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# Will advances in digital technology reduce the rural-urban income gap?

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**ABSTRACT**

The booming development of digital technology has promoted economic growth and a new round of growth in the income levels of residents. However, the uneven development of digital technology and the existence of the digital divide have led to the fact that urban and rural residents do not enjoy the dividends of income growth brought by digital technology equally. This paper analyzes the relationship between digital technology and the urban-rural income gap and finds that the development of digital technology will narrow the urban-rural income gap, but it shows a non-linear "inverted U-shaped" trend. At the same time, the current level of digital technology is still low and has not yet crossed the inflection point of the "inverted U-shaped" curve. With the continued development of digital technology at its current level, the urban-rural income gap will further widen.

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## 1. Introduction

China's economic growth since the implementation of reform and opening policies has been noteworthy. However, during the development process, there was a focus on growth first and distribution second, resulting in a more pronounced issue of development disequilibrium in China. Li (2018) highlights income disparity as a particularly prominent problem in this regard. More recently, the major contradiction in China since 2017 has been the imbalance and inadequacy of development, which has created a collision between people's desire for a better life and the current state of affairs. Recognizing the significance of income disparity, the Chinese government has repeatedly stressed the need for economic growth to be in sync with the growth of residents' incomes.

While a moderate income gap can drive economic development, an excessively wide income gap can result in various problems that hinder the sustainable and healthy growth of Chinese society. Therefore, reducing the income gap is critical to

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optimizing the income distribution pattern and achieving healthy economic development. In narrowing the income gap, it is essential to address the significant income disparity between urban and rural areas. The wide income gap between urban and rural areas in China is a primary factor contributing to the overall high income gap in the country. China's urban-rural income gap has shown an increasing and then decreasing trend, with 2009 being the turning point. Although the urban-rural income gap in China has gradually decreased since 2009, it remains high compared to global levels. Luo et al. (2021) indicate that while the urban-rural income gap in China has shown a declining trend, the degree of narrowing is not significant. The per capita disposable income ratio between urban and rural residents in China is still as high as 2.56, according to the National Bureau of Statistics' 2020 data, indicating that China has yet to address the excessive urban-rural income gap issue effectively. A wide urban-rural income gap results in rural residents being unable to fully benefit from economic growth, leading to a lack of harmony and stability in society. The lower income level of rural residents also translates to lower consumption in rural areas, weakening the national economy's consumption pull effect and hindering its balanced and stable development.

The advent of digital technology, exemplified by big data, cloud computing, and artificial intelligence, has ushered in a new stage of social development and a fresh wave of economic growth. In 2017, the Chinese government proposed to promote the deep integration of the Internet, big data, and artificial intelligence with the real economy, eventually building a digital China and a smart society. The development of digital technology has transformed the industry and society's structure, driving economic growth, albeit unequally. While the income levels of both urban and rural residents have increased, the income gap between urban and rural areas remains unaddressed, and economic growth through digital technology has been characterized by low levels of overall development and varying regional development. Chen et al. (2021) argue that digital technology's rapid growth has facilitated economic transformation, created new industries and jobs, and increased employment rates, thus raising the income levels of both urban and rural residents. However, limited digital technology access in rural areas has resulted in rural residents' inability to enjoy the dividends of digital technology, further exacerbating the income distribution issue. This digital divide problem may widen the income gap and further hinder the balanced and equitable distribution of economic growth (Liu, 2017).

Given the significance of digital technology in shaping the economy and its potential impact on the urban-rural income gap, this study aims to investigate the relationship between digital technology and the urban-rural income gap in China. To achieve this, the study first establishes an evaluation index system for digital technology and measures the urban-rural income gap in China using the Theil index. Using panel data from Chinese provinces between 2013 and 2020, a fixed-effects model is employed to analyze the relationship between digital technology and the urban-rural income gap. Furthermore, a quadratic term for digital technology is introduced to test for a non-linear relationship between digital technology and the urban-rural income gap. The moderating role of education is also investigated. The findings reveal an inverted U-shaped relationship between digital technology and the

urban-rural income gap, with education playing a significant moderating role. These findings provide valuable insights for policymakers to develop targeted policies that harness the benefits of digital technology and ultimately reduce the urban-rural income gap.

The remainder of this paper is presented below. Part II provides a literature review, Part III provides a theoretical analysis and research hypotheses, Part IV briefly describes the data sources for this study and the research methodology, Part V provides an analysis and discussion of the findings, and Part VI reports some conclusions and provides policy recommendations.

## 2. Literature review

The causes of the changes in the urban-rural income gap have been explored more in the academic community. The main influencing factors involve the dualistic economic structure between urban and rural areas (Lister, 2013), industrialization development strategy and biased policies (Li et al., 2021; Li & Pei, 2013), urbanization (Yang et al., 2015; Cheng & Li, 2007), human capital (Chen et al., 2010; Zhan & Xinwen, 2017) and many other aspects. Among them, the relationship between technology and the urban-rural income gap is a particularly important aspect that has received extensive attention. Technological progress has an important role in promoting overall economic growth (Lin & Pengfei, 2005)' but workers often do not share equally in the dividends from technological progress, and technological development exacerbates the deterioration of income distribution in the long run (Yuan & Chengsi, 2009). Piketty concludes, by collecting data from several countries, that as technology advances, capital rewards mostly grow faster than economic growth (Piketty, 2017), which implies that wealth is often not equally distributed between owners of capital and workers, and that technological advances and the widespread use of machinery will further concentrate wealth in the hands of capital (Brynjolfsson & McAfee, 2016), leading to a further widening of the income gap between capital owners and labor (Acemoglu & Restrepo, 2020). In addition, technological advances may lead to "employment polarization", which will increase the demand for high-skilled and low-skilled labor, i.e., an increase in the employment of high-skilled and low-skilled labor and a decrease in the employment of middle-skilled labor (Autor et al., 2003), thereby raising the earnings of some of the labor force and leading to a widening of the earnings gap between labor forces with different skills (Katz & Murphy, 1992). In particular, skill-biased technological progress can further increase the demand for high-skilled labor, thus increasing income inequality (Xu, 2010). On the other hand, it has also been argued that technological progress has a percolation effect, starting from one or a few sectors and gradually spreading to the entire national economy (Cohen, 1988) and ultimately resulting in inclusive growth. Therefore, as technology use becomes more widespread, the income gap will show a trend of widening and then narrowing (Li & Li, 2007).

However, technological development has reached the stage of digital technology, and completely new challenges have emerged that are different from those from previous stages of technological development. Digital technology is advancing at an

unprecedented rate, breaking the previous laws of diminishing marginal costs and diminishing returns to scale, and possibly even entering a Rifkian society with zero marginal costs. Because of the rapid pace of technological advancement, it is difficult for all economies to benefit equally from technology and for economic growth to trickle down and pervade all (Cai, 2019).

Existing studies on the impact of the digital economy on the income gap are not uniform in terms of their direction of impact. Some studies have concluded that the digital economy has a significant contribution to the income of farmers and can reduce the income gap between urban and rural areas (Guo & Xiang, 2021; Qiu & Yahong, 2021; Zhang & Li, 2022). However, some studies have also argued that digital technology has an obvious Matthew effect, which will further aggravate the income gap between poor and non-poor households (Wang & Yaxiong, 2020). The specific reason is that the popularity of artificial intelligence technology (Wang et al., 2020) as well as the cost threshold of information utilization and the difference in farmers' abilities to utilize information elements can further exacerbate the widening income gap (Zhu & Zhu, 2022). Liu Huan argues that industrial intelligence will reduce the income of the peasant group by reducing the employment stability of the rural labor force, thus widening the urban-rural income gap (Liu, 2020). For example, the widespread use of smart devices such as robots has had a marked substitution effect on labor, particularly on rural labor, further widening the income gap between low-skilled rural labor and high-skilled urban labor (Wang & Dong, 2020). In addition, some studies have also concluded that the relationship between the digital economy and the income gap shows a non-linear correlation. Within industries, the development of digital technology has led to an inverted U-shaped trend of widening and then narrowing the income gap in the service sector (Li et al., 2021). In terms of the urban-rural income gap, the study found that the impact of the development of the Internet on the urban-rural income gap may also show an inverted u-shaped trend (Cheng & Zhang, 2019).

By summarizing the existing studies, it is easy to see that there are three different views on the relationship between digital technology and the urban-rural income gap in the extant studies, which are that digital technology will widen the urban-rural income gap, digital technology will narrow the urban-rural income gap and there is a non-linear effect of digital technology on the urban-rural income gap. And the choice of research subjects is also more limited. Most studies treat digital technologies in isolation, such as the Internet (Cheng & Zhang, 2019) or artificial intelligence technologies (Ma & Renzhong, 2022), or focus solely on digital finance issues (Zhou et al., 2020), and rarely examine digital technology as a whole. Therefore, there is a need for a more in-depth study on the issue of the impact of digital technologies on the income gap.

Compared with previous studies, the marginal contribution of this paper is in the following three aspects. Firstly, previous studies have not well defined digital technology, whereas this paper constructs an evaluation system for digital technology as a whole and empirically tests the correlation between digital technology and the urban-rural income gap. Secondly, previous studies have disagreed on the view of the relationship between digital technology and the urban-rural income gap. This paper finds

through empirical tests that there is a correlation between the two and that this correlation is non-linear, showing an inverted U-shaped trend. Thirdly, this paper discusses the role of education in the relationship between digital technology and the urban-rural income gap and finds that it plays an important moderating role.

## 3. Research mechanism

The key to narrow the urban-rural income gap lies in figuring out how to raise the income of rural areas so that the income of rural residents grows faster than the income of urban residents. The development of digital technology can affect the income of rural residents in two aspects: agricultural income on the one hand and non-agricultural income on the other. In terms of agricultural income, the development of digital technology has increased the speed of technological renewal, rationalized the allocation of resources, and enabled smarter methods of agricultural production, thus increasing the efficiency of agricultural production. In addition, by making full use of digital technology, it is possible to change sales channels, such as through the use of e-commerce platforms, livestream e-commerce, etc., and thus increase agricultural income.

In terms of non-agricultural income, there are three pathways through which digital technologies can impact non-agricultural income. First, the job creation effect. The development of technology, according to Schumpeter's theory of creative destruction, will have both substitution and creation effects on society. On the one hand, it will have a substitution effect on human labor and lead to the disappearance of some industries; on the other hand, it will also create some new types of jobs and increase employment. The development of digital technology has driven the change of economic form from an industrial to a digital economy. The platform economy and sharing economy are both important manifestations of the digital economy. This economic model generated by digital technology has blurred the boundary between producers and consumers, and consumers can be transformed into producers as long as they have idle resources and the willingness to provide services. Typical types of jobs include car drivers, short-term rentals, and auntie kitchens. As long as they have ample time and are willing to work, they can do it without long-term skill training and earn a relatively high income. This gives urban workers more job options and higher incomes, thus narrowing the gap between urban and rural areas.

The second pathway is the effects of lowering the work threshold. As Hoselitz (1952) argues, changes in the demand for workers' skills brought about by technological upgrading will dramatically alter the pattern of social division of labour and accelerate the mobility of workers, thus bringing about social change. Digital technology is a typical example of technological upgrading, and its development will lead to substantial changes in the demand for workers in the labour market. It will lower the threshold to participate in labor for rural labor, allowing even surplus rural labor to fully participate in non-farm work. This could change the binary economic pattern described by Lewis, which is the current urban-rural state of China. Due to the natural seasonality of agricultural work, many laborers also have seasonal characteristics when they work, going out to work during agricultural leisure time and returning

home to do agricultural work during agricultural busy time. However, such a work pattern inevitably leads to restrictions on the choice of work, with the laborers having to choose only odd jobs rather than permanent jobs. If they choose to work permanently, they will have to give up the agricultural production at home, and the inability to combine agricultural work and non-agricultural work will lead to a decrease in income level. The development of digital technology has enabled workers to have more digital infrastructure and to face more work options. As a result, workers are able to choose their working hours, workplaces, and work intensity more freely, and they are able to use their fragmented time more fully for flexible work, which increases their marginal income and contributes to the realization of the Pareto optimal state. Rural women, especially pregnant women, who were not involved in labor or only engaged in simple labor, have more opportunities to perform jobs with higher value added, thus increasing their income and alleviating the income gap.

Rational labor allocation effects constitute the third pathway. An important reason for the large income gap between rural and urban areas in China is the urban-rural dichotomy. The poor circulation of factors between urban and rural areas leads to a lower utilization of resources in rural areas, which in turn leads to a lower level of overall growth and a lower income level. The widespread use of digital technology has enabled a smoother flow of information between urban and rural areas, and the free flow of information can significantly reduce the mismatch between jobs and rural labor. The main manifestation is that the channels for finding jobs and the transparency of job content have been improved, and laborers can more easily find jobs that match their abilities, thus achieving higher incomes and reducing the income gap.

This leads to Hypothesis 1 (H1): The development of digital technology has a catalytic effect on the reduction of the urban-rural income gap, and with the continuous development of digital technology, the urban-rural income gap will continue to decrease.

When considering the level of digital technology, two aspects should be considered: the degree of digital technology development and the technical penetration of digital technology. Technology penetration is an important part of the level of digital technology. The higher the level of digital technology development, the higher the penetration rate of digital technology will be. A higher penetration rate also means that more of the workforce will be able to share in the dividends of technological progress. However, generally speaking, the development of digital technology originates in the big cities with higher development, and the jobs created by digital technology are popularized in the cities first, but the penetration rate in the rural areas is relatively low and slow, and there are many new industries that exist only in the cities and do not penetrate into the rural areas. Therefore, these jobs that can bring a higher income are exclusively occupied by the urban labor force, while the rural labor force can hardly enjoy the dividends. As a result, urban laborers are the first to enjoy the dividends of digital technology and achieve higher income levels, thus widening the income gap between urban and rural areas at the early stage of digital technology development. As the penetration rate of digital technology rises, the rural labor force also gradually profits and raises its income level, thus narrowing the urban-rural income gap.

On the other hand, the cost of digital infrastructure in China is generally borne by the government as well as enterprises, but in reality, residents themselves also have to bear some hardware or traffic costs, which creates a threshold for using digital technology. In addition to the actual physical cost threshold, there are also non-physical thresholds for using digital technologies, such as knowledge base, skill level, and level of understanding. At the early stage of digital technology development, the cost threshold is relatively high, so urban residents with better initial capital accumulation on average are more likely to enjoy the benefits of digital technology and thus increase their income levels, thus leading to a widening of the urban-rural income gap. As the development of digital technology continues to mature, the threshold for using digital technology continues to decrease, and more and more rural laborers are able to cross the threshold of use, thus using digital technology to achieve higher incomes, which eventually leads to a narrowing of the income gap.

And digital technology has a stronger substitution effect on low-skilled labor than high-skilled labor (Park & Zhang, 2021). In the early stages of digital technology development, technology was not only difficult to use by the low-skilled workforce from rural areas, but even had a strong substitution effect. Therefore, in the process of rural laborers entering urban jobs, they are more likely to be substituted for their lower skill levels, receive lower wages, and further widen the income gap with urban laborers. At the same time, although the booming casual labor and platform economy under digital technology will promote higher income levels in general, the lack of centralized training for participants and a competition pattern closer to perfect competition, which makes it easier for workers with an experienced base to get support and thus obtain higher incomes, may also further exacerbate the widening income gap. However, with the gradual diffusion of technology, the rural labor force can also use technology, reducing the substitution effect and increasing competitiveness. Therefore, in the short run, the urban-rural income gap will widen, while in the long run it will narrow. Therefore, this paper argues that the impact of digital technology on the urban-rural income gap may show a dynamic trend of phased changes.

This leads to Hypothesis 2 (H2): The urban-rural income gap shows an inverted U-shaped trend of widening and then narrowing with the expansion of digital technology diffusion.

In summary, this paper argues that the development of digital technology will reduce the urban-rural income gap in general, but in the process of digital technology development, it takes time and the accumulation of various factors such as experience to expand from urban to rural areas, so it leads to an inverted U-shaped trend in the change of the urban-rural income gap.

## 4. Research strategy

### *4.1. Data sources*

This paper uses panel data for 31 provinces, municipalities directly under the Central Government, and autonomous regions from 2013 to 2020. The data used were

obtained from the China Statistical Yearbook as well as the Provincial Statistical Yearbook. A total of 279 observations are obtained, which constitute the balanced panel data.

## 4.2. Selection of variables

### 4.2.1. Urban-rural income gap

When measuring the urban-rural income gap, the commonly used indicators include the ratio of urban-rural disposable income, the coefficient of variation method, and the Theil index method. Among them, the Theil index can not only reflect the difference of income between urban and rural areas but also take into account the difference in population, which can more accurately measure the urban-rural income gap. And Theil index treats equally differences in all parts of the distribution. So it is more widely used in studies of income distribution and the extent of inequality (Duro, 2008; María Sarabia et al., 2017). Therefore, this paper uses the Theil index to calculate the urban-rural income gap, and the specific calculation method is

$$\mathrm{Theil}_{\mathrm{i,t}} = \sum_{i=1} \left(\frac{\mathrm{Y}_{i,t}}{\mathrm{Y}_t}\right) * \ln\left(\frac{\mathrm{Y}_{i,t}}{\mathrm{Y}_t} \Big/ \frac{N_{i,t}}{N_t}\right), \tag{1}$$

where i = 1 and 2 represent urban and rural areas, respectively; t represents the year; Y represents disposable income; and N represents the population size.

### 4.2.2. Digital technology

There is no unified measurement standard for digital technology for the time being, and this paper measures the level of digital technology from two dimensions, which are the degree of digital technology penetration and the degree of digital technology development. Among them, the digital technology penetration rate includes the Internet penetration rate and the cell phone penetration rate. In measuring the degree of digital technology development, we draw on Ren and Deng (2022) and Liu and Chen (2022) for the measurement method of digital technology. The development level of digital technology is measured in four dimensions: digital infrastructure, digital factor input, digital technology-related output, and digital transaction development. Among them, digital infrastructure includes the length of long-distance fiber optic cable lines and the number of Internet broadband access ports; digital factor inputs include the number of employed persons in telecommunication and other information transmission services, the number of enterprises with websites, and the number of enterprises with e-commerce transaction activities; digital technology-related outputs include e-commerce sales and software business income; and digital transactions use the Peking University Digital Inclusive Finance Index (Guo et al., 2020). And the entropy weighting method was used to assign weights to the indicators, and finally the comprehensive index of digital technology development was calculated. The specific indicators are shown in the following table (Table 1).

**Table 1.** Digital technology level index system.

| First-level index | Second-level index | Third-level index | Fourth-level index |
|---|---|---|---|
| Digital technology | digital technology penetration | digital technology penetration rate | Internet penetration rate |
| | | | cell phone penetration rate |
| | digital technology development | Digital infrastructure | length of long-distance fiber optic cable lines |
| | | | the number of Internet broadband access ports |
| | | digital factor input | the number of employed persons in telecommunication and other information transmission services |
| | | | the number of enterprises with websites |
| | | | the number of enterprises with e-commerce transaction activities |
| | | Digital technology-related output | e-commerce sales |
| | | | software business income |
| | | digital transaction development | Digital Inclusive Finance Index |

Source: Author Estimation.

**Table 2.** Descriptive statistics of variables.

| Variables | Indicators | Means | Standard deviation |
|---|---|---|---|
| Urban-rural income gap | Urban-rural income Theil Index | 0.3692 | 0.1497 |
| Digital Technology | Level of Digital Technology Development | 7.7731 | 1.0162 |
| Economic Development Level | Logarithm of GDP per capita | 10.8199 | 0.4243 |
| Level of urbanization | Urban resident population/total population | 0.5869 | 0.1285 |
| Industrial structure | Value added of tertiary industry/GDP | 0.5005 | 0.0868 |
| Fiscal expenditure level | Urban public finance expenditure/GDP | 0.2985 | 0.2101 |
| Level of opening up to the outside world | Import and export volume/GDP | 0.2614 | 0.2735 |

Source: Author Estimation.

#### *4.2.3. Control variables*

In this paper, the level of economic development, the level of urbanization, the industrial structure, the level of fiscal expenditure, and the level of openness to the outside world are selected as control variables. The descriptive statistics of each variable are shown in the following table (Table 2).

### *4.3. Model construction*

The data used in this paper is panel data for the period 2013–2020. In order to ensure that the model selection was sound, the choice of model was tested before determining the empirical model in order to determine whether a mixed OLS, random effects, or fixed effects model should be used. The first test was conducted using an F-test, which showed that the random effects model outperformed the mixed model. This was followed by a Hausman test, which showed that the fixed-effects model was superior to the random-effects model. Therefore, the fixed effects model was chosen for the empirical analysis.

Hence, this paper uses a fixed-effects model for regression analysis to construct the following model to test the relationship between digital technology and the urban-rural income gap.

$$Y_{it} = \alpha_0 + \alpha_1 A + \beta X_i + \mu_i + \eta_t + \delta_{it}, \quad (2)$$

where i stands for province; t stands for year; Y stands for urban-rural income gap; A stands for digital technology; and X stands for other control variables that would

have an impact on the urban-rural income gap. μ denotes province fixed effects; η denotes time fixed effects; and δ denotes a random disturbance term.

Considering that the impact of digital technology on the urban-rural income gap may show a non-linear trend, this paper adds the squared term of digital technology to the model, and the specific equation is as follows:

$$Y_{it} = \alpha_0 + \alpha_1 A + \alpha_2 A^2 + \beta X_i + \mu_i + \eta_t + \delta_{it}. \quad (3)$$

## 5. Analysis of the empirical results

### 5.1. Baseline results

The relationship between digital technology and the urban-rural income gap is analyzed through regression using a fixed-effects model. The regression results are shown in Table 3, where Model I is the result without adding the squared term and Model II is the result after adding the squared term.

In Model I, the effect of digital technology on the urban-rural income gap did not pass the significance test. However, with the inclusion of the squared term in the model, both the first and quadratic terms of digital technology passed the significance test, being significant at the 1% and 5% statistical levels, respectively, suggesting that there is indeed a non-linear correlation between digital technology and the urban-rural income gap. In Model II, the regression coefficient of digital technology is positive and significant at the 1% statistical level, and the coefficient of the squared term of digital technology is negative and significant at the 5% statistical level, which proves that there is a significant "inverted U-shaped" relationship between digital technology and the urban-rural income gap. The coefficient of the squared term of digital technology is negative and significant at 5% statistical level. That is, at the early stage of digital technology development, digital technology will cause the urban-rural income gap to gradually expand, while with the further development of digital technology, the urban-rural income gap will gradually decrease. This is mainly due to the fact that the development of digital technology tends to start in urban areas, and although the development level of digital technology is high nationwide, the development is actually uneven and the penetration rate of digital technology is low, so the time for rural residents to benefit from the development of digital technology will be postponed later compared with urban residents, resulting in a faster growth of urban

**Table 3.** Regression results.

| Variables | Model I | Model II |
|---|---|---|
| Digital Technology | 0.0060 | 0.0462*** |
| Digital Technology Squared | | −0.0027** |
| Economic Development Level | −0.0439*** | −0.0387*** |
| Level of urbanization | −0.4085*** | −0.4395*** |
| Industrial structure | 0.0062 | 0.0164 |
| Fiscal expenditure level | −0.0639*** | −0.0613*** |
| Level of opening up to the outside world | −0.0393*** | −0.0416*** |
| F test | *** | *** |
| Hausman test | *** | *** |

Note: *, ** and *** are respectively significance level of 10%, 5% and 1%.
Source: Author Estimation.

residents' income than that of rural residents, which in turn leads to a widening income gap between urban and rural areas. However, on the whole, digital technology will increase the income of rural residents through three paths: the job creation effect, the threshold reduction effect, and the rational labor allocation effect, so that the income growth rates of the rural labor force and the urban labor force can be increased simultaneously and the income gap between urban and rural areas can be narrowed eventually. The inflection point of the "inverted U-shaped" curve can be estimated through Model II, and it is calculated that the curve reaches the inflection point when the digital technology level is 8.5556. In the descriptive statistics of Table 2, the current mean value of the digital economy is 7.7731, which is still a bit different from the inflection point. Therefore, it can be concluded that the current development level of digital technology is still at the early development stage, and the impact on the urban-rural income gap is still at the stage of expansion, which has not yet been able to play the role of reducing the urban-rural income gap.

Furthermore, other control variables besides digital technology also have different degrees of influence on the urban-rural income gap. Among them, the regression coefficient of economic development level is significant at the 1% statistical level, indicating that the urban-rural income gap will gradually decrease as the economy develops. The level of urbanization is significantly negative at the 1% level, indicating that the urban-rural income gap decreases with increasing urbanization. The level of fiscal expenditure is significantly negative at the 1% level, indicating that the gap between urban and rural incomes decreases with the increase of fiscal expenditure, which is probably due to the concern about problems in agriculture in recent years, which has led to a greater tilt of fiscal investment to rural areas. The regression coefficient of the level of external openness is significantly negative at the 1% level, indicating that an increase in the level of external openness will lead to a decrease in the urban-rural income gap. The regression coefficient of industrial structure is positive, but it fails the significance test. In conventional circumstances, this variable should be a significant influencing factor. In order to avoid unnecessary misunderstandings, we decided to keep this factor in the model, even though it is not statistically significant.

### 5.2. Robustness test

In this paper, the Gini coefficient is used to replace the Theil index to measure the urban-rural income gap for robustness testing. The following formula is used in calculating the Gini coefficient.

$$G = \sum_{i}^{N} P_i Y + 2 \sum_{i}^{N-1} P_i (1 - Y_i) - 1, \tag{4}$$

where $i = 1, 2$ represent urban and rural areas; Y represents disposable income; and P represents population size. A fixed effects model was used to test the results, which are presented in the following table (Table 4).

Model I and Model III are the results without adding control variables, and Model II and Model IV are the results after adding control variables. In Models III and IV,

**Table 4.** Robustness test results.

| Variables | Model I | Model II | Model III | Model IV |
|---|---|---|---|---|
| Digital Technology | 0.2087*** | 0.0194*** | 0.4315*** | 0.0977*** |
| Digital Technology Squared | | | −0.0146*** | −0.0053*** |
| Economic Development Level | | −0.0316*** | | −0.0215*** |
| Level of urbanization | | 1.5762*** | | 1.5159*** |
| Industrial structure | | −0.0971*** | | −0.0771*** |
| Fiscal expenditure level | | −0.0132 | | −0.0080 |
| Level of opening up to the outside world | | −0.0054 | | −0.0099 |

Note: *, ** and *** are respectively significance level of 10%, 5% and 1%.
Source: Author Estimation.

the squared terms of digital technology and digital technology are significant at the 1% statistical level, and the coefficients of the primary term are positive and the coefficients of the secondary term are negative. Although the significance of the control variables differs somewhat from the original test, it is generally accepted that as long as the significance and sign of the main variables remain the same as in the original test, it can be considered to pass the robustness test (Wooldridge, 2015). Therefore, the finding that the impact of digital technology on the urban-rural income gap has an 'inverted u-shaped' trend passes the robustness test.

### 5.3. Moderating role of education

The impact of digital technology on the income level of the labor force with different skill levels has significant differences (Park & Yun, 2021), and the abundance of educational resources is an important factor affecting the skill level of the labor force. Therefore, this paper argues that education can moderate the relationship between digital technology and the urban-rural income gap by affecting the skill level of the labor force. Thus, this paper constructs the following model to test the moderating role of education in the relationship between digital technology and the urban-rural income gap.

$$Y_{it} = \alpha_0 + \alpha_1 A * edu + \alpha_2 edu + \alpha_3 A + \beta X_i + \mu_i + \eta_t + \delta_{it}, \quad (5)$$

where i stands for province, t stands for year, Y stands for urban-rural income gap, A stands for digital technology, edu stands for educational resources, measured using the number of students enrolled in general higher education, and X stands for other control variables that would have an impact on the urban-rural income gap. μ denotes province fixed effects, η denotes time fixed effects, and δ denotes random disturbance terms (Table 5).

Model I is the regression result without adding an interactive item, and Model II is the regression result after adding an interactive item. With the addition of the interaction variable between education and digital technology, digital technology, education, and the interaction variable all passed the significance test and were significant at the 5% and 1% levels of significance, respectively. It shows that education does play a moderating role in the effect of digital technology on the urban-rural income gap. The coefficient of digital technology is negative, while the coefficient of the interaction term is positive, indicating that digital technology has a negative impact on the urban-rural income gap, while education significantly inhibits the impact of digital

**Table 5.** Regression results of the moderating effect of education.

| Variables | Model I | Model II |
|---|---|---|
| Digital Technology | −0.0012 | −0.0097** |
| Education | −0.0005*** | −0.0017*** |
| Education*Digital Technology | | 0.00013*** |
| Economic Development Level | −0.0825*** | −0.0730*** |
| Industrial structure | −0.0397 | −0.0614** |
| Fiscal expenditure level | −0.07242** | −0.0587** |
| Level of opening up to the outside world | −0.0696*** | −0.0604*** |

Note: *, ** and *** are respectively significance level of 10%, 5% and 1%.
Source: Author Estimation.

technology on the urban-rural income gap and has a negative moderating effect. In other words, the development of digital technology will reduce the urban-rural income gap, while the increase in education level will actually inhibit the rate of reduction of the urban-rural income gap. In addition, both digital technology and increased levels of education will have a negative effect on the urban-rural income gap, yet the interaction term between the two has a positive effect on the urban-rural income gap, implying that there may be an antagonistic interaction between digital technology and education (Cohen et al., 2002). The two interfere with each other in the development process, ultimately leading to opposite aggregate effects. This is mainly due to the fact that the combination of higher levels of education and digital technology may further exacerbate the gap between the elite and the general class, thus leading to a widening of the urban-rural income gap. This is an important reason why education plays a negative moderating role between digital technology and the rural-urban gap.

## 6. Conclusions and policy Implications

### *6.1. Conclusion*

This paper empirically analyzes the relationship between digital technology and the urban-rural income gap using panel data from 2013 to 2020. Previous studies have not reached a consistent conclusion on the impact of digital technology on the urban-rural income gap. This paper builds on the existing studies to conduct a more in-depth study and finds that the impact of digital technology on the urban-rural income gap does not show a simple linear effect but a non-linear correlation. The study found that in the long run, the development of digital technology will eventually reduce the urban-rural income gap, but in the process of digital technology development, the level of the urban-rural income gap will show an "inverted U-shaped" trend. This is mainly due to the change in the level of digital technology penetration. At low levels of digital technology penetration, the increase in digital technology will widen the urban-rural income gap, but as digital technology penetration increases, the use of digital technology in urban and rural areas will gradually converge, and more and more farmers will be able to benefit from digital technology, thus reducing the urban-rural income gap. Having verified the inverted U-shaped impact of digital technology on the urban-rural income gap, the article calculates the inflection point of the impact of digital technology on the urban-rural income gap. It was found that the current stage of digital technology development is still low, has not reached the inflection point, and is still on the left side of the inflection point, proving that it is

still at a stage where the development of digital technology has led to a widening of the income gap between urban and rural areas. In addition, this paper highlights the important role of education. Through further research, it was found that education has an important moderating role in the relationship between digital technology and the urban-rural income gap.

### 6.2. Policy implications

Based on the findings of this study, the following policy insights can be drawn. Firstly, the importance of digital technology in reducing the urban-rural income gap should be acknowledged. As digital technology promotes a change in economic form, its development will significantly affect the distribution of national income. However, it is noted that the current level of digital technology development in China has not yet crossed the "inverted U-shaped" inflection point, and therefore has not played a role in reducing the income gap. In the future, more attention should be paid to the development of digital technology and its penetration rate to narrow the income gap. Secondly, to achieve a balanced development of digital technology between urban and rural areas, efforts should be made to promote the penetration of digital technology in rural areas. This will help to address the income gap between urban and rural residents. Lastly, education and skills training for the labor force should be increased to narrow the income gap caused by skill level disparities. This will prevent low-skilled rural labor force from being replaced by technology and forced to leave the labor market. By implementing these policies, China can harness the positive effects of digital technology and achieve a more equal distribution of income between urban and rural areas.

### 6.3. Future research perspectives

This paper makes a valuable contribution to the literature on digital technology and the urban-rural income gap. However, there are some limitations to the study. Firstly, due to data availability constraints, this study only uses data from Chinese provinces, which may limit the sample size and generalizability of the results. In future studies, expanding the sample size and including data from Chinese cities could increase the robustness of the findings. Additionally, this study only examines China as a whole and does not consider regional differences. It is important to note that there are significant regional variations in China, and future research should take these into account to provide more specific analyses for different regions. Furthermore, it may be worthwhile to explore the impact of "employment polarization" on the urban-rural income gap and investigate whether the gap takes on a more complex N-shaped pattern in the future. These considerations could provide a more comprehensive understanding of the impact of digital technology on the urban-rural income gap.

## Author contributions

Conceptualization, X.S. and X.K.; methodology, X.S.; software, X.S.; validation, X.S. and X.K.; formal analysis, X.S.; investigation, X.S.; resources, X.S.; data curation, X.S.; writing—original

draft preparation, X.S.; writing—review and editing, X.S. All authors have read and agreed to the published version of the manuscript.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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## Data availability Statement

Data used for this study is available and can be provided by the corresponding author upon request.

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