Research on the Non-linear Impact of Fintech on the Urban-rural Income Distribution gap

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Abstract. This paper uses Python web scraping technology to construct a fintech index and panel data from China from 2005 to 2021 to study the impact of fintech on the urban-rural income distribution gap. The results of the study show that the relationship between FinTech and the urban-rural income distribution gap is in a "U" shape. At the optimal threshold, the development of FinTech has a mitigating effect on the income distribution gap, while overdevelopment has the opposite effect and exacerbates income inequality. The results remain significant after eliminating the endogeneity problem through the instrumental variables approach. There is also regional heterogeneity in the impact of fintech on the urban-rural income distribution gap. Eastern and central regions show significant impacts, while western regions do not. Improvements in digital infrastructure, innovation capacity and human capital amplify the impact of fintech on narrowing the urban-rural income gap. To further narrow the gap between urban and rural income distribution, it is necessary for each region to take into account its own development and keep fintech within a reasonable range. This will lay the foundation for the realisation of common prosperity and high-quality economic development.

Keywords: Fintech; Non-linear research; Python; Urban-rural income gap.

1 Introduction

Currently, rising inequality in income distribution is a significant obstacle to the sustained and stable growth of national economies. The World Inequality Report, published by the World Inequality Lab in 2022, highlights that the low-income group, which accounts for 50 % of the global population, owns just 2 % of the world's wealth. while the high-income group of 10% controls 76% of the world's wealth. Furthermore, the spread of the COVID-19 has contributed to an even greater income distribution gap. For an extended period, eliminating income distribution gaps, improving people's livelihoods have constituted the starting and ending point of China's economic endeavours. With the convening of the Eighth Congress of the Communist Party of China (CPC) in 2012, by reforming the income distribution system, consolidating and expanding the achievements of poverty alleviation, improving and optimizing the income distribution structure, while comprehensively eliminating absolute poverty, China has greatly improved the distribution of income between regions and urban-rural areas, this has created another Chinese miracle. Nevertheless, at present stage, the issue of excessive income distribution gap in our country remains prominent. According to statistics , per capita disposable income ratio of urban and rural residents in China in 2022 is 2.5. Furthermore, the Gini coefficient still exceeds the international warning line, and the

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problem of relative poverty caused by the excessive income distribution gap between urban and rural areas has already become a significant obstacle for China to overcome the middle-income trap and advance towards high-quality economic development. Xi Jinping, the General Secretary, has emphasized that achieving common prosperity is a fundamental aspect of China's modernization efforts. And addressing the gap between urban and rural income distribution consciously and proactively, realising common prosperity gradually[1] Furthermore, the 20th Party Congress has specified that promoting the development of the digital economy is an important way to address the income distribution gap and realise common wealth. In this process, fintech will play an important leading and promoting role as an organic component and concrete manifestation of the digital economy. Fintech applies digital information technology to financial supply, which can significantly improve financial inclusion[2], reduce the cost of financing effectively, provide convenient services for low-income groups in urban and rural areas that are difficult to reach through traditional finance, This, in turn, can alleviate the urban and rural financial plight and improve the income distribution gap[3]. Consequently, the Chinese government's “Financial Technology Development Plan (2022-2025)” proposes the development of financial technology as a means of achieving common wealth. Consequently, a comprehensive reaserch of the intrinsic relationship between fintech and income distribution, has considerable theoretical and practical value in facilitating the profound integration of the digital economy and entities, exploring an effective approach to managing relative poverty, and advancing the achievement of the objective of common wealth.

2 Theoretical analysis and research hypothesis

Since the 1970s, the existence of a long-term, trend-changing relationship between technological progress and income distribution has been demonstrated by the practice of economic development in various countries. In recent years, the integration development of new technologies, including big data, artificial intelligence, blockchain and 5G with traditional finance has promoted the rapid rise of fintech, the enhancement in the scope and depth of financial services has been notable. Nevertheless, the impact of fintech on the income disparity between urban and rural areas continues to be debated. Some studies have posited that the advancement of fintech may serve to narrow the urban-rural income distribution gap, whereas others have suggested that fintech may exacerbate the urban-rural income distribution gap.

Firstly, advancements in fintech have the potential to reduce the income distribution gap between urban and rural areas. Relying on the construction of digital infrastructure, financial technology can empower rural revitalization, lower the entry threshold for rural financial services, alleviate the financial exclusion caused by insufficient resource endowments of low-income groups, this can also improve the availability and inclusivity of financial services in rural areas, making them more accessible to all residents[4], this can assist farmers in obtaining diversified incomes through the utilisation of financial services[5]. Thus, enhancing financial services in rural areas can effectively curb the widening income disparity between urban and rural settings[6]. Advancement of fintech can also stimulat innovation and entrepreneurial vitality of farmers[7], facilitate the integration of agriculture, industry, and services in rural areas, boosting their combined development[8], and promote the development

of industries towards poverty alleviation and diversification[9], enable farmers to share the benefits of regional economic development[10], thereby, the sustained increase in rural incomes will help narrow the income disparity between urban and rural areas[11].

Secondly, The advancement of fintech could potentially widen the income distribution gap between urban and rural areas. Fintech represents biased technological progress, which can intensify the gap between human capital and make urban incomes grow faster than rural incomes, thus, this could exacerbate the economic disparity between urban and rural areas[12]. Due to the existence of the digital divide and marginal agglomeration effects, the development of fintech will also lead to relatively lower costs for regions with higher levels of economic development and high-income groups to access financial services, causing social welfare growth to tilt towards specific regions and groups, thereby inhibiting the two-way transfer of urban and rural labor, and through the Matthew effect, widening the income disparity between urban and rural regions[13].

In conclusion, the affect of fintech about the urban-rural income distribution gap is non-linear. Within a specific threshold, the development of fintech reduces the urban-rural income distribution gap. However, beyond this threshold, the expansion of fintech triggers an increase in the income disparity between urban and rural populations, resulting in a U-trend[14]. At this stage, the coverage of traditional financial services in rural areas is still much lower than that in towns, the rapid expansion of fintech may significantly enhance financial accessibility and inclusivity in rural areas compared to urban areas. As a result, during this period, fintech contributes more significantly to income growth for rural residents, thereby potentially narrowing the income gap between urban and rural areas.

However, when the development of fintech enters a high-level mature stage, constrained by the development of human capital, the role of fintech in boosting the income growth of residents in rural areas will be lower than that of urban areas. During this period fintech will result in a significant widening of the gap between urban and rural income distribution during this period. Accordingly, this research proposes the following hypotheses:

Hypothesis 1: There is a U-shaped variation relationship between fintech and the urban-rural income distribution gap. Within the optimal threshold, fintech development can reduce the urban-rural income distribution gap. Conversely, outside the optimal threshold, fintech development will widen the urban-rural income distribution gap.

Furthermore, Considering the significant differences in economic development, digital infrastructure construction, innovation capabilities, and human capital cultivation among different regions in China, this will influence the impact of financial technology on the urban-rural income distribution gap. In regions with a high level of economic development, the maturity of digital infrastructure construction and regional innovation capacity is relatively higher, the popularity and application of fintech is more extensive, and the financial services provided are more diversified, which are more able to satisfy the financial needs of residents. Meanwhile, in regions with a high level of economic development, the disparity in human capital is relatively minor, which is more conducive to enhance the influence of fintech on the economic disparity between urban and rural regions. Conversely, in economically underdeveloped regions, the slow and uneven development of digital infrastructure, limited regional innovation capabilities, and lagging human capital development hinder the effective utilization of financial technology to bridge the income gap between urban and rural

residents[15]. Accordingly, the following hypotheses can be put forward:

Hypothesis 2: There is regional heterogeneity in the impact of fintech on the urban-rural income distribution gap. The digital infrastructure development, innovation capacity, and human capital development level can play a moderating role, and Alter the impact of fintech on the disparity in income distribution between urban and rural areas.

3 Study design

3.1 Variable selection

3.1.1 Explained variables

The urban-rural income gap as the dependent variable, can be measured by constructing the Thiel index ($\mathrm{T}h\mathrm{eil}_{\mathrm{it}}$), which can be represented in the following equation:

$$\mathrm{Theil}_{\mathrm{i,t}} = \sum_{\mathrm{i=1}}^{2} \left(\frac{\mathrm{I_{it}}}{\mathrm{I_t}}\right) \mathrm{Ln}\left(\left(\frac{\mathrm{I_{it}}}{\mathrm{P_{it}}}\right) / \left(\frac{\mathrm{I_t}}{\mathrm{P_t}}\right)\right) \quad (1)$$

In equation (1), I_1 represents the disposable income of urban residents, expressed as the product of the disposable income per urban resident and the urban population. I_2 represents the disposable income of rural residents, expressed as the product of the disposable income per rural resident and the rural population. Irepresents the total disposable income of regional residents. P_1 represents the urban population. P_2 represents the rural population. The variable P stands for the resident population at the end of the year in a given area. . The larger the value of the Theil index, the greater the income distribution gap between urban and rural areas.

3.1.2 explanatory variables

Fintech ($\mathrm{FinTec}h$) is the core explanatory variable. There are three main methods to measure it. First, using Peking University's Digital Inclusive Finance Index as a alternative variables to measure the degree of development of fintech. This method has a certain degree of credibility due to the strong positive correlation between digital inclusive finance and fintech development. However, since digital inclusive finance is based on data sampling of Alipay's individual users, there may be significant bias in measuring the development of Fintech, which is difficult to reflect the actual level of fintech development. Secondly, primary indicators is selected according to domestic fintech development norms and guidance documents, and select keywords from different dimensions as secondary indicators, use Python data crawler technology to obtain Baidu search index data corresponding to each keyword, and then use entropy weight method or analytic hierarchy process to construct fintech development indicators.

In general, this measurement method is relatively accurate. However, due to the number of search terms in the relevant region does not represent the number and development status of fintech enterprises , this method also has significant measurement bias in measuring the level of fintech development. Thirdly, using Python data crawler technology to obtain the number of physical companies in different regions matching the keywords such as fintech in

“Tianyancha”at different times to construct a fintech index. This method can measure the actual level of fintech development in different regions better, so the measurement error is relatively smaller. Consequently, the measurement bias is relatively smaller. This article uses a third measurement method to obtain company data that matches fintech keywords in different regions at different times. In order to ensure the accuracy of the data, companies samples that have been out of business, revoked or operated for less than one year are deleted, and obtained the data of fintech companies in 31 regions of China from 2005 to 2021.Then add one to the data and take the natural logarithm in order to obtain the regional fintech index.

3.1.3 Control variables

The control variables in the analysis include the degree of regional openness to external influences(Open), population density（Pop）, R&D investment intensity（ReIn）, energy structure（ReSt）, the degree of government intervention（Gov）, and the degree of informationisation（Info）.Generally, factors such as regional openness, population density, energy structure, and degree of informatization tend to inversely affect the urban-rural income distribution gap. In contrast, R&D investment intensity and the level of government intervention usually have a direct positive correlation with the urban-rural income gap. This is because regions with a high degree of openness to the outside world and informatisation,Areas with high population density and a refined energy structure often exhibit a high degree of industrial diversification and potential for quality economic development, which contributes to mitigating the expansion of the urban-rural income distribution gap. Correspondingly, regions with a high level of R&D investment intensity are conducive to the advancement of scientific and technological progress, which in turn facilitates the clustering and development of high-tech industries in urban and rural areas. This acceleration in urban residents' income growth can, in turn, potentially exacerbate the income distribution gap between urban and rural residents. In regions with high levels of government intervention, market vitality is relatively lower, industrial homogenization tends to be more prominent, and the income distribution gap between urban and rural areas is also larger. In order to assess the above control variables, the degree of regional openness to the outside world can be measured by the ratio of the total amount of regional import and export of goods to the regional gross domestic product (GDP). The population density can be measured by the ratio of the total population of the region to the area of administrative divisions. The R&D investment intensity can be measured by the ratio of R&D expenditures to the regional GDP.

The energy structure can be measured by the ratio of the regional consumption of electric power to the national total consumption of electricity. The degree of government intervention can be measured by the ratio of regional fiscal transfer payments to the total fiscal expenditures of the country. The degree of informatisation is measured by the number of mobile phones and computers per capita in the region.

3.2 Data sources and descriptive statistics

The statistical data of the 31 regions in China were obtained from the CSMAR database, the EPS database, and the China Statistical Yearbook. Some of the data were processed and organized, and the data sample period is from 2005 to 2021. The statistical description of the related variables is shown in Table 1.

Table 1 Descriptive statistics of variables

Variable name	Number of individuals	Minimum value	Maximum values	Mean value	Median
Theil	527	0.0180	0.2760	0.1036	0.0970
Fintech	527	0.0000	10.3986	3.8385	3.4657
Fintech2	527	0.0000	108.1317	18.6039	12.0113
Open	527	0.0076	1.7215	0.2902	0.1365
Pop	527	2.2801	3925.8700	440.9990	270.5990
ReIn	527	0.0014	0.0653	0.0149	0.0119
ReSt	527	0.0005	0.1080	0.0323	0.0250
Gov	527	0.0798	1.3337	0.2563	0.2098
Info	527	0.0143	0.2896	0.0655	0.0549

3.3 Modelling

3.3.1 Two-way fixed effects models

To explore the dynamic relationship between fintech development and the urban-rural income distribution gap, a two-way fixed effects model is proposed for detailed analysis. The structure of the model is outlined below.

$$\mathrm{Theil}_{i,t} = a_0 + a_1\mathrm{Fintech}_{i,t-1} + a_2{\mathrm{Fintech}_{i,t-1}}^2 + a_3X_{i,t-1} + \delta_i + \eta_t + \varepsilon_{i,t} \quad (2)$$

In equation (2), t represents the year, i represents the region. Theil_{it} is the explanatory variable that refers to the urban-rural income distribution gap in region i in year t. $\mathrm{Fintech}_{it-1}$ is the core explanatory variable, representing the financial technology development level in region i of the t-1 period. ${\mathrm{Fintech}_{i,t-1}}^2$ represents the square term of the core explanatory variable. a_0 is a constant term. a_1 is the coefficient for financial technology. a_2 is the square coefficient for fintech. X_{it-1} represents the control variables of the t-1 period. a_3 represents the coefficient of the control variable. η_t represents fixed time effects. δ_i represents fixed regional effects. $\varepsilon_{i,t}$ is random perturbation terms.

3.3.2 Moderating effects model

The influence of fintech on the urban-rural income distribution gap is likely to differ significantly due to variations in digital infrastructure, innovation capabilities, and human capital across regions. To address this, we introduce moderating variables β based on model (1), and construct the moderating effect model as shown below.

$$\mathrm{Theil}_{i,t} = a_0 + a_1\mathrm{Fintech}_{i,t-1} \times \beta_{i,t-1} + a_2{\mathrm{Fintech}_{i,t-1}}^2 \times \beta_{i,t-1} + a_3\beta_{i,t-1} + a_4X_{i,t-1} + \delta_i + \eta_t + \varepsilon_{i,t} \quad (3)$$

In equation (3), $\beta_{i,t-1}$ is the moderating variable for region i in period t-1. $\mathrm{Fintech} \times \beta$ and $\mathrm{Fintech}^2 \times \beta$ represent the interaction terms of fintech and its squared term with the moderating variable, respectively.there are three moderating variables in this paper.

4 Empirical evidence Analysis of results

4.1 Baseline regression analysis

Before running the benchmark regression, as the Hausmann test results significantly reject random effects, The analysis initiates by accounting for fixed effects related to time and geographic areas, with the benchmark regression results displayed in Table 2.

Table 2 Comparison of regression results

	Static model (1)	Static model (2)	Static model (3)	Dynamic model (4)	Dynamic model (5)	Dynamic model (6)	instrumental variable (7)
Fintech	-0.0080***	-0.0207***	-0.0095***	-0.0025*	-0.0028*	-0.0026**	
	(0.0088)	(0.0000)	(0.0014)	(0.0538)	(0.0702)	(0.0107)	
Fintech2		0.0015***	0.0005***		0.0002*	0.0002**	0.0008**
		(0.0000)	(0.0026)		(0.1108)	(0.0154)	(0.0897)
Open			-0.0220***			-0.0060	-0.0523***
			(0.0003)			(0.1789)	(0.0022)
Pop			0.0000***			0.0000*	0.0000**
			(0.0000)			(0.9070)	(0.0266)
ReIn			1.2790***			0.0239*	0.7954*
			(0.0009)			(0.0508)	(0.0638)
ReSt			-0.2053***			0.0002	0.3406***
			(0.0044)			(0.9845)	(0.0022)
Gov			0.0282*			0.0096*	0.0611***
			(0.2791)			(0.0800)	(0.0000)
Info			-0.0727*			-0.0229	-0.3533***
			(0.0517)			(0.1304)	(0.0000)
L.Theil				0.9493***	0.9414***	1.0117***	
				(0.0000)	(0.0000)	(0.0000)	
individual fixed effect	containment	containment	containment	containment	containment	containment	containment
time fixed effect	containment	containment	containment	containment	containment	containment	containment
N	527	527	527	496	496	496	527
R2	0.8147	0.8594	0.8931				0.8014

Notes: *** denotes that the results are statistically significant at the 1% level; ** denotes that the results

are statistically significant at the 5 % level; * denotes that the results are statistically significant at the 10 % level; numbers in parentheses represent standard errors, which are consistent with those presented later in the document.

In Table 2, column (1) shows the regression results only used the core explanatory variables and the dependent variables, column (2) shows the regression results with the addition of the squared terms of the core explanatory variables, and column (3) shows the regression results with the addition of all the control variables. Based on the regression results in Column (3), the analysis combined with the three conditions of the U-test proposed by Haans (2016) reveals that, firstly, the coefficients of the primary term of fintech have opposite signs to the coefficients of the quadratic term, and the coefficients of the primary term of fintech are significantly positive at the 1% level, while the coefficients of the quadratic term are significantly negative at the 1% level. Secondly, the slope of the curve is steeper in the range of interval values of fintech, when fintech takes the minimum value of 0, the slope of urban-rural income distribution gap with fintech is less than 0, and its value is -0.0095. Thirdly, the inflection point of the curve falls within the range of fintech values. Through calculation, it is found that the inflection point of the curve, i.e. the optimal value of fintech is 8.5181, which is within the range of finrech interval [0,10.3986]. iven that all three conditions are met, there exists a U-shaped relationship between fintech and the urban-rural income distribution gap. Within the optimal threshold, the development of fintech helps reduce this gap. However, beyond this threshold, excessive fintech growth can exacerbate the disparity. In addition, in the baseline regression results, the effects of each control variable on the explanatory variables are consistent with expectations, so hypothesis condition 1 holds.

4.2 Endogeneity test

4.2.1instrumental variable approach

In equation (2), the coefficient of financial technology development (Fintech) may be shifted by some factors, and the narrowing of the urban-rural income gap may also contribute to the development of Fintech, and there may be a reverse causality. In order to alleviate the endogeneity problem due to measurement error, omitted variables or reverse causality, referring to the study of Song Min et al[16] and combining with data availability, the mean value of the level of Fintech development of the three other prefectures in the province where the enterprise is located whose GDP is closest to that of its place of incorporation is used as an instrumental variable, and regression is conducted using the panel instrumental variable method. From the following perspectives: ① Correlation. From the perspective of financial institutions' location selection, when banks set up branches, the region with the closest provincial GDP is often the alternative region with similar probability of entry and considered by banks. From the perspective of economic development, prefecture-level cities within a province are affected by the same provincial policies, and similar GDPs indicate similar development experiences. In addition, cities with similar GDPs also have similar financial industry structure, which is the basis for fintech "empowerment". Therefore, the development of FinTech between provincial cities with similar GDP and target cities is highly correlated. Exogenous. In cities with similar provincial GDP, the direct impact of FinTech development on the urban-rural income gap among businesses is minimal. Therefore, the instrumental variables (IVs) chosen in this study adhere to the necessary assumptions of correlation and exogeneity.The instrumental variable regression results are shown in Table 2 model (7),

compared with the baseline regression results, the explanatory variable coefficients are still significant after adding instrumental variables.

4.2.2dynamic panel

The regional urban-rural income distribution gap may have an impact on the level of fintech development. At the same time, the adjustment and change of fintech and the urban-rural income distribution gap will also be affected by other variables. This scenario could lead to endogeneity issues between fintech development and the urban-rural income distribution gap, suggesting that factors influencing one may internally affect the other. In order to eliminate the endogeneity problem, this research uses one-period lagged data of fintech and control variables in the benchmark regression. This weakened the endogeneity caused by reverse causality between fintech and urban-rural income distribution gap. Meanwhile, lagging the urban-rural income distribution gap by one period is introduced into the dynamic model. The regression results are shown in columns (4) to (6) in Table 2. Column (4) is the regression result using only the core explanatory variable while introducing the lagged data of urban-rural income distribution gap for one period. Column (5) is the regression result of incorporating the squared term of the core explanatory variables. Column (6) is the regression result of incorporating all the control variables. The test results confirm that the relationship between fintech and the urban-rural income distribution gap aligns with the findings from the benchmark regression, suggesting that the model's endogeneity issues have been effectively mitigated.

4.3 Robustness Tests

To further examine the robustness of the regression results, the following methods can be applied to develop separate tests.

First, the core explanatory variables can be replaced. As digital inclusion finance can reflect the development of fintech to a certain extent, the Peking University Digital Financial Inclusion Index (Peking) can be used to replace fintech as the core explanatory variable in the regression. The regression results are shown in column (1) of Table 3. The regression analysis reveals that, with the Digital Financial Inclusion Index as the core explanatory variable, fintech development significantly reduces the urban-rural income distribution gap at a 1% significance level. Furthermore, the coefficient of the squared term of the Digital Financial Inclusion Index is significantly positive at the 1% level, which is consistent with the benchmark regression results.

Second, the explanatory variables were replaced. The ratio of disposable income per capita of urban and rural residents is employed as an explanatory variable in the regression, replacing the Tyrell index. The regression results are presented in column (2) of Table 3.According to the regression findings, even after substituting different explanatory variables, fintech development continues to have a statistically significant negative effect on the income distribution gap between urban and rural residents at the 1% significance level. Furthermore, the coefficient of the squared term of fintech is significantly positive at the 1% level, which is consistent with the results of the benchmark regression.

Finally, the sample interval is replaced. Given that the concepts related to fintech were not widely disseminated prior to 2010, fintech companies were not established in some regions.

Furthermore, constrained by epidemic prevention after 2020, the size and number of fintech companies in certain regions were significantly affected.

This study uses data from 2010 to 2019 across various regions for regression analysis, with results presented in column (3) of Table 3. After narrowing the sample interval, the impact of fintech development on the urban-rural income gap remains significantly negative at the 1% significance level, and the coefficient for the squared term of fintech remains significantly positive at the same level.The combination of the three methods demonstrates that the conclusions drawn are robust.

Table 3 Comparison of robustness test results

	Substitution of explanatory variables (1)	Substitution of dependent variables (2)	Substitution of sample intervals (3)
Peking	-0.0003***		
	(0.0000)		
Peking2	0.0000***		
	(0.0000)		
Fintech		-0.0393***	-0.0207***
		(0.0064)	(0.0000)
Fintech2		0.0034***	0.0009***
		(0.0032)	(0.0000)
individual fixed effect	containment	containment	containment
time fixed effect	containment	containment	containment
control variable	containment	containment	containment
N	527	527	310
R2	0.9328	0.7917	0.8246

5. Heterogeneity analysis and testing

5.1 Tests for regional heterogeneity

Currently, the uneven development across China's regions could lead to varied effects of financial technology on regional income distribution, highlighting the heterogeneity in its impact. The sample can be divided into eastern, central and western regions according to their respective levels of regional economic development. The regression results are presented in Table 4.

Table 4 Comparison table for heterogeneity analysis

	Eastern Region	Central Region	Western Region
Fintech	-0.0157***	-0.0043*	-0.0000
	(0.0006)	(0.0859)	(0.9941)
Fintech2	0.0003**	0.0002	0.0001
	(0.0362)	(0.4682)	(0.8349)
individual fixed effect	containment	containment	containment
time fixed effect	containment	containment	containment

control variable	containment	containment	containment
N	170	153	204
R2	0.9360	0.9369	0.9331

The coefficients of the primary terms in Table 4 indicate that the impact of fintech development on the urban-rural income distribution gap varies significantly across different regions, demonstrating considerable heterogeneity.In the eastern and central regions, fintech development has the potential to significantly reduce the gap between urban and rural income distribution. The inhibition effect of fintech on the gap between urban and rural income distribution in the eastern region is more significant, while the effect of fintech on the gap between urban and rural income distribution in the western region is not significant. Similarly, the coefficient of the quadratic term indicates that there is a U-shaped change relationship between fintech development and the urban-rural income distribution gap solely in the eastern region, but not in the central and western regions.

5.2 Tests for heterogeneity of moderating effects

Given the regional disparities in digital infrastructure (Diginf), innovation capabilities (Innovation), and human capital development (HumCap), a moderating effect model can be employed to investigate how these differences influence the intensity of fintech's impact on the urban-rural income distribution gap, thus exploring the underlying mechanisms.

Among these factors, the level of regional digital infrastructure construction can be reflected by the ratio of the number of urban broadband access subscribers to the number of rural broadband access subscribers. Innovation capacity is measured by the logarithm of the number of annual patent applications received in the region. The development of human capital is quantified by taking the logarithm of the ratio of the population with education above high school level to the total employed population, increased by one. Concurrently, in order to further compare the heterogeneity of the effect of moderating variables on regional impact, digital infrastructure construction, innovation capacity and human capital status of different regions can be divided into two categories of high and low, then assigned the value of 1 and 0, respectively. The regression outcomes from the moderating effect model are detailed in Table 5.

Firstly, the moderating effect of regional digital infrastructure development on the influence of fintech on the urban-rural income distribution gap is notably significant. Column (1) of Table 5 indicates that a U-shaped relationship persists between fintech and the urban-rural income distribution gap, irrespective of the level of regional digital infrastructure development. In regions with less developed digital infrastructure, the primary and secondary coefficients of fintech are -0.0068 and 0.0004, and the optimal level of fintech development is 8.5001. In regions with higher levels of digital infrastructure development, the coefficients of the primary and secondary terms of fintech are -0.0101 and 0.0006, respectively, and the optimal level of fintech development is 8.4167. This indicates that within the optimal threshold, the more advanced the digital infrastructure, the more significant is fintech's role in reducing the urban-rural income distribution gap. On the other hand, the impact of fintech on this income gap tends to have a lasting effect.

Furthermore, the moderating effect of regional innovation capacity on the relationship between fintech and the urban-rural income gap is highly significant, as demonstrated in column (2) of Table 5. A U-shaped relationship is evident across regions, irrespective of their

innovation capacity. In regions with lower innovation capacity, fintech's primary and secondary coefficients are -0.025 and 0.0029, respectively, with an optimal development level at 4.3103. Conversely, in regions with higher innovation capacity, the coefficients are -0.0237 and 0.0027, with an optimal level of 4.3889, indicating that fintech has a relatively stronger dampening effect on the income gap in less innovative regions within the optimal threshold.

Finally, the moderating effect of regional human capital development on the relationship between fintech and the urban-rural income distribution gap is highly significant, as evidenced in column (3) of Table 5. Regardless of the level of human capital formation, a U-shaped relationship persists between fintech and the income gap. In regions with lower levels of human capital development, the primary and secondary coefficients of fintech are -0.0410 and 0.0048, respectively, with an optimal fintech level at 4.2708. Conversely, in regions with higher human capital, the coefficients are -0.0454 and 0.0054, respectively, with an optimal level at 4.2037. This indicates that fintech exerts a stronger inhibitory effect on the income gap in regions with more developed human capital within the optimal threshold.

Table 5 Comparison of regression results for moderated effects

	Digital infrastructure (1)	innovation capacity (2)	human capital (3)
Fintech	-0.0068*** (0.00145)	-0.0250*** (0.0000)	-0.0410*** (0.0000)
Fintech2	0.0004*** (0.0001)	0.0029*** (0.0000)	0.0048*** (0.0000)
Fintech-Diginf	-0.0033*** (0.0000)		
Fintech2 - Diginf	0.0002*** (0.0000)		
Fintech-Inn		0.0013*** (0.0004)	
Fintech2 -Inn		-0.0002*** (0.0000)	
Fintech-Lab			-0.0044*** (0.0000)
Fintech2 -Lab			0.0006*** (0.0000)
individual fixed effect	containment	containment	containment
time fixed effect	containment	containment	containment
control variable	containment	containment	containment
N	341	527	527
R2	0.8712	0.8971	0.8997

Note: Since China started to compile data on digital infrastructure development in 2011, the N value in column 2 of the table is only 341.

6 Conclusion

This research uses Python data crawling technology to construct a fintech index, using the Theil index to measure regional income distribution disparities. Utilizing panel data from 31 regions in China spanning from 2005 to 2021, the study employs a non-linear two-way fixed

effects model and a moderating effect model to investigate the influence of fintech development on the urban-rural income distribution gap. The analysis yielded the following key findings.

Firstly, the relationship between fintech development and the urban-rural income distribution gap is characterized by a U-shaped non-linear pattern. There exists an optimal level of fintech development within regions, and fintech proves beneficial in narrowing the income disparity between urban and rural areas when operating within this optimal threshold.

Secondly, the impact of fintech development on the urban-rural income distribution gap exhibits significant regional heterogeneity. In the eastern region, there is a pronounced U-shaped relationship between fintech and the income gap. In the central region, while the U-shaped relationship is not significant, fintech development notably reduces the income gap. Conversely, in the western region, there is no U-shaped relationship, and the impact of fintech on the income gap is minimal.

Thirdly, the development of digital infrastructure, innovation capacity and human capital cultivation play a significant moderating effect in impact of fintech on the urban-rural income distribution gap. Within the optimal threshold range, fintech has a greater inhibitory effect on the urban-rural income distribution gap in areas with high levels of digital infrastructure construction, low innovation capabilities, and high levels of human capital cultivation. In regions characterized by underdeveloped digital infrastructure, high innovation capabilities, and low human capital development, the effects of financial technology on urban-rural income distribution disparities tend to be more enduring.

In conclusion, given the U-shaped relationship between financial technology and the urban-rural income distribution gap, along with regional variations in the impact of fintech development, it is imperative for each region to tailor its approach by leveraging the policy benefits of China's new infrastructure projects. This includes significantly enhancing digital infrastructure, reducing the human capital gap between urban and rural areas, and augmenting the positive effects of fintech on income disparities. Additionally, regions should actively improve their innovation capacities to ensure the enduring benefits of fintech. Establishing a system for forecasting and evaluating fintech development is also crucial to maintain development within a reasonable threshold, thus preventing the exacerbation of income disparities due to excessive fintech growth and supporting the goals of common prosperity and high-quality economic development.

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