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Assessing the effectiveness of targeted poverty alleviation policies in Xinjiang, China

Yujie Huang^{1,5}, Xianke Huang^{2✉}, Ruiliang Li^{3,5}  & Wei Cheng⁴

To consolidate and expand the effective connection between the achievements of poverty alleviation in Xinjiang's deeply impoverished areas and rural revitalization, it is necessary to study the effects and mechanisms of poverty alleviation policies. In this paper, the value of night light is used to measure regional economic development, and the panel data of 32 national key counties for poverty alleviation in Xinjiang and the remaining 48 counties in the province under its jurisdiction are analyzed by using the dual difference method to evaluate the promotion effect of poverty alleviation policies on regional economic development. The indirect impact of different poverty alleviation measures on economic development is explored by using the intermediary effect model. The study found that the implementation of the policy significantly promoted the development of the county economy, and the poverty alleviation policy in minority counties in the region had a stronger role in promoting the economy than that in nonminority counties. Further analysis of the mechanism shows that industrial poverty alleviation and education poverty alleviation have a significant role in county economic development, and the promotion of education poverty alleviation is lower than that of industry poverty alleviation.

¹School of Economics and Management, Beijing University of Technology, Beijing 100124, China. ²Graduate School of Chinese Academy of Social Sciences, Beijing 102488, China. ³Department of Health Policy and Management, Yale University, New Haven, CT 06520, USA. ⁴Xinjiang Sannong Science Development Center, Urumqi, Xinjiang 830052, China. ⁵These authors contributed equally: Yujie Huang, Ruiliang Li. ✉email: 1106330557@qq.com

Introduction

As a long-standing worldwide problem, poverty is closely related to political, economic and social development, which makes the sustainable development of society extremely challenging. According to the statistics of the United Nations, 1.2 billion people still live in multidimensional poverty at this stage, and the violent attack of COVID-19 has pushed more than 250 million people around the world to the brink of hunger, which is expected to cause 176 million people to fall into extreme poverty (Programme 2020; UNDP United Nations Development Programme 2022). Therefore, all countries regard “solving poverty or eradicating poverty” as an unavoidable historical task and one of the sustainable development plans in the new era. Regardless of the standard of measuring poverty at the national level, solving the problem of poverty depends more on the command and guidance of various systems and policies.

In 2022, the Ministry of Finance of China, the Development Research Center of the State Council and the World Bank jointly released the report “40 years of poverty reduction in China: driving forces, implications and future policy directions”, which comprehensively combined China’s achievements in poverty reduction in the past 40 years. According to the World Bank’s absolute poverty standard of \$1.9 per person per day, China’s poverty population has decreased by approximately 800 million, accounting for 75% of the global poverty reduction in the same period. Such achievements only mean the elimination of China’s absolute poverty. From the perspective of economics, Amartya Sen and Peter Townsend put forward the concept of “relative poverty” and divided poverty into absolute poverty and relative poverty. The distinction between the two is mainly reflected in that if absolute poverty is a survival proposition, then relative poverty is more of a developmental proposition (Yamamori 2019). As a developing country, China has highlighted the problem of unbalanced and insufficient development since the reform and opening up. This problem is reflected not only in the economic differences between the eastern and western regions and urban and rural areas but also in all aspects of residents’ lives.

The formulation of the poverty eradication policy of the Chinese government is also based on the principle of eliminating absolute poverty first and then solving relative poverty. From the reform of the agricultural management system in the early stage of reform and opening up to the further establishment of special funds and the formulation of particular preferential policies in the 1980s, we have solved the problem of unbalanced rural development in China. By March 1994, the “national poverty alleviation plan” clearly proposed narrowing the gap between eastern and western regions and achieving the goal of shared prosperity. At the beginning of the 21st century, the State Council formulated the outline of China’s rural poverty alleviation and development (2001–2010). The main task of this stage is to implement the Western development strategy (Outline of Poverty Alleviation and Development in China’s Rural Areas (2001–2010) 2014). In this long-term process, many researchers have participated in the evaluation criteria of measuring “absolute poverty” and “relative poverty”, as well as the effect evaluation of the use of poverty policy tools. Because of the differences in the implementation standards and effects of poverty alleviation policies in different regions, it is difficult to comprehensively and quantitatively evaluate the overall performance and effects of China’s poverty alleviation policies after implementation. To have a more comprehensive understanding of the progress and existing problems in China’s Poverty Alleviation Policies, we selected Xinjiang, the most typical ethnic minority inhabited area in China, as the key area of the study from the perspective of the mechanism of Poverty Alleviation Policies on ethnic minority areas. Xinjiang was chosen for the study for several reasons. First, it is a region

with a high concentration of ethnic minorities, historically experiencing higher levels of poverty and marginalization compared to the majority Han Chinese population. Second, the Chinese government has invested significant resources into poverty reduction programs in the region, making it a focus of poverty alleviation efforts. Finally, Xinjiang has been the subject of significant international attention and controversy, particularly regarding the treatment of the Uyghur population. The study of poverty alleviation policies in Xinjiang can contribute to a better understanding of the broader social and economic context in the region, inform poverty alleviation efforts in other regions of China (Khan 2021; Peng et al. 2021; Yunfeng and Nana 2023) and differentiate the heterogeneity of the spatial impact of poverty alleviation policies in 80 poverty-stricken national counties in Xinjiang. The study area is composed of 32 regions in southern Xinjiang and 48 regions in northern Xinjiang. The method of propensity score matching and difference in difference (PSM-DID) regression is used to determine the effectiveness of targeted poverty alleviation policies on county-level regional economic development. Night light data are used instead of GDP to measure economic indicators to achieve a better objective and independent purpose. In this study, we also found that the poverty alleviation policy promoted the improvement of the night light index in poverty alleviation counties. Moreover, the effect of the policy usually increases over time within three years after the implementation of the policy. The poverty alleviation effect in southern Xinjiang is more substantial. This has significant reference value for the era of “post-poverty alleviation” and rural revitalization.

Literature review and assumptions

Poverty reduction is a global challenge. Governments have always continued their efforts to narrow the income gap and eradicate poverty (Tollefson 2015; Zhang et al. 2015). Academics have conducted extensive and in-depth research on theories, measures and types of poverty and poverty eradication (Du et al. 2005; Montalvo and Ravallion 2010; Ravallion and Chen 2007; Zhang and Wan 2006). From the perspective of world experience, to alleviate and eliminate poverty, governments around the world have formulated corresponding poverty alleviation policies in accordance with the situation, time and place. How effective are the policies? What is the more effective way to help the poor? India’s fiscal expenditure policies, such as the rural private transfer payment plan and urban and rural employment security plan, can effectively alleviate poverty (Lal and Sharma 2009). The nonfood subsidy policy of the Philippines has a better poverty alleviation effect than the food subsidy policy (Rivera and Conchada 2013).

As a populous country in the world, China has a long way to go in helping the poor. To achieve the goal of lifting all poor people out of poverty and achieving a well-off society for all by 2020, the Chinese government has introduced a series of effective poverty alleviation policies, such as setting up a national poverty county (Binbin 2013; Zhiping 2018). In addition, the state has also increased financial support for ethnic minority areas and old revolutionary base areas (Guangrong et al. 2016). From the perspective of the policy evolution and historical process of China’s poverty alleviation and development, the focus of poverty work has gradually shifted from the eradication of absolute poverty to the eradication of relative poverty (Zongsheng et al. 2013). It is an important goal of China’s poverty alleviation policy in the new era to implement targeted poverty alleviation based on local conditions and policies. Since 2011, the central government has introduced a series of poverty alleviation measures, such as cadres

going to the countryside, targeted poverty alleviation, relocation from other places, and industrial poverty alleviation (Binbin 2013; Tin et al. 2017). The focus on poverty reduction has shifted from “promoting the whole village” to focusing on contiguous poverty-stricken areas as the main battlefield, with more emphasis on targeted poverty alleviation. All regions are also constantly exploring new ways to help the poor according to the actual situation.

Generally, economic growth is the most fundamental and important source of strength to fight against poverty (Sangui 2008). If the establishment of the poverty alleviation reform pilot zone cannot promote economic growth, that is, the policy cannot produce the “poverty reduction effect of economic growth”, then it can only be redistributed in the zero-sum game and cannot achieve the ultimate goal of eliminating poverty, narrowing the income gap, and promoting the endogenous development of poor areas. On the one hand, economic development can increase employment and income levels for the poor. On the other hand, it also increases local fiscal revenue, which is conducive to infrastructure construction and improvement of social welfare. Therefore, economic growth has a diffusion effect and a trickle-down effect on the reduction of poor people (Yu and Sangui 2016). Scholars liken economic growth to the increase in sharing cake. On the premise that the poor population and income distribution mechanism remain unchanged, the share of cake per capita will increase, which will reduce the absolute poor population calculated by income and achieve the goal of poverty reduction (Angang et al. 2006; Barrett and Carter 2013; Montalvo and Ravallion 2010). Dollar et al. found that economic growth is an important factor in reducing poverty, and an increase in total income will promote an increase in the per capita income of poor groups (Dollar et al. 2016). Balisacan believed that the trickle-down effect of economic growth on the poor could not occur automatically, and it is affected by a series of policy conditions and the environment (Balisacan 2004). In other words, to bring the trickle-down effect of economic growth into play, we must consider the effectiveness of poverty alleviation policies. However, whether the poverty alleviation policy can play a role in poverty alleviation and thus affect economic performance is a proposition to be tested. As an important poverty reduction policy at the national level, the way, mechanism and effect of the poverty alleviation reform pilot area may be similar to, but not identical to, other poverty alleviation policies. Therefore, based on the above theoretical analysis and system background introduction, this paper proposes the following:

Hypothesis 1: The establishment of poverty alleviation reform pilot areas can effectively improve the economic situation of poor areas and promote the economic development of counties by giving play to the role of diversified poverty alleviation measures

The treatment group includes ethnic minority autonomous counties. The state originally had a series of preferential policies for ethnic minority districts and counties. In China’s poverty alleviation plan, special policies for ethnic minority areas have also been established, such as the implementation of a comprehensive poverty alleviation project for ethnic minorities and poverty-stricken groups (Xiaoling et al. 2020). Therefore, this paper proposes the following:

Hypothesis 2: In minority/nonminority counties, there is heterogeneity in the effect of poverty alleviation policies.

On the one hand, academic research on poverty alleviation in China focuses on the analysis of the poverty structure and the causes of poverty. On the other hand, it focuses on the development of industrial poverty alleviation and education poverty alleviation, and some scholars have carried out field research in some areas to analyze and discuss the sustainable livelihood of poor households.

Regional lagging development is often related to the lack of regional resources. First, Xinjiang’s backward economy and high dependence on planting and animal husbandry lead to poor poverty eradication policies, which are the main obstacles to the socioeconomic development of the region. Second, many residents are unable to improve their cognitive level through education, which hinders employment opportunities and leads to intergenerational poverty. When evaluating the impact mechanism of poverty alleviation policies, this study added the added value of the primary industry (lnins-1), the logarithm of the added value of the secondary industry (lnins-2) and the logarithm of the added value of the tertiary industry (lnins-3) to reflect the implementation performance of industrial poverty alleviation, and the number of secondary school students was used to indicate poverty reduction. Therefore, this paper proposes the following:

Hypothesis 3: There is an intermediary mechanism for poverty alleviation in deeply impoverished areas, and different poverty alleviation measures have different economic benefits.

Methods and Indicators

Econometric model. The double difference method is mainly used to evaluate the policy effect in empirical research. Compared with other methods, the identification method of the double difference method is very intuitive. This would entail observing the changes in those affected by the policy and those not covered by it. The difference between these groups can then be used to evaluate the impact of policy interventions. The double-difference method was used in this study to evaluate the impact of policy on local economic development.

Controlling for other factors, the double-difference method can analyze the difference in economic development between the treatment and the control groups before and after implementing policy in the poverty-stricken area (Zhang et al. 2020a, 2020b). The model form is given by the expression:

$$\ln light_{c,t} = \beta_0 + \beta_1 DID_{c,t} + \lambda Ctrl_{c,t} + \mu_c + \gamma_c + \varepsilon_{c,t} \quad (1)$$

where $\ln light_{c,t}$ (i.e., the logarithm of county night light data) is the dependent variable used to measure the performance of regional economic development; c refers to county; t denotes year; $Ctrl_{c,t}$ represents the control variables that affect economic growth and change with time and region; μ_c refers to the individual fixed effect, which controls the individual factors that affect the regional economy but do not change with time; γ_t represents the period effect, which controls the time factors affecting all counties over time; $\varepsilon_{c,t}$ represents the error term; and $DID_{c,t}$ is the core explanatory variable, such that $DID_{c,t} = treatment_c \times Time_t$ in the sample period. If County C (District) belongs to the national deep poverty area, $treatment_c$ is 1; otherwise, $treatment_c$ is 0. When $t = 2016$, then $time_t$ is 1; otherwise, $time_t$ is 0. In this study, the treatment group is composed of key counties with poverty alleviation measures, while the rest are part of the control group.

The estimated coefficient β_1 is used as the key basis in evaluating the effect of poverty alleviation policies in this study. If the policies are effective, then β_1 is positive and significant. To determine the heterogeneity in the deployment of poverty alleviation policies, the national poverty alleviation counties located in northern Xinjiang are excluded, and the basic model is expanded into:

$$\ln light_{c,t} = \beta_0 + \beta_1 DID_{c,t} Min_c + \vartheta DID_{c,t} + \sigma Min_c + \lambda Ctrl_{c,t} + \mu_c + \gamma_c + \varepsilon_{c,t} \quad (2)$$

where Min_c is a virtual variable to distinguish whether the treatment group and the control group are located in southern Xinjiang. This dummy variable is used to explore the heterogeneity in poverty alleviation among the different administrative

units. If County C is located in southern Xinjiang, $Min_c = 1$; otherwise, value is 0.

Indicator selection and data sources

Explained variable. Researchers have recently started investigating whether GDP can accurately measure China's economic development. Due to the imbalance in China's GDP statistics, the current assessment system has numerous shortcomings. The country's GDP accounting methods and statistical system lag behind developed countries. Inconsistencies in the statistical measures for each province and price factor effects are also extremely difficult to address. These limitations in the system result in considerable distortions in the statistical data (Henderson et al. 2012; Pinkovskiy and Sala-i-Martin 2016; Rehman et al. 2021; Ying et al. 2022).

In some instances, the accuracy and integrity of official government data have been questioned. There is political pressure on China's local governments to reach certain benchmarks based on GDP, which has caused some to commit data fraud (Movshuk 2002). Therefore, the natural logarithm of National Oceanic and Atmospheric Administration (NOAA) night light data is used instead of official government data as an indicator of economic activity. Given its significant correlation with GDP, light has become widely used in various fields, such as economic development, urbanization, carbon emissions, and power consumption (Kangning et al. 2015). Therefore, this paper uses night light instead of GDP as an important indicator to measure economic development.

Core explanatory variables. The core explanatory variable in this study is the interactive term DID_{ct} for the policy effect. Poverty alleviation has become a national priority in Xinjiang since 2016 (Hong and Xin 2016). The interactive term is multiplied by the virtual variable for time and the virtual variable for the policy impact group.

Control variables. In addition to the fact that the establishment of the poverty alleviation reform pilot area will affect the county economic development performance, many other factors will affect it. Therefore, it is necessary to control the interference of these exogenous factors. Drawing on the relevant research of Liu Ruiming and Zhao Renjie, Li et al., Huang Zhiping, etc., this paper selects the following control variables (Li et al. 2016; Ruiming and Renjie 2015; Zhiping 2018), and all nominal variables obtain actual values through CPI index processing (taking 2013 years as the base period) and logarithmize the absolute value variables to reduce the interference of heteroscedasticity on the estimated results:

Fiscal expenditure level (fel), given by the ratio of fiscal expenditure to the regional GDP, was used in this study. Xinjiang cannot shake off poverty without state financial support. From the perspective of social resource allocation, the proportion of fiscal expenditure reflects the actual use and control scale of fiscal expenditure on GDP.

The savings rate (sav) was calculated using the ratio of residents' savings to the regional GDP. Researchers have also found that the low savings rate of farmers in poor areas is mainly due to their consumption habits, which are closely related to low income and national customs. Savings are the main source of development funds, and an appropriate savings rate is a necessary guarantee for economic take-off. Considering the policy differences among counties, this study used the logarithm of the ratio of residents' savings deposit balance to GDP (lnsav) to assess the impact of the savings rate (Dewen et al. 2004; Kelley 1973). In addition, the country's rural population outflow rate at the county

level has shown a deepening trend. The concentration of the agricultural registered residence population and rural permanent population has decreased significantly, showing pronounced spatial clustering and positive spatial correlation. Population density can be used to evaluate poverty characteristics and gauge the spatial distribution patterns of the population (Manzoor et al. 2019).

The ratio of the number of social welfare adoption beds to the population of the area is used to measure the local level of welfare (wel). In many studies, the number of beds in medical institutions is commonly used to measure the relationship between health care and poverty. For example, Bosheng and Zisheng used the number of beds per thousand medical institutions in the regression analysis of the spatial lag model (Bosheng and Zisheng 2019). They found that for every increase in the number of beds per thousand medical institutions in Yunnan Province, China, the incidence of rural poverty in the county will be reduced by 1.257% (Ting et al. 2014). Therefore, our research used the total number of social beds to explore the impact of the government's poverty alleviation policies.

Population density (pop), which measures population distribution calculated by the resident population divided by county administrative area, was used to control the impact of population agglomeration on the level of economic development. Xinjiang is inhabited by ethnic minorities; by the end of 2019, its ethnic population reached 1,778,183 (68.22%), spatially overlapping with the region's rural poor. One study found that the higher the proportion of ethnic minorities in counties, the higher the incidence of relative poverty. This suggests that ethnic factors are an important factor affecting the degree of relative poverty (Lijun 2022).

When assessing the impact mechanism of poverty alleviation policies, the logarithm of the added value of the primary industry (lnins-1), the logarithm of the added value of the secondary industry (lnins-2), and the logarithm of the added value of the tertiary industry (lnins-3) were used in this study to reflect the implementation performance of industrial poverty alleviation (Jiansheng et al. 2017; Manzoor et al. 2019). The number of students in secondary schools (lnedu) was used to indicate poverty reduction through education (Han et al. 2021).

Industrial poverty alleviation refers to the process of developing characteristic industries, improving economic benefits, and increasing the income of poor households by relying on local resources, with the support of government assistance and guided by market demand. This approach encompasses various forms of poverty alleviation, including agriculture, tourism, e-commerce, science and technology, and others. In 2011, the Central Committee of the Communist Party of China and the State Council issued the Opinions on the Innovation Mechanism and Solid Promotion of Rural Poverty Alleviation and Development, which underscored the importance of guiding, encouraging, and supporting poor families to develop production, overcome poverty, and establish professional cooperatives and mutual aid organizations. Subsequently, the CPC Central Committee and the State Council issued further opinions on actively developing the innovative system for rural poverty alleviation, with a focus on improving the income growth level of local characteristic industries (Siqi 2022).

Education poverty alleviation is a crucial aspect of poverty alleviation efforts that targets the root causes of poverty. Given the multidimensional and complex nature of poverty, including natural and man-made disasters, theoretical research on poverty alleviation has extended to various fields. In 2015, the Central Committee of the Communist Party of China and the State Council issued the Decision on Winning the Struggle against Poverty, which emphasized the importance of education in

Table 1 Descriptive statistical results of each variable.

	Description	Calculation method	Mean value	Standard deviation	Minimum value	Maximum
Light	Night light value	/	2.62	5.60	0.03	36.52
FEL	Financial expenditure level	Fiscal expenditure / regional GDP	0.09	0.05	0.03	0.40
Pop	Population density	Registered residence population / county administrative area	52.34	131.66	0.15	836.91
Sav	Savings rate	Year end resident savings deposit balance / regional GDP	0.61	0.28	0.01	1.86
Wel	Welfare level	Social welfare adoption unit beds / registered residence population	0.01	0.00	0.00	0.03
Edu	Educational development	Number of students in secondary schools	11903.93	10512.73	924	58312
Ln ins-1	Development of primary industry	Ln (added value of primary industry)	11.67	0.90	9.02	13.56
Ln ins-2	Development of secondary industry	Ln (added value of secondary industry)	11.85	1.12	9.36	15.56
Ln ins-3	Development of tertiary industry	Ln (added value of tertiary industry)	12.17	0.84	10.20	14.69

Table 2 Variance inflation factor test.

Variable	VIF	1/VIF
Lnlight		
LnFEL	1.48	0.68
Lnpop	2.49	0.40
Lnsav	1.68	0.59
Lnwel	5.42	0.18
Lnins-1	2.23	0.45
Lnins-2	3.02	0.33
Lnins-3	5.28	0.19
Lnedu	5.24	0.19

carrying out poverty alleviation efforts. Education poverty alleviation was officially included as one of the key measures in the national poverty alleviation strategy, and the concept of education poverty alleviation became an important aspect of targeted poverty alleviation work (Youxing and Jiahui 2020).

Data sources. The nighttime light data were obtained from NPP/VIIRS images taken between 2013 and 2019(Information).

The data on fiscal expenditure, official GDP, residents' savings, population, total number of social beds, county administrative area, number of students in secondary schools, and added value of the primary, secondary, and tertiary industries were sourced from the Xinjiang Statistical Yearbook for 2013 to 2019. The descriptive statistical results for each variable are summarized in Table 1 (Region).

Variable correlation test. After analyzing the differential expansion factor, we found that the values were less than 10 (see Table 2). This suggests that there was no collinearity problem.

Parallel trend hypothesis test. The unbiased DID estimation result is used to satisfy the parallel trend hypothesis. This requirement indicates that the treatment and control groups should have the same trend before the event. Otherwise, the DID method will overestimate or underestimate the impact of the event. To test parallel trends, we used the event study method. If the parallel trend hypothesis holds, the effects of poverty alleviation policies occur only after implementing the policy (there is no significant difference in the trend before the implementation of the policy).

To implement the event study method, we use the formula:

$$\lnlight_{c,t} = \beta_0 + \beta_1DID_{c,t} + \beta_2DID_{c,t-4} + \beta_3DID_{c,t-3} + \beta_4DID_{c,t-2} + \dots + \beta_7DID_{c,t+3} + \lambda Ctrl_{c,t} + \mu_c + \gamma_c + \epsilon_{c,t} \tag{3}$$

$DID_{i,t\pm n}$ are dummy variables representing the years before and after the implementation of the policy. The model takes the policy implementation time t (2016) as the current observation point to assess the changes before and after the implementation. In the regression results, if the coefficients of $DID_{i,t-n}$ are not significant, there is a parallel trend between the experimental and control groups before the policy implementation. If the coefficient of $DID_{i,t+n}$ is significant, the policy has a significant effect on improvement.

DID Model estimation with matched samples. We used PSM to obtain a comparable control group and utilized the characteristics of each county level as the matching standard. Nonnational poverty counties were selected as the control group. The ratio of fiscal expenditure to regional GDP, the balance of savings deposits to regional GDP, and the ratio of the number of beds in social welfare to the regional population were used as matching variables. These variables indicate the regional financial support

level, savings, and social welfare. To increase the observation of matched samples, we selected matching ratios of 1:30, 1:40, 1:50, and 1:70, which yielded similar results. The matching rate used in this study was set to 1:50.

Intermediary effect analysis. Using dual differential identification of policy effects, the following equations were employed to explore the economic benefits produced by different poverty alleviation measures:

$$\ln \text{light}_{c,t} = \beta_0 + \beta_1 \text{DID}_{c,t} + \lambda \text{Ctrl}_{c,t} + \mu_c + \gamma_c + \varepsilon_{c,t} \quad (4)$$

$$M_{c,t} = \alpha_0 + \alpha_1 \text{DID}_{c,t} + \lambda \text{Ctrl}_{c,t} + \mu_c + \gamma_c + \varepsilon_{c,t} \quad (5)$$

$$\ln \text{light}_{c,t} = \varphi_0 + \varphi_1 \text{DID}_{c,t} + \varphi_2 M_{c,t} + \lambda \text{Ctrl}_{c,t} + \mu_c + \gamma_c + \varepsilon_{c,t} \quad (6)$$

where M is the intermediary variable used to express the effects of industrial poverty alleviation (primary industry $\ln \text{ins-1}$, secondary industry $\ln \text{ins-2}$ and tertiary industry $\ln \text{ins-3}$) and educational poverty alleviation ($\ln \text{edu}$). The coefficient of interaction term β_1 refers to the total effect of poverty alleviation policy, φ_1 is used to express the direct effect of poverty alleviation policy after adding intermediary variables, and α_1 indicates the indirect effects of intermediary variables.

The three equations were then regressed based on the test steps of the intermediary effect model. If φ_1 is not significant and α_1 and φ_2 are significant, the intermediary variable reaches complete intermediary, and the effects of poverty alleviation policy are produced. If φ_1 and φ_2 are significant and positive, and if the coefficient decreases, M is part of the intermediate variable. Similarly, if φ_1 is significant and positive and φ_2 is significant and negative, the coefficient of φ_1 is lower, β_1 has increased, and M is still part of the intermediary.

Empirical analysis

For the above-established measurement model and variable selection. The final results are as follows:

DID model estimation results. Table 3 shows the DID estimation results. The basic model (Eq. (1)) was first regressed. In Column 1, when the time effect is controlled, the interaction term is positive and significant at the 1% level, indicating a positive causality between poverty alleviation measures and economic development in poverty areas. The results suggest that the poverty alleviation policy helps promote the growth of the county's economy. In Column (2), when the time and individual effects are controlled, the interaction term in the regression model is also positive and significant. However, the regression coefficient is reduced after the period effect is controlled. This could be due to the economic policy playing a role in the long term under the control of other factors. In the overall benchmark regression results, the poverty alleviation policy was found to have a significant role in promoting the economic effect in both vertical and horizontal analyses. The poverty alleviation policy is related to an increase in regional economic development by approximately 19.13%, which validates research hypothesis 1. The regression coefficients of the control variable were robust in each column of the model results. The positive and negative directions were highly consistent, and all had a significant impact on the development of the county economy.

Column (3) of Table 3 examines the additional impact of minority counties on the effect of poverty alleviation policies. The results of the interaction item show that the implementation effect of the policies of the counties and cities in southern Xinjiang is better than that of the counties and cities in northern Xinjiang in

deep poverty areas Fig. 2. This shows that the state has given full consideration to the characteristics of ethnic minority areas and given more preferential policies in the key deployment of poverty alleviation policies, and southern Xinjiang has also played a greater subjective initiative under the deployment of poverty alleviation policies. The same result can be obtained from the coefficient of \ln : the poor counties in southern Xinjiang have higher economic growth performance, which fully reflects the policy freedom space for ethnic characteristics. According to the above analysis, hypothesis 2 is fully verified. In the analysis of heterogeneity, regardless of the angle from which the model is regressed, the policy effect interaction term is significantly positive, which again confirms the conclusion of hypothesis 1.

Parallel trend hypothesis test results. Because the double difference method requires that the treatment group and the control group should maintain a basically balanced time trend before the policy impact, it is necessary to test that there is no significant difference in the trend between the economic growth of poor counties and nonpoor counties. In this paper, the event study method is used to generate the interaction term of the year dummy variable and the treatment group dummy variable, and the dynamic effect of the treatment group is observed back. The coefficient of the interaction item reflects the difference between the treatment group and the control group in a specific year. If the coefficient of the interaction item is not significant, it indicates that there is no significant difference between the economic growth levels of the two groups before the time node of the sample period, meeting the parallel trend assumption. The regression results in Table 4 show that there is no significant difference between the interaction term and 0, indicating that there is no significant difference in the trend between the treatment group and the control group two years before the implementation of targeted poverty alleviation measures. As shown in Fig. 3, although the interaction conditions are not significant, the policy effects after implementation are significantly different from those in previous years.

Replacement of the explained variable test. Regional gross domestic product (GDP) is a traditional variable measuring regional economic development. In the robustness test, we replaced the $\ln \text{light}$ value with the regional $\ln \text{GDP}$ as the explanatory variable and conducted benchmark regression to evaluate the robustness of the research conclusions. The robustness test results of the benchmark regression are shown in Table 5. In the table, Column (1) does not control the results of the time effect. Column (2) controls the time effect and individual effect. Column (3) shows the results of the alternative model specification, which examines the additional impact of the poverty alleviation policy effect in southern Xinjiang.

The test results show that the DID regression coefficients were significant and positive, indicating that the poverty alleviation policy had a significant positive effect on the county's economy. The test results are consistent with the results of our benchmark regression, indicating that our model and regression results have high robustness and explanatory power.

DID estimation with matched samples. The results in Table 6 are similar in direction and size to those in Table 4. As shown in Table 6, the t test for the mean value of matching variables after PSM is not significant at the 10% level. This means there was no significant difference between the treatment and control groups. After going through the propensity score matching method, we continue to use the double difference method (DID) to evaluate the policy effects of the treated samples, and thus, we can obtain the net effect of the poverty alleviation policy on economic

development. The regression results are shown in Table 6. The article uses three methods to regress the samples, and the cross-term regression coefficients obtained by controlling the individual fixed effect and simultaneously controlling the individual fixed effect and time fixed effect are significantly positive. Therefore, it

can be determined that the poverty alleviation policy can significantly promote regional economic growth, which again verifies hypothesis 1.

Table 3 Influence of poverty alleviation policy on regional night light.

	(1) Lnlight	(2) Lnlight	(3) Lnlight
DID	0.46*** 10.75	0.19*** 6.06	0.23*** 6.42
LnFEL	-0.26*** -3.46	0.07* 1.65	0.06 1.43
Lnsav	0.17*** 3.23	-0.01 -0.27	-0.01 -0.41
Lnwel	0.33 4.86	0.07** 2.11	0.06** 1.96
Lnpop	0.15 0.61	0.08 0.557	0.01 0.09
County FE	Y	Y	Y
Year FE	N	Y	Y
Number of obs	560	560	560
R-squared	0.96	0.99	0.99

Asterisk symbols ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively. The t-values are in parentheses. Constant terms are omitted.

Study on the action mechanism of poverty alleviation achievements. In Table 7, column (1) shows the regression results of policy identification to compare when intermediary variables are introduced. Columns (2), (3), (4), and (5) show the direct effect of policy and the influence coefficient of intermediary variables.

The policy effect and intermediary effect in columns (2), (3) and (4) are positive and significant, while the direct effect of poverty alleviation policies has decreased, indicating that industrial poverty alleviation measures have reached a certain intermediary effect. These findings are consistent with the general idea that industrial development plays an important role in economic development.

In Columns 8 and 9 of Table 7, education-based poverty alleviation strategies have achieved some intermediary effects on economic development. The results suggest that the poverty alleviation policy has helped improve the level of education. Impoverished communities have made significant improvements in secondary education, regional infrastructure, and teacher training. The results suggest that popularizing nine-year compulsory education is not enough to cultivate human resources in poor communities and that targeted measures are still necessary to curb poverty rates in these areas. The proportion of personnel receiving higher education should be increased, and vocational and technical

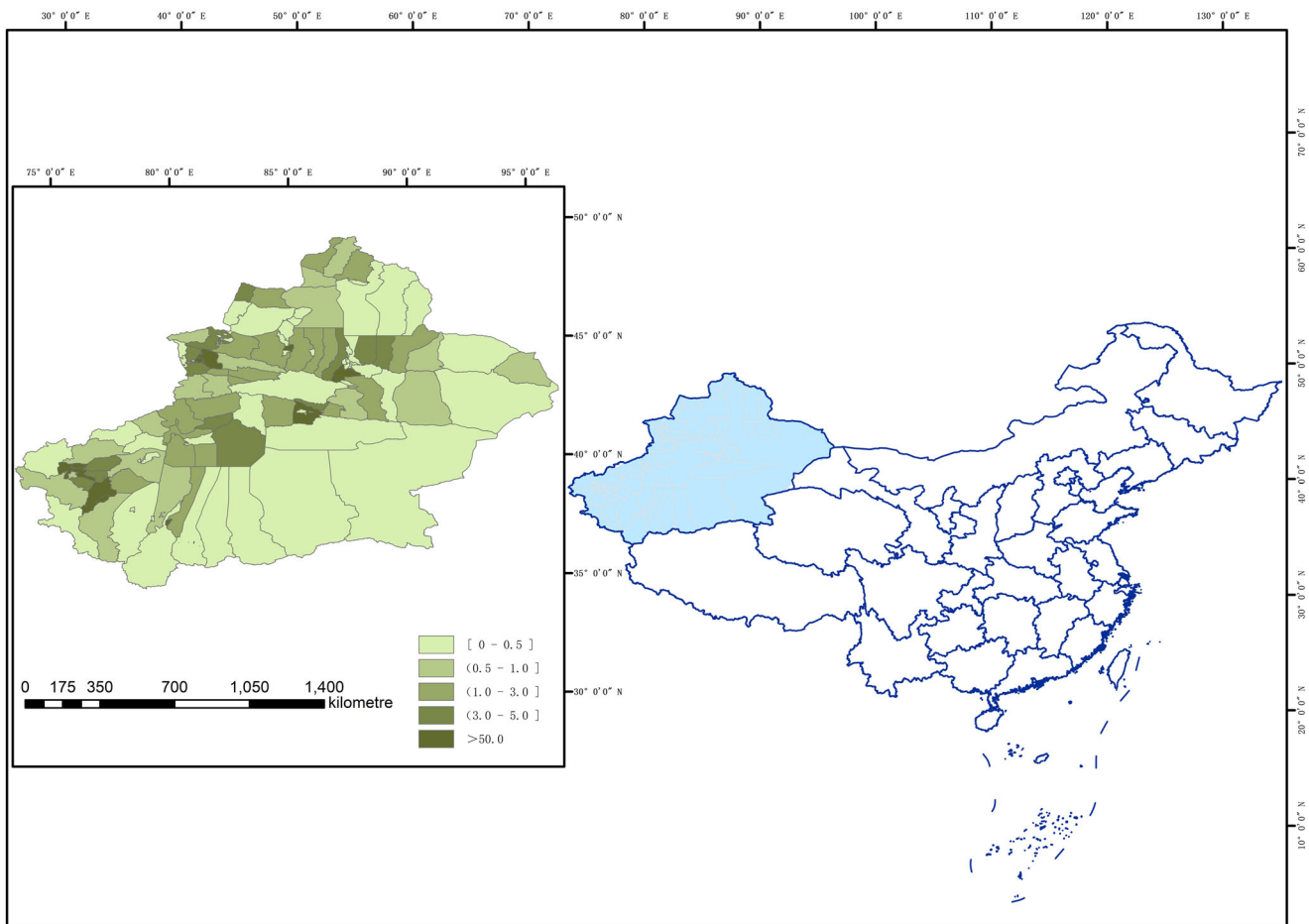


Fig. 1 Night lights in Xinjiang in 2019. Figure 1 was obtained from 80 sample counties for 2019. The number of night lights in each county was calculated. The color depth indicates the size, and the county's name has been marked. If the name of the county or city is unmarked, it is due to the lack of data, or the county belongs to the Xinjiang Production and Construction Corps. The source data are provided in the source data file.

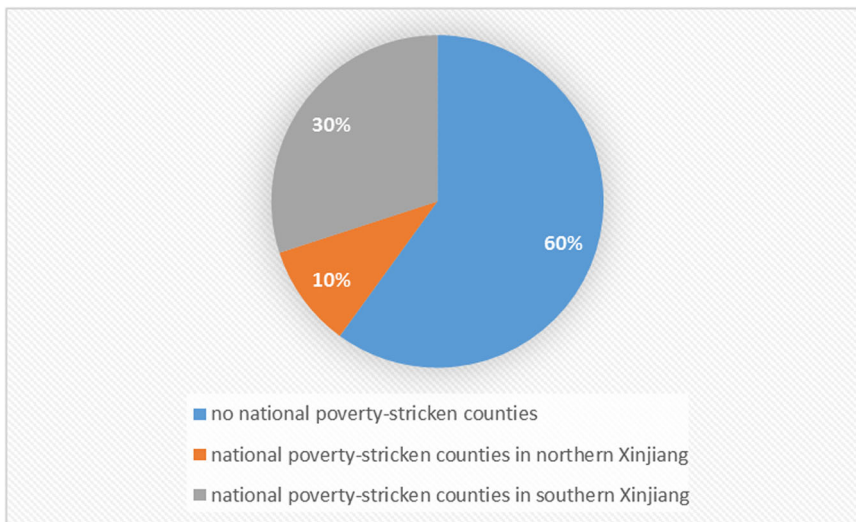


Fig. 2 Number of counties by type in our sample. Color depth indicates different types of counties. There are 80 counties. There are 48 nonnational poverty-stricken counties, 8 national poverty-stricken counties in northern Xinjiang and 24 national poverty-stricken counties in southern Xinjiang.

Table 4 Parallel trend test.

	pre_ Two	pre_ One	current	post_ One	post_ Two	post_ Three	County FE	Year FE
LnLight	-0.08	0.04	0.06	0.22***	0.24***	0.21***	Y	Y
	-1.26	0.70	0.98	3.60	3.59	2.93		

Asterisk symbols ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively. The t-values are in parentheses. Constant terms are omitted.

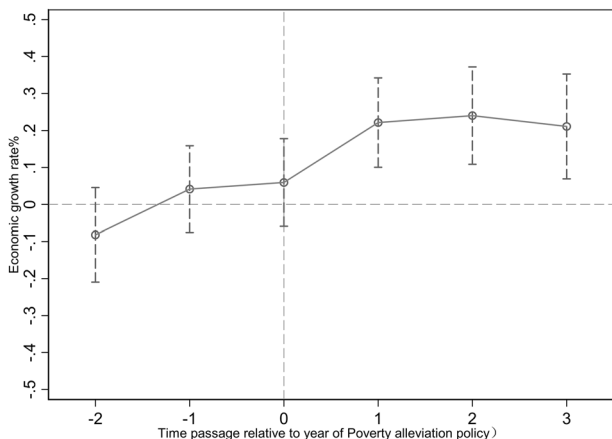


Fig. 3 Parallel trend using full samples. The annual difference in the regional economic growth rate before and after treatment (Poverty Alleviation Policy) assesses the parallel trend hypothesis. Points represent point estimates, while the vertical lines represent 95% confidence intervals.

Table 5 Influence of poverty alleviation policy on regional night light.

	(1) Lngdp	(2) Lngdp	(3) Lngdp
DID	0.22***	0.08***	0.09***
	9.63	4.08	3.82
LnFEL	-0.34***	-0.16***	-0.16***
	-6.12	-3.90	-3.91
Lnsav	-0.03	-0.12***	-0.12***
	-1.34	-4.39	-4.39
Lnwel	0.14***	0.02	0.02
	4.13	0.91	0.86
Lnpop	-0.06	-0.06	-0.06
	-0.55	-0.54	-0.56
County FE	Y	Y	Y
Year FE	N	Y	Y
Number of obs	560	560	560
R-squared	0.97	0.99	0.99

Asterisk symbols ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively. The t-values are in parentheses. Constant terms are omitted.

training should be further strengthened to improve economic growth, especially in remote and impoverished communities.

Discussion

The reason why China’s poverty alleviation policies have shown a consistently positive effect may be closely related to the unprecedented increase in poverty alleviation investment and the strengthening of the supervision and local accountability of poverty alleviation funds. The latter has primarily alleviated the problems that weaken the policy effect, such as the irregular use

of funds and the capture of elites. On the other hand, it provides some inspiration for the transformation of poverty alleviation policies after 2020. The dynamic analysis of the policy growth effect in this paper shows that the policy effect declines after three years of implementation, which means that the effective rate of external development assistance is likely to be short-term. This has something to do with the policy focus on productive investment projects such as infrastructure for a long time.

In the regression results of this paper, the policy implementation of poor counties in southern Xinjiang is better than

Table 6 DID estimation with matched samples.

	(1) Lnlight	(2) Lnlight	(3) Lnlight		
DID	0.07	0.51***	0.20 ***		
	0.92	8.26	4.15		
LnFEL	0.55***	-0.29**	0.06		
	5.14	-2.77	0.93		
Lnsav	-0.04	0.08	-0.02		
	0.71	1.03	-0.58		
Lnwel	0.04	0.31***	0.05		
	0.56	3.06	0.9		
Lnpop	0.8	-0.03	0.09		
	23.21	-0.08	0.47		
County FE	N	Y	Y		
Year FE	N	N	Y		
Number of obs	291	291	291		
R-squared	0.77	0.97	0.99		
Group B: covariate balance					
Variable	Sample	Treated	Control	T	p > t
LnFEL	U	-2.63	-2.48	-3.98	0
	M	-2.63	-2.65	0.43	0.67
Lnsav	U	-0.6	-0.6	0.03	0.98
	M	-0.59	-0.62	0.77	0.44
Lnwel	U	7.11	6.95	2.31	0.02
	M	7.1	7.05	0.77	0.44
Lnpop	U	2.89	2.58	2.41	0.02
	M	2.89	2.77	0.84	0.4

Asterisk symbols ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively. The t-values are in parentheses. Constant terms are omitted.

Table 7 Analysis of policy mechanism.

variable	Industrial poverty alleviation				Poverty alleviation through education
	(1)	(2)	(3)	(4)	(5)
	Light	Lnins_1	Lnins_2	Lnins_3	Lnedu
DID	0.20***	0.18***	0.18***	0.18***	0.19***
	6.06	5.75	5.97	5.82	5.86
Lnins_1		0.06*			
		0.93			
Lnins_2			0.12***		
			3.12		
Lnins_3				0.17***	
				2.67	
Lnedu					0.08*
					0.098
County FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
Number of obs	560	560	560	560	560

Asterisk symbols ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively. The t-values are in parentheses. Constant terms are omitted.

that in northern Xinjiang. This shows that the poverty alleviation policies deployed by the state can take into account the characteristics and conditions of ethnic minority communities and provide them with more preferential policies. This is consistent with what the Chinese government has promised in its poverty alleviation plan (Xiaoling et al. 2020).

The industrial poverty alleviation path has achieved some intermediary effects, and the development of the tertiary industry and secondary industry has significantly promoted the regional

economy more than the primary industry. The conclusions based on statistical significance are consistent with the previous general experience that the development of industry and service industry has a better role in promoting the economy (Liu et al. 2021; Yao and Fu 2021; Zhang et al. 2020a, 2020b). In particular, the poverty alleviation industrial projects focused on the cultivation of deep poverty areas in recent years have also fully focused on the development and exhibition of local characteristic agricultural products, which has led to the development of the tourism industry with natural scenery and unique ethnic customs.

Although education investment in deeply impoverished areas has a weak role in promoting the economy in the short term, industrial poverty alleviation is far less effective. However, China should still devote itself to increasing the proportion of people receiving higher education in the future, strengthening the training mechanism of vocational and technical skills in a targeted way, and promoting the rise of education level by the path of “improving adult vocational education - improving regional education system - increasing the number of people in higher education”. The economic effect brought by the education poverty alleviation belt and the investment of human capital are the long-term factors that can truly change the poor areas. Therefore, the “post-poverty era” policy should increase the investment in public service resources that affect the formation of human capital, such as education, and pay more attention to enhancing the inclusive growth role of the policy.

In addition, this study also has some shortcomings, and future research needs to address the following: (1) The data set used in this study only covers the period from 2013 to 2019, which may not accurately reflect the long-term impact of China’s poverty alleviation initiatives. This is a potential research limitation. To better understand the overall and long-term impact of poverty reduction plans and the variables that affect their effectiveness and sustainability, future research should continue to monitor poverty reduction interventions. (2) Poverty alleviation is the overall evolution and development process of the whole social system, involving economic, political, cultural, social construction, ecological civilization construction and other aspects related to economic development. Poverty alleviation is complex and diverse, and it is difficult to cover all aspects. Therefore, it is necessary to continue such case studies to include more factors in the analysis. (3) This paper only studies the effect of China’s poverty alleviation policies, especially the setting of key development counties for national poverty alleviation work. Due to the lack of data, what impact will the government’s poverty alleviation funds have on the poverty situation? Whether the use of funds is perfect will be our focus in the future.

Conclusion: practical implications and recommendations

The purpose of this research is to evaluate the effectiveness of China’s poverty alleviation policies in Xinjiang and to provide insights into how these policies can be improved in the future. The primary discovery of this research is that the poverty alleviation policies in Xinjiang have been largely effective in reducing poverty rates and improving the living conditions of the people in the region. However, there are still some challenges and limitations that need to be addressed to ensure the sustainability of poverty reduction efforts.

This paper examines the effectiveness of China’s poverty alleviation policy in Xinjiang, a region with a large population of ethnic minorities. The research uses both quantitative and qualitative methods to analyze the poverty alleviation policies in Xinjiang and their impact on poverty reduction. The results show that China’s poverty alleviation policy has been effective in

reducing poverty in Xinjiang, particularly in terms of increasing income and providing basic social services.

First, the research finds that poverty alleviation policies in Xinjiang have been focused on increasing the income levels of rural residents. This has been achieved through the promotion of agricultural modernization, improvement of rural infrastructure, and provision of credit to farmers. The results show that these policies have been effective in increasing the income of rural residents and reducing poverty.

Second, the research shows that the provision of basic social services, such as education and healthcare, has also been an important factor in reducing poverty in Xinjiang. The government has invested heavily in improving the quality of education and healthcare in the region, which has resulted in an increase in school enrollment rates and a decrease in infant mortality rates.

Third, the research indicates that industrial poverty alleviation policies have been successful in creating employment opportunities and increasing the income of rural residents. The government has encouraged the development of various industries in Xinjiang, such as textiles, agriculture, and tourism, which has led to the creation of new job opportunities and increased income for local residents.

Based on the research results of this article, it can be concluded that the poverty alleviation policies in Xinjiang have been effective in reducing poverty rates and improving the living conditions of the people in the region. However, there are still some challenges and limitations that need to be addressed to ensure the sustainability of poverty reduction efforts.

The economies of key national poverty alleviation counties in Xinjiang have been significantly improved under the promotion of poverty alleviation policies, but their development still lags behind that of other regions. After overall poverty alleviation, it is recommended that relevant policies to assist the development of backward areas should be flexibly adjusted to identify effective mechanisms to link up with poverty alleviation policies. Industrial development has significant effects on the economic development of the region.

In promoting the industrial development of Xinjiang's national poverty alleviation key counties, it is necessary to have a deep understanding of market orientation and properly handle the issue of interest distribution among relevant entities. After the completion of the poverty alleviation task, it is necessary to continue to develop and expand the poverty alleviation industry, strengthen the construction of industrial development infrastructure in poverty alleviation areas, expand sales channels for characteristic products, innovate circulation methods, and promote stable sales of characteristic products.

The development of education has been significantly improved under the influence of poverty alleviation policies, but the promotion effect of poverty alleviation through education on the regional economy is relatively small, and only focusing on the realization of universal nine-year compulsory education is not sufficient to meet the needs of local construction. In the future, it is recommended to effectively improve the salary and welfare benefits of teachers in deeply impoverished areas and improve the development mechanism of basic and vocational education. For adults receiving vocational education, government departments should provide follow-up employment security for them, forming a "targeted to people" security mechanism that helps them to the end.

Data availability

The datasets analyzed during the current study are available in the Harvard Dataverse, <https://doi.org/10.7910/DVN/0E2AMB>.

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Author contributions

YJH and XKH conceived the idea presented herein. Authors YJH, XKH, RLL, and WC developed a plan for the theory. YJH and XKH designed the methodology, with the support of RLL and WC. YJH collected the data under the guidance and supervision of XKH. YJH and XKH analysed the findings and drafted the first version of the manuscript. All authors provided critical feedback and helped shape the research and analysis. All authors revised and contributed to drafting the final manuscript and approved it.

Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

Additional information

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Correspondence and requests for materials should be addressed to Xianke Huang.

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