)	(-2.834)
Constant term	-8.418***	-11.149***
	(-2.801)	(-5.091)
National fixed effect	Yes	Yes
Time fixed effect	Yes	Yes
Industry fixed effect	Yes	Yes
Observed value	7,995	25,440
R^2	0.647	0.674

5. Mechanism test of digital economy input affecting trade export

In order to prove hypothesis 2, this paper establishes an intermediary utility model by selecting total factor productivity as an intermediary variable to prove that government input or digital economy input affects all possible channels of foreign trade output. Here, total productivity (TFP) is expressed by the output of all production factors calculated by LP method.

Table 7 test results of action mechanism

variable	(1) lnexport	(2) tfp	(3) lnexport
lndiginput	0.506**	0.044*	0.369***
	(2.175)	(1.918)	(3.621)
tfp			2.251***
			(40.304)
lngoempe	0.562***	0.781***	-1.244***
	(17.653)	(146.194)	(-22.215)
lnkempe	-0.082***	-0.137***	0.226***
	(-3.459)	(-56.769)	(9.579)
lnnfba	-0.056***	-0.004**	-0.046***
	(-4.346)	(-2.394)	(-3.705)
lnpcg	1.605***	0.668***	0.138
	(9.138)	(19.488)	(0.774)
lnavi	0.820	0.252***	0.268
	(1.636)	(3.932)	(0.550)
lnfdi	-0.013	-0.009***	0.004
	(-1.199)	(-5.510)	(0.389)
Constant term	-17.771***	-7.564***	-0.854
	(-6.139)	(-14.915)	(-0.290)
National fixed effect	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes
Observed value	33,047	31,640	31,640
R^2	0.562	0.948	0.609

In the chart, the estimation results of the basic model are included in column 7 (1), and the estimation coefficient of lndiginput in column (2) is obviously positive, indicating that investment digitization can effectively reduce trade production costs, optimize operation effects and promote the output efficiency of small and medium-sized enterprises. This is consistent with hypothesis 1, which proves the accuracy of hypothesis 1. The investment digitization and productivity variables are also added in column (3), and the results show that TFP has effectively improved trade exports, This conclusion is consistent with the argument of LV Yue et al. (2020), and the estimated coefficient of lndiginput is obviously positive, and it is significantly reduced compared with the estimated value of the coefficient in column (1), indicating that the total factor productivity level of small and medium-sized enterprises can absorb the impact of digitization, and the level of foreign trade export can also be improved by increasing the total output through investment digitization, which also confirms hypothesis 1. Digital economy will affect the total factor productivity of society in four aspects: output factor information, productivity, technological upgrading and transformation of traditional industries and innovation of new industrial models: first, big data is another important output factor of digital economy. The data elements are characterized by strong information fusion, diminishing marginal cost, repeatability, easy transmission and strong information circulation. The data will penetrate into manufacturing, transportation, medicine, education and other fields, and improve the total factor productivity. Second, due to the vigorous development of new generation artificial

intelligence, blockchain, virtual reality, big data analysis and other high and new technologies, the vigorous development of new productivity will force the traditional form of productivity to change to a digital form of productivity with more transparent data, more perfect integrity system, more symmetrical information and faster exchange. The interaction and evolution between advanced productive forces and production relations in digital society will have a great impact on improving the level of human total factor productivity. Third, the large-scale application of digital information technology has promoted the transformation and upgrading of China's traditional industries, improved production efficiency by means of technology upgrading, data-driven decision-making and intelligent information processing, promoted cross-border integration of production by means of promoting the circulation of production factors, reducing transaction costs, coordinating and responding to requirements and jointly building a digital environment, and promoted the allocation of resource factors by user value Integrating the internal and external value network in the digital environment, reducing production entry barriers and so on to reconstruct the competition mode of traditional production organizations, so as to improve the efficiency of total factor output. Fourth, through innovative modes such as flexible production, personalized service and collaborative manufacturing of the whole industry chain, due to the continuous breakthrough and application of emerging technologies such as artificial intelligence, industrial interconnection and virtual reality, the production development has been accelerated, resulting in some new industry technologies and innovation modes with high efficiency and high added value. Relying on these new business forms and models, the digital economy further improves the total factor productivity, which not only brings more foreign investment and the improvement of the competition level of the digital economy industry, but also promotes trade and export.

6. Conclusion and Enlightenment

This paper studies the impact and mechanism of digital investment on foreign trade export. The conclusions include: (1) digital investment plays an obvious role in promoting foreign trade export. This conclusion can be realized by replacing variable test and overcoming endogenous problems. (2) The digital economy of countries with higher economic freedom has a greater impact on trade exports, and the digital economy of countries with lower development level of national digital economy has a greater impact on trade exports. In manufacturing and service industries, digital economy input is positively correlated with trade export. Among them, in the service industry, digital economy investment has a great impact on Trade and export. (3) Digital economy investment improves trade and export through total factor productivity. The above conclusions provide evidence for the improvement of trade and export in digital economy. The corresponding policy implications are as follows:

First, in the "14th five year plan" for the development of digital economy, it is pointed out that the government should focus on promoting the electronic transformation of industries and fully promote the electronic transformation of key industries. Accelerate the construction of information technology network security infrastructure. Form a modern comprehensive digital information infrastructure with high-speed ubiquitous, integration of the world, combination of cloud and network, intelligence and agility, greening, low-carbon and controllable security. Reasonably promote the expansion of backbone network, coordinate and promote the construction of gigabit optical fiber network system and 5g network security infrastructure, prospectively arrange the network security technology reserve of the sixth generation mobile communication (6g), further strengthen the supporting force of 6G scientific and technological research, and actively promote the international standardization of 6G. Aim at the strategic position and forward-looking application fields such as sensor products, quantum information technology, computer network communication, integrated circuits, important application software and materials, give full play to the resource advantages of the new China's socialist system, the new national system and super large-scale market resources, and further enhance the strength of basic research in digital science and technology.

Second, according to the "14th five year plan" for the development of digital economy, develop and establish a social management system for the operation of data economy, and improve the digital management ability of local governments. Accelerate the construction of a global unified big data center system for the coordination of computing resources, computing, big data and application resources. Establish national support nodes for the construction of global unified computing Internet in key areas such as Beijing Tianjin Hebei, the Yangtze River Delta, Dawan District of Guangdong, Hong Kong, Macao, Chengdu Chongqing Economic and social development circle, Guizhou, Inner Mongolia, Gansu and Ningxia, focus on the construction of large-scale data center aggregation areas, and optimize the construction pattern of national big data centers according to the development needs of applications and industries. Actively build a big data monitoring and decision analysis system completely based on new generation information technologies such as big data, artificial intelligence and blockchain, so as to enhance the accuracy, coordination and efficiency of government data economic and social management. In the "digital economy governance capability improvement project", it is clearly proposed to establish a market supervision system for digital services, and study and develop the application of digital technologies such as big data analysis, artificial intelligence and blockchain technology in the field of financial supervision.

Third, actively promote the vigorous development of digital economy and society and improve the overall pattern of digital country construction in accordance with the action plan for digital village development (2022-2025). We will actively build digital information infrastructure, promote the large-scale use of 5g, promote the digital transformation of traditional industries, and actively develop smart cities and build digital villages. We will accelerate the development of the Internet in the information industry, focus on cultivating and developing digital formats such as integrated circuits and artificial intelligence, and enhance the innovation and supply capacity of important software and hardware. We will expand the coverage of smart infrastructure construction in large and medium-sized cities to rural areas, further enrich the supply of information-based public services in urban and rural areas, promote the two-way transformation of urban factor information from the mainstream, reasonably allocate public resources, and establish a new pattern of digital city information integration and development with cities leading towns, joint construction and sharing.

Fourth, the G20 initiative for the healthy development and collaborative development of digital economy and society has gained broad consensus in the world. Under the background of China's implementation of internal circulation system leading, external circulation system enabling and double circulation system transportation, China's interconnection of electronic information infrastructure has made outstanding progress. The strategic cooperation of "Silk Road e-commerce" has yielded fruitful results, and China's platform companies in the field of digital economy have accelerated their investment to the sea, International influence and competitiveness continued to increase. The digital economy industry also needs to continue to attract the influx of foreign capital, actively absorb the world's cutting-edge science and technology, build an integrated supply chain ecosystem with big data analysis technology as the core, smooth the internal circulation with greater strength, and effectively integrate world capital, knowledge, science and technology, information and human resources in more fields, so as to accelerate the improvement of enterprise management level and further enhance the global competitiveness of enterprises.

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