The mediating effect of digital economy on international trade--Evidence from China

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Abstract: According to the World Economic Forum, for every 10% increase in a country's digitalization, the country's GDP per capita grows by 0.5%~0.62%, and the potential of the digital economy cannot be ignored. Based on the inter-provincial panel data of China from 2010 to 2020, this paper constructs a mediating effects model to analyze the path of the digital economy affecting foreign trade through human capital and industrial upgrading, and then explores the impact of human capital and industrial economy on foreign trade in different geographical conditions from a geographical perspective. It is found that there is a significant mediating effect of human capital and industrial upgrading in the process of digital economy's influence on foreign trade development, and this effect is regionally heterogeneous, playing a better role in the eastern coastal region than the central and western regions. In order to narrow the regional gap, a balanced layout of educational resources is realized to improve the human capital level in the central and western regions, and a mechanism of industrial synergy development in the central and western regions is established.

1. Introduction

The "digital economy" was coined by Tapscott in 1966 and is considered to be a collection of ICT industries, including telecommunications, Internet, communications, etc.[1]. With the continuous development of digital technology, the cost reduction and efficiency of the digital economy has made it shine in the global development. The Global Digital Economy White. Paper measured the size of the digital economy value added in 47 countries at US$38.1 trillion, a nominal increase of 15.6% year-on-year, and a 45.0% share of GDP. Therefore, the degree of digital economy available to countries with different economic strength is also different. Yuzhu Wang[2] believes that in the era of digital economy, developing countries will face higher usage costs due to shortage of digital technology, which partially offsets the cost reduction of digital economy due to the weakening of geographical distance in international trade barriers. This means that different countries can enjoy the "digital economy dividend" to different degrees. The White Paper mentions that developed countries have a clear lead in the digital economy, accounting for 55.7% of GDP, while the digital economy in developed countries accounts for only 29.8% of GDP. In the case of China, the digital economy will reach $25.5 trillion in 2021, accounting for 39.8 percent of GDP, and has become one of the main ways to drive economic growth. For the first time, China's imports and exports surpassed the RMB 40 trillion mark this year to set a new record high, up 7.7% from 2021. Imports and exports with countries along the "Belt and Road" grew by 19.4% year-on-year.

As one of the important factors for the growth of foreign trade, the existing literature focuses on the study of the impact of the digital economy on the existence of export trade. In terms of the impact mechanism, scholars generally agree that the digital economy has an impact on foreign trade by reducing trade costs. Changjie Xia[3] et al. argue that communication technologies can reduce the trade costs of goods and services in cross-border trade and break down various information barriers, thus promoting significant growth of export trade. In terms of the path of action, Yao Zhanqi[4] used the mediating effect to study the interaction between digital economy and human capital to influence foreign trade through the improvement of innovation output and innovation efficiency. Zhenguo Han et al.[5] constructed a gravity model to quantitatively assess the impact of digital economy on foreign trade efficiency from infrastructure level and communication technology development index, and pointed out that the development of digital economy in Europe and America is significantly better than that in Asia and Africa.

In summary, the existing literature is more consistent on the promotion of the digital economy on international trade, based on this, this paper will use the inter-provincial panel of China with data from 2010-2020 to empirically analyze the impact mechanism of the digital economy on China's foreign trade using human capital and digital technology innovation, and put forward reasonable policies and suggestions.

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2. Theoretical mechanism and hypothesis study

The digital economy can optimize information networks and simplify information matching to achieve a reduction in search costs and transaction costs in the international trade process. In services trade, it enables importers and exporters to interact and communicate in real time to increase transaction efficiency. For exporters themselves, the digital economy can also optimize internal processes and improve business processes, thus achieving a reduction in management costs. On a micro level,[6] the digital economy is supported by digital technology, which leads to an increase in production output and allows companies to focus on diversifying their products, which means that the development of the economy inevitably leads to division of labor and specialization. From a macro perspective, the digital economy is not only matching various information and production, but also matching various factors of production and changing the way resources are allocated, making better use of each factor of production. First, new technologies such as cloud computing and artificial intelligence can bring about an increase in total factor productivity; second, the increase or change of various factors can make the output of enterprises increase, and this step improves the efficiency of resource allocation. Accordingly, the following research hypotheses are proposed.

H1: The digital economy is significantly and positively correlated with the development of foreign trade.

2.1. Digital economy drives foreign trade through industrial upgrading

The digital economy is essentially bridged by technological progress. According to endogenous growth theory, digital technology can drive GDP growth, which is reflected in the increase of foreign trade in the import and export sector. Digital resources are becoming a key factor of production, which can improve the efficiency of all factors such as labor, technology and capital inside the enterprise, and outside the enterprise can enable the synergistic turnover of the upstream and downstream of the industrial chain, such as the service chain, supply chain, logistics chain and financial chain of products[7]. Not only that, all industries are turning to digitalization, constantly stimulating new business models and new business models. The rise of the digital economy, the inevitable transformation and upgrading of traditional industries, with artificial intelligence, big data and other core driving technologies are bringing new opportunities for traditional industries. The process of industrial digitization and industrial upgrading is based on technology, and then eventually affects every industry including international trade. Jun Wen et al.[8] used a fixed utility model to regress technological innovation with the digital economy, and the study showed that the development of the digital economy has greatly contributed to the improvement of innovation capacity, but this potential has not yet been fully realized. Localities should integrate digital technologies into traditional industries to form digital industries and reduce regional development differences in order to achieve innovation in the whole country. Based on this, this paper proposes the following hypotheses.

H2: Digital economy drives foreign trade through industrial upgrading

2.2. The digital economy drives foreign trade through human capital

First, the application of digital technology in the education and training industry has made knowledge and technology accessible, resulting in the continuous advancement and accumulation of human capital. China's "demographic dividend" is gradually shifting to a "human capital dividend," a trend that meets the need for an increasingly skilled workforce in the digital economy. At the same time, foreign trade also requires high quality human resources to handle cross-border business, and the improvement of human capital provides human resources support for foreign trade. Secondly, high quality talents will in turn influence the R&D level of enterprises and promote the rapid development of high technology industries, thus influencing the optimization of industrial structure and promoting the upgrading of import and export structure, which ultimately affects the development of foreign trade. Based on this, the following hypotheses are proposed in this paper.

H3: The digital economy affects the development of foreign trade through human capital.

3. Model setup and data description

3.1Selection of indicators

3.1.1. Explanatory variables

Digital Economy (Dig). Three first-level indicators (digital infrastructure, digital industrialization, and digital city services) and ten second-level indicators which are number of Internet broadband accesses (IBAuser), number of domain names (NDN), cell phone penetration rate (CPPR), number of websites owned by enterprises (NWO), software product service revenue (SPSR), cell phone exchange capacity (CPEC), fiber optic cable line length (OCLL), and electronic information product output (EIPO),were constructed. Because of the different magnitudes of various indicators, these eight secondary indicators are standardized; and the following results are obtained by measuring the weights of each indicator using the entropy value method.

Table 1 Weights of digital economy indicators

Indicators	Entropy value e	utility value d	Weighting(%)
EIPO	0.663	0.337	18.457
CPEC	0.784	0.216	11.811
CPPR	0.973	0.027	1.504
NWO	0.761	0.239	13.087
SPSR	0.722	0.278	15.181
OCLL	0.764	0.236	12.904
NDN	0.713	0.287	15.69
IBAuser	0.792	0.208	11.366

3.1.2. Explained variables

Foreign trade (Tra). This paper draws on the indicator selection method of Zhenshan Bao and Jian Han et al. (2022)[9] and selects five primary indicators (foreign trade dependence(EDT), trade import/export balance, R&D input rate, TC index), five secondary indicators (total import/export/GDP, import/export, R&D expendituretotal output value of tertiary industry, (export-import)/(export+import)) . Again, these four secondary indicators are standardized and the entropy value method is used to calculate the weight of each indicator.

Table 2 Weights of foreign trade indicators

item	Entropy value e	Utility value d	Weighting(%)
EDT	0.914	0.086	42.473
Trade Balance	0.928	0.072	35.313
TC Index	0.982	0.018	8.843
R&D rate	0.973	0.027	13.371

3.1.3. Mediating variables

Human capital (Humal). Using the average number of college students per 10,000 population measures the level of human capital under different provinces.

Industrial Upgrading (Up) uses the tertiary/secondary sector to represent this indicator.

3.1.4. Control variables

Drawing on the methodology of Yao Zhanqi[4] , other variables affecting China's foreign trade are controlled for, including the degree of openness to the outside world (Open) and per capita GDP (Pergdp).

3.2. Data description

In order to ensure the validity and accuracy of the sample, 30 provinces (cities and districts) in China were selected from 2010 to 2020, and the data sample of Tibet was really serious so it was discarded, while Hong Kong, Macao and Taiwan were also excluded from consideration. If the sample has some data missing, the average growth rate is used to measure the missing data. Data are from the National Bureau of Statistics.

3.3. Modeling

In the process of the impact of digital economy on foreign trade, it is achieved through three channels: human capital and technological innovation, and industrial upgrading, and the parallel mediating effect approach is used here. The set-up model is as follows.

$$\mathrm{Tra}_{it}=\alpha_1+\alpha_2\mathrm{Dig}++\alpha_i\mathrm{Contral}_i+\varepsilon_{it} \quad (1)$$

$$\mathrm{Humal}_{it}=\beta_1+\beta_2\mathrm{Dig}_{it}+\beta_i\mathrm{Contral}_i+\varepsilon_{it} \quad (2)$$

$$\mathrm{Tra}_{it}=\rho_1+\rho_2\mathrm{Dig}+\rho_3\mathrm{Huaml}+\rho_i\mathrm{Contral}_i+\varepsilon_{it} \quad (3)$$

$$\mathrm{Up}_{it}=\eta_1+\eta_2\mathrm{Dig}_{it}+\eta_i\mathrm{Contral}+\varepsilon_{it} \quad (4)$$

$$\mathrm{Tra}_{it}=\rho_1+\rho_2\mathrm{Dig}+\rho_3\mathrm{Up}+\rho_i\mathrm{Contral}+\varepsilon_{it} \quad (5)$$

where i represents the province, t represents the year, and ε represents the random disturbance term.

4. Empirical Analysis

4.1.Intermediary effect

4.1.1. The mediating effect of the digital economy on foreign trade through human capital

As can be seen from Table 3, column (1) is only the effect of digital economy on foreign trade, which indicates the direct effect of digital economy on foreign trade 0.742, column (2) indicates the regression analysis for human capital and foreign trade together; column (3) indicates the regression of foreign trade on foreign trade through human capital. Thus with human capital as the mediating variable, the total effect of the digital economy on foreign trade is 0.647 and the mediating utility of human capital is significant.

Table 3 Mediating effects of human resources

Dig	Tra(1)	Humal(2)	Tra(3)
item	0.742	0.946	0.067
Standard error SE	0.171	0.423	0.167
t	4.343	0.237	3.874
β	0.946	0.067	0.012

Summary of intermediary effect size results				
item	Tot	a*b	c	result
Dig=>Humal=>Tra	0.742	0.095	0.647	12.776%

C denotes the process of digital economy's impact on foreign trade, a denotes the process of digital economy's impact on human capital, and b denotes as the process of human capital's impact on foreign trade. The test of the mediating effect of human capital concludes that it is partially mediated and its effect share is a*b/c, which is 12.776%.

4.1.2. The intermediary effect of digital economy affecting foreign trade through industrial upgrading

Table 4 Mediating effects of industrial upgrading

Up	Tra (1)	Humal (2)	Tra (3)
Item	0.735***	-0.076**	0.453
SE	0.171	0.009	0.160
t	4.310	-8.293	-0.031
β	0.013	-0.415	-0.000

As shown in Table 4, column (1) is only the effect of digital economy on foreign trade, which indicates the direct effect of digital economy on foreign trade of 0.735, column (2) indicates the regression analysis of industrial upgrading and foreign trade together; column (3) indicates the regression of foreign trade on foreign trade through industrial upgrading. Therefore, with industrial upgrading as the mediating variable, the total effect of digital economy on foreign trade is 0.453 and the mediating utility of industrial upgrading is significant.

Summary of intermediary effect size results				
item	Tot	a*b	c	result
Dig=>Up=>Tra	0.735	0.740	-0.005	100%

A full mediation effect is also a type of mediation effect, which occurs when the direct effect of c is not significant. the significance of c is affected by the sample size, and the larger the sample size, the more likely it is that c is partially mediated. Some scholars, such as Preacher and Hayes (2008), call for abandoning the concept of full mediation, as all full mediation is a mediating effect. Therefore, the results of full mediation are not discussed here. With the same sample size of 320, the mediating effect of human capital in the impact of digital economy on foreign trade is 12.776%. In the mediated regression model, the mediating effect of industrial upgrading is more significant.

4.2. Endogeneity test and treatment

The Durbin-Wu-Hausman test is carried out in this paper, which shows that the model has an endogeneity factor. In order to test the effect of endogeneity on the reliability of the equation, this paper uses the instrumental variable method, using the lagged period of the digital economy as the instrumental variable. The instrumental variables should be chosen to be strongly correlated with the explanatory variables and if correlated with the explained variables. Table 5 (R^2 is 0.264.) shows the results of the instrumental variables method.

Table 5 2sls regression results

	B	SE	t	p	R2
Constants	-55.263	94.504	-0.585	0.559	0.264
Dig	-1.218	8.929	-0.136	0.892	
Huaml	1.011	0.286	3.538	0.000**	
Up	171.002	17.213	9.935	0.000**	

From the above table, it can be seen that Dig as endogenous variable, Dig(t-1) as instrumental variable, and Huaml, Up as exogenous variable, while the external as explanatory variable was subjected to two-stage least squares regression, with the first stage being Dig as explanatory variable Y and Dig(t-1) and Humal, Up as explanatory variables, followed by linear regression to obtain the predicted estimated values. The model R-squared value is 0.264, implying that Dig and Humal, Up can explain 26.4% of the causes of variation in Tra. When the model was subjected to Wald *chi-square* test, it was found that the model passed the Wald chi-square test (Chi=114.331, p=0.000<0.05), which means that at least one of Dig and Humal, Up would have an impact relationship on foreign trade.

5. Heterogeneity analysis

In this paper, the data of China are divided into three parts, the eastern region includes: Beijing, Hebei, Shanghai, Tianjin, Jiangsu, Shandong, Liaoning, Zhejiang, Fujian, Guangdong and Hainan; the central region includes: Jiangxi, Henan, Shanxi, Anhui, Jilin, Heilongjiang, Hubei and Hunan; the western region includes: Chongqing, Sichuan, Yunnan, Gansu, Qinghai, Shaanxi, Inner Mongolia, Guangxi, Guizhou, Ningxia and Xinjiang. To test the robustness of the model, group regressions were conducted in this paper, and the results are shown in Table 6.

Table 6 Group regression results

	East	Middle	West
Dig	0.478	0.234	0.166
Pergdp	12.031	0.454	0.446
Open	0.427	23.7	-1.286
Humal	-0.017	-0.104	-6.057
Up	-8.084-00	-14.247	0.075
R^2	0.999	0.931	0.985

In terms of regional differences, human capital and industrial upgrading have the largest impact on the eastern region with an impact coefficient of 0.478, followed by the central region with 0.234, and finally the western region with 0.166. There are three main explanations for the largest impact coefficient in the eastern region, firstly, the value added of the digital economy has exceeded 40% of GDP in some developed eastern regions, but in the western region most provinces are only 10%. Second, the development of digital economy has a clear "Matthew effect"[10], which indicates that its impact through production factors is not simply driven, but shows a geometric growth. Third, the eastern region is geographically close to the coast, with Tianjin and Shanghai being coastal port cities, and ports have a decisive influence in foreign trade. While the central and western regions also have inland ports connecting to the Middle East, the top 10 Chinese national ports in terms of cargo throughput in 2021 are still coastal ports. The eastern region is well positioned for foreign trade due to its superior geographical location.

6. Conclusions and proposals

6.1. Conclusion

This paper draws the following conclusions: First, the development of digital economy affects China's foreign trade level through human capital and industrial upgrading, and digital economy, human capital and industrial upgrading can explain 26.4% of the reason for the change in foreign trade. Second, all other things being equal, the mediating effect of human capital is 12.776%, while the mediating effect of industrial upgrading is fully mediated. Third, regional development imbalance leads to different levels of digital economy development, with the eastern region having a significantly better level of digital economy development than the central and western regions, and the impact on regional foreign trade is also different. The role of human capital and industrial upgrading is significantly stronger in eastern China than in the central and western regions.

6.2. Recommendations and Policies

To promote the high-quality development of the digital

economy, establish a complete industrial system for its development, and continuously promote the upgrading and improvement of the digital ecosystem. Promote the digital transformation of the real economy. Create regional manufacturing digital clusters, accelerate the digital transformation of infrastructure in key regional manufacturing clusters, and promote the common construction and sharing of new infrastructure such as intelligent logistics networks and energy control systems.

There are obvious disparities in the development levels of digital economy in different regions, especially in the eastern region where the development of digital economy is better than in the central and western regions. Therefore, how to solve the regional gap through industrial upgrading, while affecting foreign trade, has also become an important issue in the development of the current digital economy. From the perspective of industrial upgrading, the central and western regions should take digital transformation as the direction to promote industrial upgrading and enhance the industrial competitiveness of the central and western regions. By implementing flexible policies, it encourages enterprises to set up R&D centers and production bases in the central and western regions, and raises labor costs in the eastern regions to promote the flow of talents and increase employment opportunities in the central and western regions.

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