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The Impact of Digital Economy Development in Eastern and Western China on Income Inequality

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Abstract— The development of the digital economy has become a new economic growth point, and its development will have an impact on income inequality in eastern and western China. Therefore, this study selects 83 cities in eastern and western China as the research objects, calculates the level of digital economy development and income inequality in eastern and western China, constructs a two-way fixed-effect model for empirical research, and conducts endogeneity test, robustness test, heterogeneity analysis and moderating effect analysis. The results show that from 2011 to 2022, the level of digital economy development in the east and west is improving, but the development of the east is better. Income inequality is declining in both regions year by year, but the situation is worse in the west. The development of China's digital economy will worsen income inequality between the east and west. The heterogeneity analysis shows that the development of the digital economy has a more obvious effect on the aggravation of income inequality in the eastern region, and the development of urban agglomerations also indicates that there is regional heterogeneity. The moderating effect analysis shows that the improvement of education level has a greater effect on alleviating income inequality in the western region. Based on this, it is proposed that the eastern part should balance efficiency and fairness, the western region should strengthen infrastructure construction and education, and the eastern and western regions should develop in a coordinated manner.

Keywords: Digital economy,Income inequality,Regional development, Regional economy,Two-way Fixed Effects Model

I. INTRODUCTION

There are many reasons for income inequality. Ge Yuhua and Zhao Yuanyuan (2011) found in their study of the causes of income inequality in China that the main reasons for this inequality are the imbalances in development between regions and industries. Yu Xie and Xiang Zhou (2014) believe that income inequality in China is largely caused by regional disparities and urban-rural gaps. This indicates that differences between regions are one of the important factors contributing to income inequality in China. With the development of technology, technological progress has also become a reason for the phenomenon of income inequality. Xu Shu (2010) found in his research that skill-biased technological advancement increases the marginal returns of education, thereby exacerbating income inequality.

The development of the digital economy is also a manifestation of technological progress, and it also has a significant impact on income inequality. According to studies from different perspectives, the digital economy has the potential to both alleviate and exacerbate income inequality. Liu Yulin and Li Xiaomei (2023) concluded that the development of the digital economy has effectively narrowed the income gap of young people under the age of 40 in their research on the income gap of their peers under the digital economy. Li You (2023) studied the impact of the development of the digital economy on household income inequality from the perspective of relative deprivation based on the digital economy index at the city level, and found that the development of the digital economy can significantly reduce the relative income deprivation of households in their groups and effectively alleviate the income gap between households. And Daud etal. (2021) Based on a multinational sample of 54 countries from 2011~2015, it is found that the superimposed impact of digital technological progress and financialization will lead to an increase in income inequality. Acemoglu and Restrepo (2018) also argue that AI has a substitution effect, a new job creation effect, and a productivity effect, and that the combination of these three effects leads to increased income inequality between high- and low-skilled workers.

In the research on the impact of China's digital economy development on income inequality, different perspectives also get different results. Bai Peiyao and Zhang Yun (2021) also found that the development of the digital economy will reduce the income of low- and middle-skilled workers to a certain extent, widening the income gap between low- and middle-skilled workers. Li Yi and Ke Jiesheng (2021) also found that the access and use of digital technology will bring differentiated income, exacerbating income inequality between groups. Hong Junjie, Li Yan, and Yang Xi (2024) found that in general, the digital economy will have more impact on labor productivity and human capital distribution, thereby widening the income gap through empirical analysis at the regional and urban-rural levels. In the study of the impact of China's digital economy development on the urban-rural income gap, Pang Limin (2022) found that the level of digital economy development in eastern China is the highest, and the western region is the lowest, while the urban-rural income gap in the western region is greater than that in the central and eastern regions of China. Yang Kai, Liu Dingrong, and Sun Shi (2024) believe that the impact of digital economy on urban-rural income inequality is regionally heterogeneous, and the impact of digital economy in the eastern region is significantly greater than that in the northeastern, central, and western regions.

It can be seen that the development of the digital economy has a great impact on income inequality. Considering the imbalance

of China's regional development, especially the differences between the development of the eastern and western regions, exploring the impact of the development of China's digital economy on the income inequality in the eastern and western regions can not only provide new ideas for solving the development and income inequality between the eastern and western regions, but also provide a more equitable development direction for China's digital economy.

However, current research on the relationship between China's digital economy and income inequality has focused on the development of the whole country, while others have studied specific regions and groups from various perspectives. However, there are few studies focusing on the development of the digital economy and income inequality between the east and the west, but the development imbalance between the east and the west is a relatively obvious problem in China's development process. Therefore, on the basis of relevant data, this paper uses principal component analysis (PCA) and the ratio of per capita disposable income of urban and rural areas to measure the digital development and income inequality between the eastern and western regions, and analyzes the panel data to test the impact of the digital economy on the income inequality between the eastern and western regions, and puts forward relevant suggestions for the further development of China's digital economy in the future and how to promote regional coordinated development under the development of the digital economy.

II.THEORY & RESEARCH HYPOTHESE

Nowadays, the rapid development of digital technology has not only accelerated the flow of information, but also made it faster and more convenient for ordinary people to obtain more professional and useful information in their daily lives. However, this also brings the problem of information asymmetry. Subjectively, this is due to the asymmetry of the ability of different economic agents to obtain information, and the objective aspect is that the amount of information obtained is mainly related to various social factors. He Yaping and Xu Kangning (2019) point out that there is an asymmetry between residents' access to information in China. In China, residents in the eastern region live in an environment with relatively complete public facilities and digital economic infrastructure, and have more channels to obtain relevant information at a faster speed and lower cost, and can join various new economic forms more quickly, and there is a certain information asymmetry between them and the residents in the western region.

At the same time, under the development of the digital economy, the differences in the application and innovation capabilities of information and network technology between the eastern and western regions and their residents will also make them have a certain gap in "information", "knowledge" and "wealth". Zhang et al. (2021) showed that the digital divide between different regions will lead to or widen the gap between rich and poor between regions. Residents of eastern China can have faster access to state-of-the-art information technology and enjoy the changes that digitalization will bring to the economy sooner. Qiu et al. (2016) also pointed out that economically developed regions such as China's southeast coast can benefit more from the development of the Internet. There may be a certain "digital divide" between residents in the western region and those in the eastern region due to access limitations, differences in basic knowledge and skills in using the Internet to process information, and differences in the willingness, motivation, goals and modes of access to information online. The existence of this "digital divide" will also affect the income situation of residents in the East and West.

In this regard, Wu Haitao and Qin Xiaodi (2022) proposed that the advantages of digital technology can be used to reduce information asymmetry and increase the wealth accumulation of low-income groups. At the same time, it can also reduce the "digital divide" between the eastern and western regions and within the region, and provide more equal development opportunities by providing universal education, improving digital literacy, deploying better digital infrastructure, providing affordable equipment and services, and paying attention to the needs of marginalized groups.

In addition, under the development of the digital economy, we must also pay attention to the improvement of human resources, so that the digital economy can achieve inclusive development. Li et al. (2015) pointed out that the main reason for the differences in economic development and income between different regions of China is the difference in human capital. Zhang et al. (2021) pointed out that most of China's highly educated labor force is distributed in the coastal urban agglomerations of eastern China, and Chen Dewen and Miao Jianjun (2013) also believe that the effect of human capital accumulation in eastern China is the most obvious. This also shows that the stock and quality of human capital in eastern China are better than those in western China. Because the eastern region of China is more abundant in educational resources, there are more platforms for workers to improve themselves, more skills to master, more competitiveness in the labor market, more opportunities to participate in technology-intensive industries, and higher wages.

Moreover, there is uneven development and income inequality between eastern and western China, mainly due to unequal economic opportunities, uneven distribution of public resources, large gaps in human capital accumulation, and insufficient sharing of development results. Faced with this situation, Lin Yifu (2008) proposed that in order for developing countries to achieve more inclusive development, it is important to strengthen basic education and medical and health care. Zhang et al. (2011) argue that increasing the concentration of human capital can increase the income level of different regions. Du et al. (2010) also proposed that in order to achieve inclusive growth, the focus is to increase opportunities for development. Therefore,

the key to addressing the uneven development and income inequality between China's eastern and western regions is to provide more opportunities for development in disadvantaged regions. This can achieve more inclusive economic growth by promoting cross-regional cooperation to achieve complementary sharing of resources, talents, and technologies between the east and west, promoting industrial transformation in the western region, and increasing investment in infrastructure and education in the western region.Based on this, the following hypotheses are proposed:

Hypothesis 1: The development of China's digital economy will have an impact on income inequality in the eastern and western regions.

Hypothesis 2: In the context of the development of the digital economy, education level has a moderating effect on income inequality.

III.MEASUREMENT & ANALYSIS CORE VARIABLES

3.1Measurement and analysis of the development level of digital economy in the east and west

3.1.1Indicator selection and measurement method

According to the principles of relevance, scientificity and availability of data, the indicators that can measure the development level of the digital economy are selected, and the corresponding indicators are selected to measure the development level of the digital economy in these two regions from the aspects of digital economy infrastructure construction and digital industry development with reference to the white paper and the practice of Wang Jun and Xiao Huatang (2021). At present, the important manifestations of the digital economy include two aspects, one is the use of digital technology and related elements to create economic value products, and the other is to integrate digital development into all walks of life, and promote the further transformation and development of these industries through the development of digital technology. Therefore, in this part, the total volume of telecommunication services (10,000 yuan), the digital inclusive finance index, the e-commerce transaction volume (10,000 yuan), and the number of employees in the information transmission, software and information technology service industry (10,000 people) are selected as indicators to measure the level of digital economy development in these two regions.

Because principal component analysis can reduce the dimensionality of high-dimensional data, and retain the most important information in the data, it is convenient to analyze the data. In this study, principal component analysis (PCA) was used to measure the development level of digital economy in eastern and western China.

3.1.2Results and analysis

Based on the selected measurement indicators, this paper uses principal component analysis to measure and analyze the development level of digital economy in 83 cities in eastern and western China from 2011 to 2022. The data used in the measurement process are all from the city statistical yearbook and the statistical bulletin of each city.

Table 1: *Principal Component Variance Contribution Rate*

Principal Component	Contribution Rate	Cumulative Contribution Rate
PC1	0.5908	0.5908
PC2	0.1600	0.7508
PC3	0.1028	0.8536
PC4	0.0853	0.9388
PC5	0.0337	0.9726
PC6	0.0274	1.0000

During the measurement process, the data were tested by KMO and Bartlett, and KMO=0.79 and P=0 were obtained, rejecting the null hypothesis, indicating that the data were suitable for factor analysis and principal component analysis could be performed.The following table lists the explanatory degree of the six main principal components in this analysis, and the first three principal components are selected to represent the digital economy development level of 83 prefecture-level cities in eastern and western China from 2011 to 2022 based on the cumulative variance contribution rate of ≥80%.

This research measures the level of digital economy development of 83 cities in eastern and western China from 2011 to 2022 across six dimensions and will analyze the situation of the top ten cities in the digital economy development level of eastern and

western China for the years 2011, 2015, and 2022. Based on the top ten rankings of digital economy (DE) development levels in eastern and western cities for 2011, 2015, and 2022, the following conclusions can be drawn: First, there is a significant disparity in digital economy development levels between the eastern and western regions, with eastern cities performing better. In the rankings of the top ten cities by digital economy development level, there were 7 eastern cities in 2011, 7 in 2015, and 6 in 2022, with Beijing and Shanghai consistently holding the top two positions. Moreover, the development of the digital economy in China's eastern and western cities shows a clear 'hierarchical' pattern. Beijing and Shanghai, as the first tier, have consistently held the top two positions, with their DE values both exceeding 10 in 2022, far surpassing those of other cities. Among the core western third tier cities, Chongqing stands out, rising from second place in the west in 2011 to third place nationally in 2022, with a DE value increase of 201%. This stepwise distribution reflects a high concentration of digital economy resources in leading cities, highlighting significant regional developmental imbalances.

Table 2:*Top 10 Cities in 2011,2015,2022 for the Development of Digital Economy*

City	Region	Year	de	City	Region	Year	de	City	Region	Year	de
Beijing	East	2011	4.72	Beijing	East	2015	7.59	Beijing	East	2022	11.28
Shanghai	East	2011	3.88	Shanghai	East	2015	6.41	Shanghai	East	2022	10.69
Guangzhou	East	2011	3.47	Shenzhen	East	2015	4.64	Chongqing	West	2022	7.05
Shenzhen	East	2011	2.92	Guangzhou	East	2015	4.56	Guangzhou	East	2022	6.72
Chengdu	West	2011	2.35	Suzhou	East	2015	4.16	Suzhou	East	2022	6.28
Chongqing	West	2011	2.34	Chongqing	West	2015	4.03	Shenzhen	East	2022	6.05
Suzhou	East	2011	2.33	Chengdu	West	2015	3.87	Hangzhou	East	2022	4.96
Dongguan	East	2011	2.26	Hangzhou	East	2015	3.35	Chengdu	West	2022	4.93
Xian	West	2011	2.25	Tianjin	East	2015	3.34	Tianjin	East	2022	4.55
Hangzhou	East	2011	2.25	Xian	West	2015	3.19	Xian	West	2022	4.39

3.2Measurement and analysis of the income inequality in the east and west

The urban-rural income ratio can directly reflect the disparity between the disposable income of rural and urban residents in the region, and a relatively high ratio also indicates that the income inequality in the region is more obvious. Moreover, the availability and completeness of the data are relatively high, and it is suitable as an indicator to measure income inequality in the eastern and western regions. The equation is as follows:

ineq = per capita disposable income of urban residents / per capita disposable income of rural residents

Table 3:*Top 10 Cities in 2011,2015,2022 for the income inequality*

City	Region	Year	ie	City	Region	Year	ie	City	Region	Year	ie
Anshun	West	2011	3.51	Jinan	East	2015	3.06	Jinan	East	2022	2.40
Hefei	East	2011	3.50	Qinzhou	West	2015	2.87	Kunming	West	2022	2.39
Baotou	West	2011	3.40	Yunlin	West	2015	2.83	Baiyin	West	2022	2.38
Xianyang	West	2011	3.37	Nanning	West	2015	2.76	Lanzhou	West	2022	2.23
Beihai	West	2011	3.32	Baotou	West	2015	2.70	Qingdao	East	2022	2.15
Baiyin	West	2011	3.23	Guiyang	West	2015	2.59	Baotou	West	2022	2.12
Rizhao	East	2011	3.17	Baoji	West	2015	2.59	Rizhao	East	2022	2.11
Fangchenggang	West	2011	3.14	Qujing	West	2015	2.56	Chongzuo	West	2022	2.10
Qujing	West	2011	3.14	Lanzhou	East	2015	2.54	Weihai	East	2022	2.07

Yantai	East	2011	3.13	Guangzhou	East	2015	2.54	Dingxi	West	2022	2.06

In this ranking , from 2011 to 2022, the top 10 cities in the list of income inequality (ie) are mainly in the western region, and some cities such as Guiyang, Bijie, Dingxi, and Baiyin have been in the top 10 for a long time, indicating that the income problems in these regions are persistent.Overall, from 2011 to 2022, the income inequality index (ie) in eastern and western cities generally showed a downward trend, for example, the ie of Baiyin fell from 4.1856 in 2011 to 2.9205 in 2022, and Guiyang fell from 3.9791 to 2.9974. However, despite the decline in the overall level, the ie value of the western cities is still relatively high, indicating that the problem of income inequality is still more prominent in the western region.

IV. EMPIRICAL ANALYSIS

4.1 Data preparation

These relevant data of each variable can be collected through official channels such as the China Statistical Yearbook, the China Science and Technology Statistical Yearbook, the National Bureau of Statistics, the China City Yearbook, China Statistical Information Network,Statistical Yearbooks of Cities,and the Peking University Digital Finance Research Center.

4.1.1Variable selection

4.1.1.1 Dependent Variable

The dependent variable is the level of income inequality (ie) between the eastern and western regions of China, represented by the ratio of disposable income between urban and rural residents in these regions.

4.1.1.2 Independent Variable

The independent variable is the level of digital economy development (de) in eastern and western China, specifically the comprehensive scores of various cities derived from principal component analysis (PCA).

4.1.1.3 Control Variables

Regional Economic Development Level (pgdp): Measured by the per capita gross regional product of each city; Industrial Structure (is): Assessed by the ratio of the added value of the tertiary industry to that of the secondary industry; Degree of Openness (op): Evaluated by the ratio of total imports and exports to gross regional product; Fiscal Intervention (fs): Measured by the ratio of total fiscal expenditure to gross regional product; Urbanization Level (ul): Assessed by the ratio of the urban resident population to the total population.

4.1.1.4 Descriptive statistics of variables

In the descriptive statistics of the samples, there are obvious differences in the distribution characteristics of each variable.

Table 4:*Descriptive Statistical Results of Each Variable*

Variable	Observation	Mean	Maximum	Minimum	Std.
ie	996	2.3356	4.1857	1.0000	0.5080
de	996	2.6772	12.3333	1.0000	1.3195
pgdp	996	76746	256908	6916	43039
is	996	1.1791	5.2968	0.1136	0.6222
fe	996	0.1691	0.7044	0.0221	0.0881
op	996	0.3570	2.4898	0.0008	0.4202
ul	996	0.6545	1.0000	0.1815	0.1653

The mean value of the income inequality index (ie) is 2.3356, which is between the minimum value of 1 and the maximum value of 4.1857, and the standard deviation is 0.5080, indicating that there are some differences in income distribution among different cities, but the overall distribution is relatively concentrated. There is a large gap between the mean value of 2.6772 and the maximum value of 12.3333, and the standard deviation is 1.3195, reflecting the uneven development of the digital economy among cities. Among the control variables, the per capita GDP (pgdp) range from 6,916 yuan to 256908 yuan, highlighting the

huge gap in the level of regional economic development. The control variables such as industrial structure (is), fiscal expenditure (fe), openness (op) and urbanization level (ul) also showed different degrees of discrete characteristics.

4.1.1.5 Analysis of unit root test results

The results of LLC test show that the statistics of all variables are negative and the p-value is significant, indicating that the data does not have the unit root problem, meets the stationarity requirements, and the data can be used for modeling.

Table 5:*Result of LCC*

	LLC Test	
	Statistic	P-Value
ie	-3.20689	0.0007
de	-9.15184	0.0000
pgdp	-1.99444	0.0231
fe	-2.57191	0.0051
is	-2.91354	0.0018
op	-4.38096	0.0000
ul	-9.24977	0.0000

4.2 Model settings

In this paper, the LR test and Hausman test will be used to select the model. According to the test results, the p-value of the LR test was 0, indicating that the panel data model was better, and the p-value of the Hausman test was 0, indicating that the fixed-effect model (FE) was more appropriate.

At the same time, because the two-way fixed-effect model can not only control the regional fixed-effect effect to capture the inherent differences between the eastern and western cities that do not change over time, but also absorb the time-varying shocks faced by all cities through the time-fixed effect, this paper research chooses the two-way fixed-effect model as the benchmark regression model.

Formula as follow:

$$\mathrm{Ineq}_{it} = \alpha + \beta \mathrm{DE}_{it} + \gamma \mathrm{Cont}_{it} + \mu_{it} + \lambda_{it} + \epsilon_{it}$$

In this formula, i denotes the region and t denotes the year.And Ineq_{it} is dependent variable,indicates the income inequality level of the ith region in the tth period. DE_{it} is independent variable, indicates the digital economy development level of the ith region in the tth period. Cont_{it} are control variables,indicates other factors that may affect income inequality. μ_{it} is regional fixed effect; λ_{it} is time fixed effect and ϵ_{it} is random error term.

4.3 Benchmark regression analysis

The following table presents the benchmark regression regression results using a two-way fixed-effect model to analyze the impact of the digital economy (de) on income inequality (ie) in eastern and western China.

Column (1) is the result of without control variable, and column (2) is the result of adding the control variable. The results of the regression validate hypothesis 1 that the development of China's digital economy will have an impact on income inequality in the east and west.

Moreover, the impact of the digital economy (de) on income inequality (ie) in eastern and western China is positive and significant, regardless of whether control variables are added.

From the results of column (2), the coefficient of DE is 0.049, which is significant at the level of 5%, indicating that every 1 unit increase in the level of digital economy development in the eastern and western regions of China will lead to a 0.049 unit worsening of income inequality in these two regions.

In summary, at this stage, the development of the digital economy in eastern and western China may exacerbate income inequality in these two regions through certain channels, such as technology substitution or resource redistribution.

Table 6: *Result of Benchmark Regression*

	ie	
	(1)	(1)
de	0.070***	0.049**
	(0.022)	(0.022)
pgdp		0.000**
		(0.000)
is		-0.034
		(0.051)
fe		0.597*
		(0.325)
ul		-0.314
		(0.276)
op		-0.146**
		(0.069)
R2	0.608	0.635
Observation	996	996
City FE	YES	YES
Year FE	YES	YES

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$*

4.4 Endogeneity test

In order to solve the problem of endogeneity of the model, this paper draws on the practice of Hong Junjie (2024) to select the time-invariant geographic variable of topographic relief of each city, multiply it with the time-varying variable of Internet penetration rate (logarithmic processing), and construct an instrumental variable with time-varying characteristics to test the causal effect of digital economy on income inequality. Because topographic features are natural conditions, they are usually relatively stable, basically not affected by local government policies or economic development levels, and are exclusive.

At the same time, there is a correlation between topographic undulations and the digital economy. The flat terrain is convenient for infrastructure construction. And the higher the internet penetration, the more exposure to digital technology there is. The interaction term (IV) composed of the multiplication of the two can meet the requirements of relevance for the changes in the construction of digital infrastructure in a region at different points in time.

Column (1) is the result without the control variable, and column (2) is the result with the control variable. The regression results of the instrumental variable method show that the selected instrumental variable (IV) has a significant impact on the core variable (de) from the regression results of the first stage, and the p values of 0.0000 and 0.0055 pass the instrumental variable strength

test, and also pass the significance test, indicating that there is a strong correlation between the instrumental variable and the endogenous variable, which meets the correlation condition of the instrumental variable. In the second stage of regression, the coefficients of de to were 0.744 and 1.065 ($p<0.01$) in the two sets of models, respectively, and the p value of Hansen's J statistic was 0.000, indicating that the instrumental variables met the exogeneity condition and there was no over-identification problem.

Table 7: *Result of Endogeneity Test*

	(1)		(2)	
	1st stage	2nd stage	1st stage	2nd stage
	de	ie	de	ie
iv	-0.132***		-0.775***	
	(0.023)		(0.027)	
de		0.744***		1.065***
		(0.143)		(0.384)
pgdp				-0.000**
				(0.000)
is				-0.748**
				(0.293)
fe				0.805
				(0.612)
ul				0.922
				(0.564)
op				0.323
				(0.199)
Kleibergen-Paap rk LM statistic		26.499		7.694
		(0.0000)		(0.0055)
Cragg-Donald Wald F statistic		22.784		7.669
Kleibergen-Paap rk Wald F statistic		32.030		8.411
Hansen J statistic		0.000		0.000
Observation	996	996	996	996
City FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Note: $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$*

This result further verifies the conclusion of the principal regression, that is, the development of the digital economy (de) in the eastern and western regions of China will exacerbate the problem of income inequality (ie) in these two regions, and this effect is more obvious after considering endogeneity, and the coefficient increases from 0.049 to 1.065 of the main regression.

4.5 Robustness test

In this study, three methods are used to test robustness: the first method is to replace the explanatory variables, replacing the ratio of per capita disposable income of urban and rural areas in eastern and western China with the ratio of per capita consumption expenditure of urban and rural areas. In addition, since Karamay City does not publish information on per capita consumption expenditure, its data will be excluded from this part of the regression analysis, which covers 82 cities with a sample size of 984. Moreover, because consumers are gradually adjusting their expectations based on past experience, there is a certain time lag in consumer behavior. Therefore, in the data analysis, the replaced data was processed with a lag of one period.The second method is to exclude special years, because in 2020 and 2021, due to the greater impact of Covid-19 on e-commerce, Internet use, digital transformation, etc., the data of these two years will be excluded; The third method is to exclude the special sample of Shenzhen, because Shenzhen, as a benchmark city of China's special economic zone, has obvious particularities in economic structure and urbanization process, and it can reduce the impact of extreme samples on the results.

Table 8: *Result of Robustness Test*

	ie					
	a		b		c	
	(1)	(2)	(3)	(4)	(5)	(6)
de	0.560***	0.508***	0.077***	0.052**	0.068***	0.051**
	(0.019)	(0.021)	(0.026)	(0.025)	(0.023)	(0.023)
pgdp		0.0000***		0.000		0.000**
		(0.00000)		(0.000)		(0.000)
is		0.143***		-0.020		-0.036
		(0.042)		(0.057)		(0.051)
fe		0.005		0.577*		0.596*
		(0.321)		(0.339)		(0.336)
ul		-0.491*		-0.349		-0.299
		(0.266)		(0.290)		(0.276)
op		-0.157**		-0.147**		-0.138*
		(0.062)		(0.072)		(0.077)
R2	0.525	0.544	0.582	0.604	0.613	0.637
Observation	902	902	830	830	984	984
City FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Note: $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$*

In the table, a is the regression result after substituting the explanatory variable, b is the regression result after excluding special years, and c is the regression result after excluding extreme samples. Columns (1), (3), and (5) are the results of not adding the control variables, and columns (2), (4), and (6) are the results of adding the control variables. The results of column A show that after replacing the explanatory variables, the development of the digital economy (de) still has a significant positive impact on income inequality, which further verifies that the development of the digital economy (de) has an aggravating effect on income inequality. The regression results of column b also show that DE still maintains a significant positive effect on IE after excluding the data of special years. The regression results of column c show that de still has a significant positive impact on ie, reaffirming that the development of the digital economy (de) has an exacerbating effect on income inequality (ie). In summary, the overall conclusion of the robustness test is consistent with the results of the benchmark regression, which further verifies the research conclusion that the development of the digital economy in eastern and western China will exacerbate income inequality, and also shows that the regression results are robust.

4.6 Heterogeneity test

4.6.1 Divided by East and West

In order to better analyze the impact of the development of the digital economy on the income inequality in the east and west, the east-west group regression was carried out on the data, and the interaction term (de*west) between the east-west dummy variable (west) and the digital economy (de*west) was introduced to carry out the interactive regression.

Table 9: *Result of Heterogeneity Test*

	ie					
	a				b	
	(1)	(2)	(3)	(4)	(5)	(6)
de	0.049**	0.043**	0.039	0.041	0.083***	0.073***
	(0.024)	(0.021)	(0.046)	(0.045)	(0.020)	(0.024)
de*west					-0.125**	-0.104***
					(0.038)	(0.041)
pgdp		0.000		0.000		0.000
		(0.000)		(0.000)		(0.000)
is		0.008		-0.055		-0.040
		(0.062)		(0.061)		(0.050)
fe		-0.004		-0.307		0.138
		(0.479)		(0.552)		(0.349)
ul		-0.047		-0.744*		-0.309
		(0.297)		(0.439)		(0.260)
op		-0.060		-0.030		-0.074
		(0.087)		(0.090)		(0.062)
R2	0.521	0.524	0.724	0.737	0.654	0.646
Observation	528	528	468	468	996	996
City FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Note: $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$*

In this table, a and b represent the results of the east and west group regressions as well as the east-west interaction regressions, respectively. Specifically, (1) and (2) in column a indicate the regression results for the eastern region without and with control variables, while (3) and (4) in column a repeat the regression results for the eastern region without and with control variables.

Group regression shows that the development of digital economy in the eastern part of the country has a significant positive impact on income inequality, indicating that the development of digital economy in the eastern part of the country will exacerbate the income inequality in this region. This may be due to the fact that the eastern region has a better level of digital economy and a higher demand for highly skilled workers, which in turn exacerbates income inequality in the eastern region. However, the impact of the development of the digital economy on income inequality in the western region is not significant, indicating that the development of the digital economy in the western region has little impact on the income inequality in this region. This may be because the development of the digital economy in the western region is relatively lagging behind, and the impact on income distribution is not strong.

The results of cross-regression also indicate that the development of the digital economy will exacerbate income inequality in the eastern region. This may be because the skill-biased nature of the digital economy allows it to widen the income gap between high-skilled and low-skilled workers in the process of development. The results of the interaction term de*west show a significant negative effect, which also indicates that the impact of the digital economy on income inequality is weaker in the west than in the east. This may be because the scale of the digital economy in the western region is not large, and the role of the digital economy has not yet been fully revealed. These two regression results also indicate that the impact of digital economy development on income inequality has obvious regional heterogeneity, and the policy effect may also vary from region to region.

4.6.2 Divided by urban agglomeration

Urban agglomerations are the core of China's regional economic development, but there are also considerable differences in the development of urban agglomerations in the eastern and western regions. Therefore, regression analysis by urban agglomeration classification can more accurately capture the differences in the impact of digital economy on income inequality in different regions.

The following table mainly analyzes the regression analysis of the impact of the development of digital economy on income inequality in each urban agglomeration after the regression according to the classification of urban agglomerations.

Table 10:*Result of Group Regression of Urban Agglomerations*

	Urban agglomeration	Region	ie	Observation
de	Beijing-Tianjin-Hebei	East	-0.10	60
			(0.035)	
	Yangtze River Delta	East	0.006	228
			(0.015)	
	Strait West Coast	East	0.004	60
			(0.026)	
	Shandong Peninsula	East	-0.056	72
			(0.043)	
	Pearl River Delta	East	0.057*	108
			(0.030)	
	Hubao and Eyu	West	0.021	48
			(0.159)	
	Beibu Gulf	West	-0.063**	72
			(0.016)	
	Chengdu-Chongqing	West	-0.027	84
			(0.028)	
	Qianzhong	West	-0.007	48
			(0.44)	
	Central Yunnan	West	0.790	36
			(0.312)	
	Guanzhong Plain	West	-0.052	60
			(0.169)	

Langxi	West	0.090 (0.092)	48
Ningxia Yellow River	West	0.472*** (0.042)	48
Tianshan North Slope	West	-0.842 (-1.32)	24

Note: $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$*

From the regression results, there is obvious heterogeneity in the impact of digital economy development on income inequality in the urban agglomerations in the eastern region and the urban agglomerations in the western region. Although the results of the Beijing-Tianjin-Hebei region and the Shandong Peninsula in the eastern region are not significant, the coefficient of the regression results is negative, indicating that the digital economy development of these two urban agglomerations tends to alleviate income inequality. The regression coefficients of the Pearl River Delta, the Yangtze River Delta and the west coast of the Taiwan Strait are all positive, and the regression results of the Pearl River Delta urban agglomerations are still significant, indicating that the development of the digital economy tends to exacerbate income inequality in these three urban agglomerations. This may be related to the imbalance in the distribution brought about by the development of the digital economy in these three urban agglomerations under the dominance of the export-oriented economic model.

According to the regression results of urban agglomerations in the western region and the actual situation, the heterogeneity is even more obvious. The regression results of the urban agglomeration in the Beibu Gulf are negative and significant, and the regression results of the urban agglomerations in Chengdu-Chongqing, central Guizhou, Guanzhong and Tianshanbeipo are not significant, but the coefficient is negative, indicating that although the level of digital economy development in the western region is not as high as that in the eastern region, the digital economy can promote the inclusive development of the western region under the guidance of specific policies. For example, the development of the digital economy in the Beibu Gulf urban agglomeration can alleviate income inequality, perhaps because the digitalization of border trade and the development of e-commerce of agricultural products in this region are good and inclusive. The regression results of the urban agglomerations along the Yellow River in Ningxia are positive and pass the significance test, while the regression results of the urban agglomerations in Hubaoeyu, central Yunnan and Lanxi are not significant, but the coefficients are positive, indicating that the development of the digital economy in these urban agglomerations tends to worsen the problem of income equality, which may be closely related to the uneven development of the digital economy in the western region. For example, the Ningxia Yanhuang urban agglomeration is located in the northwest of China, where the climate and geography are relatively harsh, and the corresponding digital infrastructure is not perfect enough and the construction is more difficult, which can easily cause people with access equipment to benefit from the digital economy and widen the income gap between people with access equipment and those who lack access equipment.

In the face of such a situation, the follow-up relevant policies need to be more targeted in order to deal with the problems existing in the eastern and western regions. For example, in terms of policy, the eastern part of the country should pay more attention to optimizing the distribution mechanism, while the western part of the country should pay more attention to solving the problem of digital infrastructure construction.

4.7 Analysis of moderating effects

There is a relatively large gap between the eastern and western regions of China in terms of the stock and quality of human capital, and the eastern region performs better in terms of human capital than the western region due to better economic development, more employment opportunities, and higher wages. Investment in education is the most basic means of improving human capital, and on the basis of obtaining more and better educational resources, the quality of human capital in the western region can also be improved, and there will be more opportunities for obtaining high incomes. Zhang et al. (2011) also argue that increasing the concentration of human capital can increase income levels in different regions.

Therefore, it can be speculated that the improvement of education level can moderate the impact of the development of digital economy on income inequality in eastern and western China on the basis of improving the human capital of a region.

In this paper, we introduce education level and its interaction term into the model to test the moderating effect of education level on the impact of digital economy on income inequality in eastern and western China. Among them, the level of education is measured by the ratio of education expenditure to general public budget expenditure.Formula as follow:

$$Ineq_{it} = \alpha + \beta_1 DE_{it} + \beta_2 Edu_{it} + \beta_3 (DE_{it} \times Edu_{it}) + \gamma Cont_{it} + \mu_{it} + \lambda_{it} + \epsilon_{it}$$

In this formula, i denotes the region and t denotes the year.$Ineq_{it}$ is dependent variable, indicates the income inequality level of the i-th region in the t-th period.DE_{it} is independent variable,indicates the digital economy development level of the i-th region in the t-th period. Edu_{it} is moderator variable, represents the education level of the i-th region in the t-th period, $DE_{it} \times Edu_{it}$is interaction term, represents the interaction between digital economy and education level, used to test whether education level plays a moderating role in the process of digital economy affecting income inequality.$Cont_{it}$ are control variables,indicates other factors that may affect income inequality.μ_{it} is regional fixed effect; λ_{it} is time fixed effect and ϵ_{it} is random error term.

In order to analyze the education level in the east and west more clearly, the moderating effect of education level on the relationship between digital economy and income inequality was also regressed into two groups: east and west.

Table 11: *Results of the Moderating Effect of Education Level*

	ie			
	(1)	(2)	(3)	(4)
de	0.072	0.073	0.396***	0.396***
	(0.047)	(0.044)	(0.116)	(0.115)
edu	0.796	0.879	4.056***	3.989***
	(0.813)	(0.796)	(1.200)	(1.289)
edu_de	-0.169	-0.194	-2.177***	-2.169***
	(0.227)	(0.224)	(0.578)	(0.622)
pgdp		-0.000		0.000
		(0.000)		(0.000)
is		-0.007		-0.011
		(0.063)		(0.064)
fe		0.063		-0.228
		(0.506)		(0.574)
ul		-0.044		-0.707*
		(0.309)		(0.381)
op		-0.057		-0.071
		(0.087)		(0.090)
R2	0.524	0.527	0.749	0.761
Observation	528	528	468	468
City FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Note: p < 0.1, ** p < 0.05, *** p < 0.01*

In this table ,column (1) and (2) are the regression results of the eastern region without the addition of control variables and after the addition of control variables, respectively, and columns (3) and (4) are the regression results of the eastern region without the addition of control variables and after the addition of control variables, respectively.

According to the regression results, after adding the education level and its interaction terms, in the eastern region, whether the control variables were not added or the control variables were added, de changed from positive to non-significant, and edu and

de*edu were positive and negative, respectively. This indicates that in the eastern region, improving the education level can partially alleviate the aggravation of income inequality in the context of the development of the digital economy, but due to the high education level in the eastern region, the moderating effect of education on income distribution may have a marginal diminishing effect.

In the western region, de and edu had significant positive effects, while de*edu had significant negative effects, regardless of whether the control variables were not added or controlled. Considering that in the grouped regression of the east and west, the regression result of the impact of the digital economy on income inequality in the western region is not significant, but after the adjustment of education level is added, the regression result of the impact of the digital economy on income inequality becomes positive and significant, while the interaction term de*edu is negatively significant, indicating that the development of the digital economy will aggravate the income inequality in the western region, but the improvement of education level can reduce the negative impact of the digital economy in the western region. This may be reflected in the fact that the overall economic level and education level in the western region are low, and the development of the digital economy in the western region is initially more beneficial to those who are highly skilled workers, exacerbating income inequality. However, the improvement of education level can not only improve the education level of workers and improve the quality of labor, but also allow more people to benefit from the digital economy, reduce the skill premium brought by the digital economy, and narrow income inequality. It can also be seen that the role that can be played by the improvement of education level is even more crucial in reducing income inequality in the western region.

V. CONCLUSION

Based on the relevant data of 83 cities in eastern and western China from 2011 to 2022, this study uses principal component analysis (PCA) and calculates the ratio of per capita disposable income between urban and rural areas to measure the development of the digital economy and income inequality in eastern and western China. In addition, based on the urban panel data from 2011 to 2022, the impact of China's digital economy development on income inequality in the eastern and western regions is empirically examined. The results show that: 1) The level of digital economy development in eastern and western cities in China from 2011 to 2022 is getting higher and higher, but there is a relatively large gap between the eastern and western cities, and the level of digital economy development in eastern cities is generally higher than that in western cities. 2) From 2011 to 2022, income inequality in both eastern and western cities in China has decreased, but the level of income inequality in cities in western China is still higher than that in eastern cities. 3) The development of the digital economy will exacerbate income inequality in eastern and western China, and this conclusion is still true under a series of robustness tests. 4) There is regional heterogeneity in the impact of China's digital economy on income inequality in the east and west. The effect of the digital economy on the expansion of income inequality is more obvious in the eastern region, and the impact is weaker in the western region. 5) The analysis of moderating effect showed that the moderating effect of education level in eastern China was not large. But in the west, improving education is an important way to alleviate income inequality caused by the digital economy.

Therefore, in the context of the development of the digital economy, the following suggestions are put forward in this research. First, the eastern region should balance the efficiency and fairness of the development of the digital economy and achieve digital inclusion, which can be achieved by promoting the inclusive development of the digital economy. For example, we should establish a mechanism for redistributing the benefits of the digital economy, improve the laws on the digital economy, and strengthen the supervision of relevant enterprises, so as to achieve a rebalance between efficiency and fairness. Second, the western region should strengthen infrastructure and digital education to support digital transformation. First of all, it is necessary to solve the problem of "access" in the development of the digital economy, so that the development of the digital economy in the western region is not restricted by infrastructure. Second, we need to increase investment in education to improve the level of education and help them master more skills related to the digital economy. In addition, it is necessary to support the integration of local characteristic industries with the digital economy, innovate development models, achieve digital transformation, and increase employment opportunities. Third, the eastern and western regions should achieve coordinated development across regions. This should not only promote the in-depth connection between the advantages of digital technology in the east and the application scenarios in the west, but also strengthen the radiation and driving role of the eastern region, promote the two-way flow of technology, talents, data and other elements, realize resource sharing, and enable both regions to better benefit from the development of the digital economy.

In general, this study is helpful to understand the impact of the development of China's digital economy on income inequality in the eastern and western regions, and formulate more targeted and regional policies based on the research results, so that the eastern and western regions can achieve a more balanced development driven by the digital economy. However, the indicators used in this study are relatively single and the research scope is limited to some eastern and western cities, and is not compared with other regions, so the research is not particularly comprehensive. In the future, a more comprehensive evaluation system can be established to analyse and compare the relevant situation in more regions of China, and further explore the impact of the development of the digital economy on income inequality.

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