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Does industry convergence between agriculture and related sectors alleviate rural poverty: evidence from China

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Abstract

Enhancing the synergies between agriculture and related sectors in rural areas is considered an important development strategy to eliminate rural poverty. This article provides evidence for this view by analyzing the effect of industry convergence between agriculture and related sectors on rural poverty. Based on China's provincial panel data, we use two-way fixed effects model, system generalized method of moments and panel-corrected standard error estimator to quantitatively assess this effect. We find that: (1) the convergence of agriculture and tourism (ATOU), the convergence of agriculture and processing industry (APOS), and the convergence of planting and breeding industry (MIXA) have positive and significant effects on poverty reduction. The convergence of agriculture and the internet industry (AINT) has a positive but not significant effect. (2) Rural local employment plays an important role as a bridge in the impact of convergence on poverty reduction. ATOU and MIXA reduce poverty by increasing self-employment opportunities. APOS reduces poverty by providing more jobs. (3) Except for APOS, the effects of other types of convergence tend to stabilize or improve in the later period. (4) Convergence has the most significant impact on poverty reduction in western China. The findings provide inspiration for developing countries with agricultural foundations to choose appropriate rural development paths for reducing rural poverty.

Keywords Rural poverty reduction · Industry convergence · Agriculture · Rural revitalization · China

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1 Introduction

The latest estimates indicate that 80% of the poor live in rural areas. Affected by COVID-19, their lives are facing great challenges (United Nations, 2021). Agricultural growth in developing countries is often considered an important instrument for decreasing rural poverty (Ravallion & Chen, 2007; World Bank, 2008; Dethier & Alexandra, 2012). Recently, this view has been supplemented and refined. Kay (2009) points out that creatively strengthening the synergies between agriculture and industries is also the important strategy for rural development to eliminate the rural poor. Shan et al. (2017) gives a similar conclusion, believing that the primary, secondary and tertiary industries should be coordinated to reduce poverty. This view has been supported by many scholars (Van der Ploeg & Jingzhong, 2010; Angeles et al., 2021). However, there are few quantitative empirical studies to verify this. This article aims to fill this gap. The trajectory of China's rural development in recent years provides us with an excellent sample for studying this issue. In the second decade of twenty-first century, the Chinese government launched a rural revitalization program, which regarded industry convergence as the rural development strategy to strengthen the links between agriculture and its associated industries for increasing agricultural efficiency and enriching rural industries. Industry convergence refers to the process of gradual blurring of the initial boundary between two or more separate industries (Weaver, 2007), which is an innovative path to achieve synergy between industries. It combines the functions of the original industries to form new industries, new business formats, or products to meet new market demands and create new economic growth (Kim et al., 2015). This article will use China's rural industry convergence data to quantitatively evaluate the effect of the synergies between agriculture and related sectors on rural poverty reduction.

The Chinese government has issued a series of documents to promote industry convergence in rural areas. In 2010, the Ministry of Agriculture and the National Tourism Administration signed a cooperation agreement to jointly promote the convergence of agriculture and rural tourism, aiming to develop agricultural tourism based on the multifunctionality of agriculture. In 2015, the General Office of the State Council has issued a guideline on promoting the convergence development of primary, secondary and tertiary industries in rural areas to extend agricultural industry chain of countryside and develop new forms of agricultural business. The goal is not only to develop agritourism, but also develop agricultural processing industry, mixed farming, agricultural e-commerce, and so on. According to the official data released by the Chinese government, in 2017, the operating income of leisure agriculture and rural tourism nationwide exceeded 620 billion yuan, and 2.2 billion tourists were received annually. The number of rural online stores reached 9.856 million. In 2019, the rural industry convergence pushed the proportion of farmers producing on order to 45 percent. The operating income of China's agricultural processing industry exceeds 22 trillion yuan. However, from a national perspective, it is still not clear whether rural industry convergence has played an important role in reducing rural poverty. Quantitative assessment can bring more enlightenment for developing countries to promote rural development and alleviate rural poverty.

In the early years, industry convergence was only discussed in the field of IT, telecommunications, media, and the entertainment industry. Scholars mainly focused on the concept, types, and driving forces of industry convergence (Lind, 2004; Weaver, 2007). Qualitative research method is the most used. Gradually, scholars have observed the phenomenon of industry convergence in more industries, such as cosmeceuticals, food, and begun to use quantitative methods to predict and evaluate the degree of industry convergence, aiming to help firms prepare for the opportunities and challenges brought about by possible changes in industry boundaries (Curran et al., 2010; Sick et al., 2019). Industry convergence in rural areas has only received little attention from scholars. Shen et al. (2019) only illustrated the role of industry convergence in promoting the development of rural tourism. Chen et al. (2020) discussed the effect of industry convergence on rural sustainable development through case studies. Till now, there are few studies that quantitatively analyze the convergence of rural industries and its poverty reduction effects. Moreover, there are many types of rural industry convergence, but few scholars distinguish them and compare their effects.

This article intends to contribute to the literature. We extend the theory of industry convergence to the pro-poor rural development strategy for the first time. Based on theory and practice, this article divides the industry convergence in rural areas into four categories, which greatly expands the scope and types of rural industry convergence. Based on the quantitative empirical analysis using China's provincial panel data, this article finds that most types of rural industry convergence have a significant impact on rural poverty reduction. It indicates that the synergies between agriculture and related sectors are indeed an important rural development strategy for rural poverty reduction, which is an important finding and existing academic views are verified. In addition, this article also explores the mechanism by which industry convergence affects rural poverty and finds rural local employment plays a key role as a bridge. This is a very meaningful exploration and supplement to the anti-poverty theory. The analysis of heterogeneity based on different periods and areas highlights the importance of the rural external development environment and the endowment of rural areas. The implementation of rural development strategy must fully consider these related factors. In addition to the above theoretical contributions, the practices of China's rural pro-poor development also provide a good reference for other developing countries.

The rest of the article proceeds as follows. We first review the literature in terms of industry convergence, rural development, and rural poverty; then, the methodology is described in Sect. 3, including the classification of rural industry convergence, model specification, and data resources. After that, the empirical results are reported in Sect. 4 and Sect. 5 discusses the results. In the end, Sect. 6 gives the conclusion and provides some policy implications.

2 Literature review

2.1 Industry convergence

Industry convergence is one of the trends of industrial development and evolution. In the early 1980s, telecommunications, information technology, and electronic industries have received the early attention of scholars. Because their industrial boundaries have largely disappeared (Duysters & Hagedoorn, 1998), digital technology has promoted cross-convergence with computer and communications-related sectors. Later, the convergence of other sectors has gradually attracted the attention of scholars, such as material design and electronic technology (Hacklin et al., 2009), cosmetics and pharmaceuticals (Curran et al., 2010), food and pharmaceuticals (Lamberti & Lettieri, 2011), and so on. Industry convergence is a key source of competitive advantage for major developed countries and global companies, which have been developing and implementing industrial convergence strategies since 2000 (Heo & Lee, 2019).

The occurrence of industry convergence can be regarded as a time-series event, which generally goes through several steps from science convergence, technology convergence, market convergence, and industry convergence (Curran et al., 2010). By sharing similar technology or knowledge on the supply side (science and technology convergence), industries form competitive or complementary relationships, which will lead to changes in industry boundaries, ultimately meet the same needs in the demand-side product or service markets (market convergence) (Heo & Lee, 2019). However, without the prior steps of scientific and technological convergence, market convergence may also occur, which may be triggered by changes in customer needs. Moreover, in some cases, market convergence will also strengthen the early technological convergence (Bröring, 2010; Schmidt et al., 2016).

Industry convergence can lead to the emergence of new, previously non-existent industries, which helps to accelerate the restructuring of the existing industrial structure, (Kim et al., 2015). Industry convergence creates new business areas, and economic growth opportunities, but it may also cause some companies to lose their existing market positions. For example, in the process of the smart phone reorganization of the traditional mobile phone industry, Nokia failed because it did not follow the trend of integration of mobile communications with other sectors such as photography, navigation, and high-speed internet access in time. (Curran et al., 2010).

In order to enable enterprises to better cope with the opportunities and risks brought about by industrial changes, the process of industry convergence is monitored and evaluated. Different indicators are used to evaluate different stages of convergence. Most scholars agree that the stages of knowledge and technology convergence can be identified by scientific literature and patent data. It is difficult to identify the stage of market convergence, and the data of actual products or services with mixed functions can be considered. The final stage of the industry convergence can be identified by the cooperative behavior of enterprises in press releases and commercial media data (Curran et al., 2010; Kim et al., 2015; Sick et al., 2019). Heo and Lee (2019) believe that it is necessary to measure the industry convergence from the perspective of industry. Because it can provide a more comprehensive picture of the industry. They used South Korea's Input Output Table (IOTS) to analyze the industry convergence of 29 industries (6 industry groups) from the perspective of the supply side (technology) and the output side (market).

At present, there are few divisions in the types of industry convergence. It is often divided into "convergence within industries ($A1+A2$)" and "convergence between industries ($A+B$)" (Kim et al., 2015). Assuming that the A industry and the B industry are converging, if the newly created C industry completely replaces the original industry, this process can be called substitutive convergence ($A+B=C$). If the newly created C industry does not affect the core business of the original A and B industries but is only a supplement to the original industries, then it is called complementary convergence ($A+B=A+B+C$) (Sick et al., 2019).

So far, industry convergence is still an emerging industrial economics issue, and it is still in the development stage. Most of the research focuses on information and communication industry, while industries in rural areas are less involved. Moreover, most of the existing empirical research focuses on the prediction and measurement of industry convergence. Few scholars use numerical data to analyze its impact on poverty reduction and distinguish the effect of different types of convergence.

2.2 Industry convergence and rural poverty

The economic development of rural areas is mainly in agriculture. The poorer the family, the more they depend on agriculture for their livelihoods. Therefore, economic growth in the agriculture will have a direct and significant impact on rural poverty alleviation (Ravallion & Chen, 2007). In different types of developing countries, the role of agriculture in promoting growth and alleviating poverty is different. In agriculture-based countries, the development of agriculture and its associated industries is essential for large-scale poverty reduction and food safety. In transition countries, the development of high-value agriculture and the decentralization of non-agricultural economic activities to rural areas, combined with strong policies, could benefit hundreds of millions of the world's rural poor (World Bank, 2008).

Agriculture is closely related to other sectors. Agricultural growth can stimulate production in other sectors, and the demand growth on which agricultural growth depends is caused by growth in other sectors (Collier & Dercon, 2014). Strengthening the dynamic relationship between agriculture and industry and bridging the gap between urban and rural areas is the best rural development strategy to reduce inequality and eradicate poverty (Kay, 2009). Shan et al. (2017) gave similar conclusions, which are the development of the primary, secondary, and tertiary industries should play a synergistic role in poverty reduction, rather than separate from each other. The above findings have been endorsed by many scholars. Van der Ploeg and Jingzhong (2010) found that China's rapid industrialization has brought about the flow of rural labor to cities, which has weakened the urban–rural income gap. Angeles et al. (2021) explored the influencing factors of failures of agriculture-industry synergies (AIS) based on the case of the Philippines, believing that institutional failure is the important reason. However, to date, few quantitatively empirical studies have analyzed the effect of the synergy between agriculture and other sectors on poverty reduction.

Industry convergence is one of the important ways to achieve synergies between agriculture and other sectors. Current studies about industry convergence in rural areas mainly focus on the convergence of agriculture and tourism. Due to the fierce global competition, climate warming, and decline of rural traditional agriculture, the income of farmers is threatened. To maintain or even expand income, farmers began to expand their activities to tourism based on their farm resources and family labor (Flanigan, et al., 2015; Hung, et al., 2016). It promotes the rise of a new type of rural agricultural tourism, giving farmers opportunities to obtain non-agricultural income without leaving their hometowns. Moreover, the sales of local agricultural products with the help of rural tourism catering services are also promoted. (Torres & Momsen, 2004; Chen et al., 2020; Shen et al., 2019). However, some scholars still question the pro-poor effect of the combination of agriculture and tourism. Pillay (2013) interviewed with 50 hotels in South Africa and found that the top of the hotel's food supply chain was connected through intermediary network organizations. Very few of them represent the interests of poor agricultural producers in the region. It does not seem to be conducive to poverty reduction. Therefore, it is uncertain whether the convergence of agriculture-based industries will have a large-scale poverty reduction effect.

In summary, the synergies between agriculture and other related sectors are considered an important rural development strategy. Industry convergence is the innovative way of agricultural industry collaboration. The current research is mainly about the convergence and effect of agriculture and tourism. Whether rural industry convergence can alleviate poverty is still inconclusive. Other types of rural industry convergence and poverty reduction impacts are rarely involved.

3 Methodology

3.1 China's rural industry convergence and classification

Affected by the urban–rural dual economic structure, there are many problems in China's rural areas, such as low agricultural income, abandoned farmland, and brain drain. There is a lack of income-increasing opportunities in the countryside. Young people in rural areas often leave the country to work in cities to increase their income. Other rural residents have to stay in their hometowns for various reasons, such as raising children, taking care of the elderly, or being too old. These people have little chance to escape poverty.

With the rapid growth of China's overall economy, the development of China's rural areas has received more and more attention and support from the government and all sectors of society. Industry convergence is regarded as a key way for rural revitalization by Chinese government. The convergence of agriculture with its related sectors is advocated. A series of documents on relaxing rural land controls, providing financial support to rural areas, and encouraging rural college students and rural migrant workers in cities to return to their hometowns for starting businesses have been issued. China's rural industry convergence has been greatly promoted. The "Annual Report on the Integrated Development of Rural Primary, Secondary, and Tertiary Industries (2017)" produced by the National Development and Reform Commission of China pointed out that more than 82% of the projects initiated by entrepreneurs returning to rural areas are rural industry convergence projects, including featured planting and breeding industry, agricultural product processing industry, leisure agriculture and rural tourism, agriculture-related information services, and e-commerce industries.

According to the theory of industry convergence and practices in China, as well as the differences in the convergence characteristics of agriculture and related sectors, we divide them into four categories as follows (Table 1).

Firstly, the convergence of agriculture and tourism has received strong support from the relevant departments of the Chinese government in the past decade. The new industry resulting from the convergence is also called agritourism or leisure agriculture, which refers to the use of agricultural resources as tourist attractions to expand the scope of tourism. Because the newly created industry does not replace the original two industries, this is a complementary convergence. Its business patterns include agricultural landscape viewing (such as canola flowers and peach blossoms), fruit and vegetable picking, agricultural manor, and so on. Local farmers with better education and economic advantages often participate in agritourism through self-employment, making full use of their farming land, family labor, and agricultural experience.

Secondly, the convergence of agriculture and processing industry in rural China is cultivated and supported at the beginning of the twenty-first century. With the government's policy support, a large number of agricultural products processing enterprises have emerged in rural and surrounding areas. Smallholder farmers are organized by rural cooperatives or enterprises to supply agricultural products to the processing enterprises. By integrating into this close agricultural value chain, farmers have reduced the market risks they had previously endured, and stabilized or increased their agricultural income.

Table 1 Classification, characteristics, results, and main policies of rural industry convergence

Classification	Characteristics	Results	Main Policies of the Chinese government
Convergence of agriculture and tourism (ATOU)	Convergence between industries ($A+B$) Complementary convergence ($A+B=A+B+C$)	It promotes the development of agritourism based on the multiple functions of agriculture	In 2010, the Ministry of Agriculture and Tourism Administration signed a cooperation agreement to jointly promote the development of agritourism In 2015, the Ministry of Agriculture and the Ministry of Finance, and the other 11 departments issued the "Notice on Actively Exploiting Multiple Functions of Agriculture and Vigorously Promoting the Development of Leisure Agriculture" In 2016, the Ministry of Agriculture and the National Development and Reform Commission, and the other 14 departments issued the "Guiding Opinions on Vigorously Developing Leisure Agriculture"
Convergence of agriculture and processing industry (APOS)	Convergence between industries ($A+B$) Complementary convergence ($A+B=A+B+C$)	It promotes the development of agricultural product processing in the countryside and nearby areas and integrates farmers into the agricultural value chain	In 2008, the central government established a modern agricultural production development fund to support agricultural product processing enterprises In 2012, the central government launched a subsidy program for the initial processing of agricultural products and supported farmers and cooperatives to build processing facilities In 2016, the Ministry of Agriculture issued the "National Agricultural Product Processing Industry and Rural Primary, Secondary and Tertiary Industries Integrated Development Plan (2016–2020)"

Table 1 (continued)

Classification	Characteristics	Results	Main Policies of the Chinese government
Convergence of planting and breeding industry (MIXA)	Convergence within industries ($A1+A2$) Complementary convergence ($A+B=A+B+C$)	It promotes the emergence of multiple types of mixed agriculture, and improves the use efficiency of land space, and improve production efficiency	In 2010, the No. 1 document of the Central Committee proposed to develop high-efficiency agriculture, under-forest planting, and breeding industries, and tap the potential of employment in agriculture In 2016, the Ministry of Agriculture issued the "Guiding Opinions on the Adjustment of Agricultural Structure in the Northern Agro-pastoral Zone" In 2017, the Ministry of Agriculture on the issuance of the "Engineering construction plan of Planting and breeding combined (2017–2020)"
Convergence of agriculture and internet industry (AINT)	Convergence between industries ($A+B$) Complementary convergence ($A+B=A+B+\mathrm{C}$)	It promotes the development of agricultural e-commerce and enables farmers to directly face the market by the internet	In 2015, the General Office of the State Council put forward guidelines for promoting the convergence of rural primary, secondary and tertiary industries In 2017, the Ministry of Agriculture, the National Development and Reform Commission, and the Ministry of Commerce issued the Action Plan for Promoting the Development of Agricultural E-commerce

Furthermore, farmers also use their leisure time to work in local agricultural product processing enterprises to obtain stable wage income. The government has also invested in the construction of a large number of processing workshops in rural areas, giving priority to the poor as workers.

Thirdly, China's per capita arable land is very small and is only about 0.10hm^2, which is far lower than the world average and is at the lower-middle level in the world. To make use of land resources and improve production efficiency, the Chinese government advocates the combination of planting and breeding industry. This is a special type of convergence between sub-industries within agriculture. Its types are rich and diverse, such as mixed agriculture combining grain and livestock, fruit tree, and chicken symbiosis system, and fish-rice symbiosis ecosystem, which also has many benefits for ecological protection.

Fourthly, China's internet industry and logistics industry are developing rapidly. Alipay and Taobao are very popular in both urban and rural areas, and the logistics industry has covered most of the rural areas. The Chinese government advocates the convergence of the agriculture and internet industry. With the help of Taobao's third-party e-commerce platform, farmers' fruits, vegetables, and other products can be sold directly to consumers. Agricultural e-commerce draws the distance between farmers and the market and restricts middlemen to earn the price difference. The cost of opening a store on Taobao is very low, and the skills of opening a store online are relatively easy to learn. With the support of the government, a large number of small agricultural product online stores have been created in rural China. In 2019, the transaction volume of agricultural products on the Ali platform was 200 billion yuan.

The Classification, characteristics, results, and main related policies of rural industry convergence in China are shown in Table 1.

3.2 Model specification and variables

From the previous literature review, we can find most of the current research on the effects of rural industry convergence is in the initial stage, and qualitative research methods are often used by scholars. This article decides to use the two-way fixed effects (2FE) model to quantitatively analyze the relationship between rural industry convergence and rural poverty.

The 2FE model is a widely used method of analyzing panel causality. China has a vast territory and adopted an unbalanced development strategy in the early stages of development. The economic and cultural differences between provinces are very large. 2FE model can control unobserved province-specific and time-specific characteristics and make the estimation results more accurate.

We specify the two-ways fixed effects panel model as follows.

$$\mathrm{POV}_{p,t} = cCO_{p,t}^{\mathrm{type}} + \sum_{n=1}^{n} \beta_n X_{n,pt} + u_p + \mu_t + \varepsilon_{p,t} \tag{1}$$

where $\mathrm{POV}_{p,t}$ stands for rural poverty for province p at time t. $\mathrm{CO}_{p,t}^{\mathrm{type}}$ stands for rural industry convergence of the specific type. $X_{n,pt}$ is a set of control variables that have been identified in the literature to affect the rural poverty. n is the number of control variables. c and β_n are the coefficient. u_p is the province effect. μ_t is time effect. $\varepsilon_{p,t}$ is the error term.

$\mathrm{POV}_{p,t}$ is the dependent variable. In this article, we use the rural Engel coefficient as a relative poverty indicator to measure rural poverty and give up using the absolute poverty line method. The reasons are as follows. First of all, the setting of the poverty line has always been controversial. The United Nations and different countries have proposed different poverty lines, and these lines are constantly changing. Coupled with differences in currency values and commodity prices across countries, it is difficult to achieve consistent results on poverty determination. Secondly, the rural Engel coefficient is an important indicator reflecting the standard of living, which can better reflect the welfare of rural residents. It is not affected by currency value and is more suitable for comparison between different regions. The Food and Agriculture Organization of the United Nations also use it to identify poverty. Thirdly, when the government declared that all the population was lifted out of poverty, that is, when the incidence of poverty is zero, the application of the rural Engel coefficient can enable relevant empirical research to continue without interruption. Fourthly, some doubters believe that the Engel coefficient is not suitable for representing urban poverty in China. Because housing prices and education expenditures are relatively large in cities, the index will be distorted (Yin & Tang, 2009). But so far, few people have questioned its applicability in rural China. Moreover, the fixed effects model used in this article can remove differences between provinces due to different food consumption habits, thereby ensuring its applicability in this study.

This article measured rural Engel coefficient by the proportion of food consumption expenditure out of total consumption expenditure. If the rural Engel coefficient is too high, it indicates that daily basic needs are not well met and basic living capabilities are deprived. So, the larger the rural Engel coefficient, the higher the degree of rural poverty.

$\mathrm{CO}_{p,t}^{\mathrm{type}}$ is the explanatory variable. This article will measure four different types of rural industry convergence. Because the main purpose of this article is to evaluate the impact of industry convergence. Therefore, this article skips the science, technology, and market convergence stage and directly measures the final stage of industry convergence. To fully reflect the overall development of each type of rural industry convergence, this article tries to measure industry convergence from an industry perspective as much as possible. However, not all convergence types have macro-industry data. Therefore, in this article some convergence types we use industrial data, and some convergence types we use commercial data. Because the four convergence types are used for regression analysis separately, the difference in data sources will not affect the regression results.

According to the nature of different convergence, firstly, we use the number of national agricultural tourism demonstration counties owned by each province to represent the development of convergence of agriculture and tourism ($\mathrm{CO}_{e,t}^{\mathrm{atou}}$). Secondly, we use the main business income of agricultural products processing to measure the development of convergence of agriculture and processing industry ($\mathrm{CO}_{e,t}^{\mathrm{apos}}$). To reduce the absolute value of the data to facilitate calculations, but also eliminate heteroscedasticity, this article will log transforms the data of this variable ($\ln\mathrm{CO}_{e,t}^{\mathrm{apos}}$). Thirdly, we use agricultural added value per unit area of agricultural land to denote the development of convergence of planting and breeding industry ($\mathrm{CO}_{e,t}^{\mathrm{mixa}}$). Similarly, we log transform the data of it ($\ln\mathrm{CO}_{e,t}^{\mathrm{mixa}}$). Fourthly, the number of Taobao villages in each province is used to represent the development of convergence of agriculture and internet industry ($\mathrm{CO}_{e,t}^{\mathrm{aint}}$). Since the values of $\mathrm{CO}_{e,t}^{\mathrm{atou}}$ and $\mathrm{CO}_{e,t}^{\mathrm{aint}}$ are not very large, sometimes there will be a value of 0. In order to preserve their original information as much as possible, we do not take the logarithm of these two variables.

The control variables are as follows. (1) Rural fixed asset investment (INVEST) can promote rural economic growth and improve rural employment, which plays an important role in poverty alleviation. Following Zhao and Xia (2020), the proportion of rural fixed-asset investment to the total agricultural output value is used to measure it. (2) Natural disasters

(DISASTER) such as floods, hail, and drought have severely affected agricultural production and the economic income of farmers. This is a negative indicator. We use the proportion of the disaster area per unit of agricultural land to measure it. (3) Education (EDU) is recognized as an important factor in poverty reduction. The average years of education of rural residents are used to measure it. (4) Government expenditure for agriculture (GOV) including breeding, forestry, animal husbandry, and fishery has a very positive impact on the development of the rural economy. The ratio of agricultural expenditure to total expenditure is used to measure it. (5) Rural minimum living security (SECURITY) is a living assistance that government assists the low-income people to help them get through sudden and temporary life difficulties and get their life back on track. This study uses the minimum living security expenditure proportion to rural GDP as its measure. The rural GDP is generally composed of added value for agriculture, forestry, animal husbandry, and fishery, and added value for township enterprises (Zhang & Weng, 2015). Considering the missing value-added data for township enterprises after 2011, the rural GDP here is replaced by the added value of agriculture, forestry, animal husbandry, and fishery. (6) Rural financial development level (FINA). Scholars generally use the proportion of agricultural loans to the output value of the primary industry to characterize the level of rural financial development; however, this indicator cannot reflect the degree of transfer of rural funds, so it is more appropriate to use the proportion of rural loans to rural deposits. Considering that rural credit cooperatives have a large market share in rural financial markets, this study measures the level of rural financial development using the proportion of year-end loan balance to year-end deposit balance in rural credit cooperatives.

What needs to be explained is that because there is a certain crossover phenomenon between different types of rural industry convergence. They are not completely independent of each other. So, they cannot be used as control variables for each other.

3.3 Data resources and descriptive statistics

This study uses Chinese provincial panel data of 31 provinces, municipalities, and autonomous regions (excluding Hong Kong, Macao, and Taiwan) from 2007 to 2019. Because China's rural industry convergence was mainly promoted and developed in the last ten years, the time period of the data selected in this paper is concentrated around this period.

The data relating to rural residents and agriculture are mainly collected from *China Rural Statistical Yearbook* (2008–2020). The data relating to rural education are collected from *China Population and Employment Statistics Yearbook* (2008–2020). The data of national agricultural tourism demonstration counties are collected from the website of the Ministry of Agriculture and Rural Affairs. The data relating to agricultural product processing are collected from *China Industry Economy Statistical Yearbook* (2008–2020). The data of Taobao villages come from the "China Taobao Village Research Report" published by the Ali Research Institute. The data relating to rural fixed asset investment are collected from *China Statistical Yearbook* (2008–2020). The data about rural finance are selected from *Almanac of China's Finance and Banking* (2008–2020). Very few missing values in the data are filled in by interpolation.

The descriptive statistics of the employed variables are shown in Table 2. Specifically, the maximum value of POV is 0.559 and the minimum value is 0.238. This shows that the level of rural poverty varies across provinces in China. The minimum value of CO^{atou} *is 0,* which indicates that a certain province does not own one national agricultural tourism

Table 2 Descriptive statistics

Variables	Mean	SD	Minimum	Maximum	Observations
POV	0.369	0.073	0.238	0.559	403
CO^{atou}	5.967	6.123	0	28.42	403
$lnCO^{apos}$	0.278	0.664	− 2.26	1.501	403
$lnCO^{mixa}$	− 0.048	0.574	− 2.201	0.853	403
CO^{aint}	29.727	134.49	0	1573	403
Invest	0.201	0.172	0.005	1.384	403
Disaster	0.193	0.146	0	0.696	403
EDU	7.538	0.841	3.814	9.797	403
GOV	0.112	0.033	0.029	0.203	403
Security	0.017	0.013	0.002	0.076	403
FINA	0.413	0.351	0	2.205	403

demonstration county in a specific year. The minimum value of CO^{aint} is also *0,* which indicates there is no Taobao village in a certain province in a specific year.

4 Results

4.1 Correlation analysis

The correlation analysis is presented in Table 3. The results show that all variables of rural industry convergence have a negative relationship with rural poverty. It suggests that rural industry convergence has a positive effect on rural poverty reduction. In addition to the two variables of DISASTER and FINA, other control variables also show a negative correlation with rural poverty.

To ensure the validity of the data, we also performed (Variance Inflation Factor) VIF tests on all variances and found that the maximum VIF value of the estimated values is 2.91, which is much less than 10 and indicates low correlation. Therefore, there is no need to worry about multicollinearity.

4.2 The effect of rural industry convergence on rural poverty

Table 4 shows the estimation results of the effects of rural industry convergence on rural poverty. The regression results of pooled ordinary least squares (POLS) using clustering robust standard errors are used for comparison. Most of the R^2 is above 0.5, indicating that the reliability of the regression is relatively high. The estimated results of POLS and 2FE in Table 4 are relatively close. However, the *P* values of all *F*-value tests are highly significant, indicating that fixed effects model is significantly better than pooled regression, and each individual should have its intercept term. Most of the values of Hausmann's test are significant, indicating that the fixed effects model estimator should be chosen from a statistical point of view.

In column (2), the estimated coefficient of CO^{atou} is—0.001, negative and statistically significant at the 10% level, which illustrates that the convergence of agriculture and

Table 3 The results of the correlation analysis

	POV	CO^{atou}	$lnCO^{apro}$	$lnCO^{mixa}$	CO^{aint}	Invest	Disaster	EDU	GOV	Security	FINA
POV	1										
CO^{atou}	− 0.578	1									
$lnCO^{apos}$	− 0.348	0.326	1								
$lnCO^{mixa}$	− 0.277	0.255	0.795	1							
CO^{aint}	− 0.162	0.386	0.240	0.204	1						
Invest	− 0.401	0.296	− 0.203	− 0.235	− 0.090	1					
Disaster	0.241	− 0.393	− 0.283	− 0.303	− 0.139	− 0.137	1				
EDU	− 0.473	0.144	0.563	0.720	0.111	− 0.032	− 0.124	1			
GOV	− 0.072	0.223	− 0.358	− 0.501	− 0.173	0.164	0.169	− 0.411	1		
Security	− 0.172	0.119	− 0.421	− 0.412	− 0.088	0.418	− 0.003	− 0.306	0.379	1	
FINA	0.031	− 0.188	− 0.120	− 0.131	− 0.081	0.034	0.376	− 0.026	0.179	0.228	1

Table 4 The effects of rural industry convergence on rural poverty

Variables	(1) POLS	(2) 2FE	(3) POLS	(4) 2FE	(5) POLS	(6) 2FE	(7) POLS	(8) 2FE
CO^{atou}	− 0.005***	− 0.001 3*						
	(− 0.001)	(− 0.001)						
$\ln CO^{apos}$			− 0.015**	− 0.026***				
			(− 0.006)	(− 0.006)				
$\ln CO^{mixa}$					− 0.007**	− 0.071***		
					(− 0.003)	(− 0.011)		
CO^{aint}							− 0.000 09***	− 0.000 04
							(0.000)	(0.000)
Invest	− 0.093***	− 0.027**	− 0.143***	− 0.011	− 0.136***	− 0.019	− 0.133***	− 0.124***
	(− 0.031)	(0.014)	(− 0.040)	(0.012)	(− 0.023)	(0.012)	(− 0.041)	(0.043)
Disaster	0.005	0.023**	0.034	0.016	0.060**	0.01	0.065**	0.087***
	(− 0.029)	(0.011)	(− 0.028)	(0.011)	(− 0.025)	(0.011)	(− 0.031)	(0.03)
EDU	− 0.045***	− 0.015*	− 0.041***	− 0.013	− 0.047***	− 0.014	− 0.053***	− 0.056***
	(− 0.009)	(0.008)	(− 0.01)	(0.008)	(− 0.004)	(0.008)	(− 0.009)	(0.018)
GOV	− 0.226	0.007	− 0.584***	− 0.013	− 0.604***	0.069	− 0.605**	− 0.530***
	(− 0.256)	(0.123)	(− 0.207)	(0.120)	(− 0.107)	(0.123)	(− 0.250)	(0.202)
Security	− 0.864*	0.252	− 1.273**	0.340	− 0.934***	− 0.091	− 0.848*	− 0.713
	(− 0.448)	(0.260)	(− 0.540)	(0.241)	(− 0.239)	(0.212)	(− 0.460)	(0.509)
FINA	0.000	− 0.002	0.014	− 0.002	0.011	− 0.004	0.010	0.028
	(− 0.014)	(0.009)	(− 0.014)	(0.008)	(− 0.008)	(0.008)	(− 0.015)	(0.024)
Constant	0.791***	0.543***	0.795***	0.542***	0.818***	0.508***	0.862***	0.856***
	(− 0.079)	(0.058)	(− 0.073)	(0.057)	(− 0.032)	(0.054)	(− 0.076)	(0.117)
F test		25.59***		16.82***		30.50***		14.98***
Hausman test		13.048*		26.61***		88.43***		7.423
Province fixed effects	NO	Yes	NO	Yes	NO	Yes	NO	Yes

Table 4 (continued)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	POLS	2FE	POLS	2FE	POLS	2FE	POLS	2FE
Year fixed effects	NO	Yes	NO	Yes	NO	Yes	NO	Yes
R-squared	0.593	0.911	0.543	0.915	0.496	0.920	0.515	0.783
Observations	403	403	403	403	403	403	403	403

Figures in parenthesis are robust standard error. ***, **, and * indicate significance at the 1%, 5%, and 10% levels

tourism has a significantly positive effect on rural poverty reduction. The convergence of agriculture and processing industry ($\ln CO^{apos}$) also has a significantly positive effect on poverty reduction at the 1% level in Column (4). Similarly, the convergence of planting and breeding industry ($\ln CO^{mixa}$) also has a significantly positive effect on poverty reduction at the 1% level in Column (6). However, the estimated coefficient of CO^{aint} is –0.000 04 and is not statistically significant. A possible explanation is that the convergence of agriculture and the internet industry is in the initial development stage. Although some studies have proved its poverty reduction effect in a specific year in some areas in China (Peng et al., 2021), based on provincial panel data of China its poverty reduction effect cannot pass the significance test.

4.3 Robust check

To ensure the consistency and credibility of the estimated results, we conduct robustness tests by changing the estimation method and replacing the dependent variable.

Firstly, we apply the system generalized method of moments (SYS-GMM) to re-estimate the effects of the rural industry convergence on rural poverty. SYS-GMM can eliminate the potential for endogeneity bias and produce a more precise and reliable outcome when the number of cross-sections ($N=31$) is larger than the number of time series ($T=13$).

In addition to using one and two lags of poverty as instrumental variables, we also construct new instrumental variables (IV of CO^{type}) for each rural industry convergence variable. A suitable exogenous instrumental variable needs to meet two conditions. It must have a strong correlation with the endogenous variable and is uncorrelated with the random error term. China's 31 provinces are closely linked geographically. The development of rural industry convergence in neighboring areas is related to the rural industry convergence of the province but has nothing to do with the rural poverty in the province. Therefore, this article takes the average value of neighboring provinces' convergence development as the instrumental variable of the convergence variables of the province.

The estimation results of SYS-GMM are illustrated in Table 5. The SYS-GMM has passed the first-order and second-order autocorrelation tests of the disturbance term, because the P value of AR (1) is significant, and the *P* value of AR (2) is not significant. The results of the Hansen test show that the null hypothesis that "all instrumental variables are valid" cannot be rejected. The above test shows that the regression results of SYS-GMM are robust and credible.

Table 5 shows that poverty in the former period has a strong effect on poverty in the current period. If positive actions are not taken to stop or slow down poverty, poverty is likely to continue. Except for CO^{aint}, all the core explanatory variables are significantly negative. In addition, the significance of CO^{atou} has also been strengthened. This shows that most types of rural industry convergence can significantly reduce rural poverty, which strongly supports the robustness of the previous findings.

Then, we replace the dependent variable with the income of rural residents (INC). The reason is that income is a typical indicator of economic poverty. The data of *INC* are collected from *China Statistical Yearbook* (2008–2020). As usual, we log transform the data of this variable (lnINC). As shown in Table 6, the estimated coefficient ofCO^{atou}, $\ln CO^{apos}$, $\ln CO^{mixa}$ and CO^{aint} is all positive. $\ln CO^{apos}$ and $\ln CO^{mixa}$ pass the statistical significance test in columns (2) and (3) at the 1% level. CO^{atou} and CO^{aint} fail the significance test. Most of the regression results are completely consistent with the previous findings. Only the significance of CO^{atou} is different from before. The possible reason is that the convergence of agriculture

Table 5 Robust check: Alternative the estimation method

Variables	(1) SYS-GMM	(2) SYS-GMM	(3) SYS-GMM	(4) SYS-GMM
L.pov1	0.634***	0.716***	0.828***	0.807***
	(0.098)	(0.052)	(0.043)	(0.055)
CO^{atou}	− 0.002***			
	(0.001)			
$\ln CO^{apos}$		− 0.015***		
		(0.004)		
$\ln CO^{mixa}$			− 0.01**	
			(0.004)	
CO^{aint}				− 0.000 02
				(0.000)
Invest	− 0.031**	− 0.047**	− 0.034*	− 0.031**
	(0.015)	(0.024)	(0.019)	(0.015)
Disaster	0.013	0.009	0.011	0.016
	(0.016)	(0.019)	(0.020)	(0.014)
EDU	− 0.015**	− 0.003	− 0.0004	− 0.009**
	(0.006)	(0.005)	(0.003)	(0.005)
GOV	− 0.128	− 0.295***	− 0.234***	− 0.161**
	(0.090)	(0.089)	(0.089)	(0.078)
Security	− 0.405*	− 0.725***	− 0.287**	− 0.221**
	(0.212)	(0.247)	(0.121)	(0.110)
FINA	− 0.002	0.003	0.002	0.003
	(0.005)	(0.008)	(0.003)	(0.004)
Constant	0.282***	0.183***	0.0932**	0.157***
	(0.093)	(0.050)	(0.044)	(0.061)
AR(1)	0.001	0.000	0.000	0.000
AR(2)	0.705	0.590	0.821	0.956
Hansen	0.939	0.748	0.684	0.434
Observations	372	372	372	372

Figures in parenthesis are robust standard error. ***, **, and * indicate significance at the 1%, 5%, and 10% levels

and tourism has obvious seasonal characteristics. For example, rural rape blossom viewing projects can only be carried out in spring. Therefore, its income-increasing effect is not very prominent. However, regions with advantages in agricultural tourism resources, especially those with national agricultural tourism demonstration counties, often receive more attention and investment from the government in infrastructure construction including transportation, electricity, sanitation, and communication facilities (Tew & Barbieri, 2012). This reduces the cost of living of the rural poor and improves their capability to leave from poverty.

4.4 Effect mechanism

Next, we will explore the impact mechanism of rural industry convergence on rural poverty reduction. Jan et al. (2010) pointed out that the macro-synergies between

Table 6 Robust check: replace the dependent variable

Variables	lnINC			
	(1)	(2)	(3)	(4)
	2FE	2FE	2FE	2FE
CO^{atou}	0.002			
	(0.001)			
$lnCO^{apos}$		0.101***		
		(0.009)		
$lnCO^{mixa}$			0.226***	
			(0.017)	
CO^{aint}				0.000 5
				(0.000)
Control variables	Yes	Yes	Yes	Yes
F test	29.7***	25.22***	63.32***	14.63***
Hausman test	53.6***	108.4***	268.0***	94.345***
Province fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
R-squared	0.994	0.996	0.996	0.844
Observations	403	403	403	403

Figures in parenthesis are robust standard error. ***, **, and * indicate significance at the 1%, 5%, and 10% levels

agriculture and industry mainly reflect the migration of rural population to cities for employment. Therefore, employment is likely to play an important role as a bridge in the impact of convergence on poverty reduction. The rural industry convergence projects are mainly based on agriculture. The rural residents are familiar with it and are easy to participate in it. In general, there are two main ways for poor households to participate in rural economic activities: self-employment as entrepreneurs or as employees (Gao & Liu, 2020; Haggblade, et al., 2010; Van & Maertens, 2017). This article chooses the number of rural self-employed population (*SE*) and the number of employees in rural companies (*PR*) as mediators, which can inspire us to study more deeply the role of rural industry convergence in reducing poverty. The data of *SE* and *PR* are collected from *China Statistical Yearbook* (2008–2020). To reduce the value and eliminate heteroscedasticity, this article log transforms the data of these two variables.

Because the new business forms formed by rural industry convergence such as agricultural tourism and mixed agriculture do not require too much investment, and most of them are carried out by rural households using family labor for self-employment. So, we mainly test the mediating role of lnSE in the impact of the convergence of agriculture and tourism and the convergence of planting and breeding industry on poverty reduction. The amount of investment required by agricultural product processing enterprises is relatively large, which is often established by entrepreneurs from the city. Farmers benefit by seeking jobs in these enterprises. So, we test the mediating role of *lnPR* in the impact of the convergence of agriculture and processing industry on poverty reduction.

Wen et al. (2004) proposed a three-step method based on the research of Baron and Kenny (1986), and Judd and Kenny (1981). According to the three-step method, this article adds two equations to test the mediation effect.

$$Y_{p,t} = a\mathrm{CO}_{p,t}^{\mathrm{type}} + \sum_{n=1}^{n} \alpha_n X_{n,\mathrm{pt}} + u_p + \mu_t + \varepsilon_{p,t} \tag{2}$$

$$\mathrm{POV}_{p,t} = bY_{p,t} + c\prime\mathrm{CO}_{p,t}^{\mathrm{type}} + \sum_{n=1}^{n} \alpha_n X_{n,\mathrm{pt}} + u_p + \mu_t + \varepsilon_{p,t} \tag{3}$$

where $Y_{p,t}$ represents the *lnSE* or *lnPR* of province p at time t. $CO_{p,t}^{type}$ stands for the development of the specific type of rural industry convergence. $X_{n,pt}$ is a set of control variables, which is the same as Eq. (1). $a, b,$ and$c\prime$ are the coefficients of our interest.

In the first step, we check the c in Eq. (1). If it is significant, we will continue with the next step. Otherwise, it means that there is no ground for mediation. The regression results in Table 4 report that only the c of CO^{aint} is not significant and its intermediary analysis stop.

In the second step, we check the coefficients a and b in Eqs. (2) and (3). If they are both significant, we will continue with the next step · If at least one of them is not significant, we do the Sobel test to determine whether there is a mediation effect. The regression results in Table 7 report that only the a of $\ln\mathrm{CO}^{\mathrm{apos}}$ is not significant and we must do the Sobel test to judge whether there is mediation effect. Table 8 reports that the estimated value is significant and it passes the Sobel test. These indicate that

Table 7 Regression results of mediation analysis

Variables	lnSE (1) 2FE	POV (2) 2FE	lnPR (3) 2FE	POV (4) 2FE	lnSE (5) 2FE	POV (6) 2FE
lnSE		− 0.011*** (0.003)				− 0.009*** (0.003)
lnPR				− 0.011*** (0.003)		
$\mathrm{CO}^{\mathrm{atou}}$	0.025** (0.012)	− 0.001 0 (0.001)				
$\ln\mathrm{CO}^{\mathrm{apos}}$			0.067 (0.111)	− 0.025*** (0.006)		
$\ln\mathrm{CO}^{\mathrm{mixa}}$					0.436* (0.227)	− 0.067*** (0.010)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
F test	66.87***	26.40***	23.39***	21.13***	62.18***	28.94***
Hausman test	78.36***	20.77***	32.89***	40.86***	25.13***	57.95***
Province fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.915	0.913	0.907	0.918	0.915	0.922
Observations	403	403	403	403	403	403

Figures in parenthesis are robust standard error. ***, **, and * indicate significance at the 1%, 5%, and 10% levels

Table 8 Sobel test and Bootstrap mediation test

Dependent variable	Independent variable	Mediator Variable	Sobel test	Bootstrap mediation test with 95% confidence interval	
				Indirect effects	Direct effects
POV	CO^{atou}	lnSE	− 0.0007***	(− 0.00133, − 0.00002)	(− 0.00517, − 0.00295)
	$lnCO^{apos}$	lnPR	− 0.0102***	(− 0.01409, − 0.00639)	(− 0.01028, 0.00111)
	$lnCO^{mixa}$	lnSE	− 0.0115***	(− 0.01588, − 0.00714)	(− 0.00265, 0.01188)

the convergence of agriculture and processing industry reduces rural poverty through increasing the number of employees in rural enterprises.

In the third step, we check the coefficient c'. If c' is significant, it means that the mediation effect is significant. If c' is not significant, it means that the complete mediation effect is significant. We find the c' of CO^{atou} is not significant, which indicates that the convergence of agriculture and tourism reduces rural poverty through increasing the number of rural self-employed population, and this is a completely intermediary process. The c' of $lnCO^{mixa}$ is significant, which indicates that the convergence of planting and breeding industry also reduces rural poverty through increasing the number of rural self-employed population.

In order to ensure the robustness of the conclusion of mediation analysis, we also do the Bootstrap mediation test. Table 8 reports that all the 95% confidence interval for indirect effects do not include zero, indicating that there are mediation effects. Only in the first row in Table 8, the 95% confidence interval of direct effects does not include zero, indicating that there is a completely mediation effect. The results of Bootstrap mediation test are consistent with the previous analysis. The conclusions of our intermediary analysis are robust. Rural local employment is the most important bridge for rural industry convergence to play a role in rural poverty reduction. Different types of convergence provide different employment opportunities, which help rural people out of poverty.

4.5 Heterogeneous analysis

In order to explore the heterogeneous effects of convergence on poverty reduction, we do heterogeneous test at different periods and different areas. From Table 1, we can see that the number of policies for rural industry convergence has increased significantly after 2015. Therefore, we use 2015 as the dividing line to explore the difference in the poverty reduction effects of the two periods of "2007–2014" and "2015–2019." The regression results of Eq. (1) are shown in Table 9. We find that the poverty reduction effect of the convergence of agriculture and tourism (CO^{atou}) becomes more significant after 2015. The possible reason is that agritourism is a relatively new business format in China, which has gradually matured in the later stage and exerted its poverty reduction effect. In contrast, the poverty reduction effect of the convergence of agriculture and processing industry ($lnCO^{apro}$) became insignificant after 2015, indicating that the effect tends to decline. This phenomenon should be taken seriously by the Chinese government. One possible reason is the uncertain external trade environment in recent years, which has affected the

Table 9 Heterogeneous analysis of the periods 2007–2014 and 2015–2019

Variables	2007–2014 2FE	2015–2019 2FE	2007–2014 2FE	2015–2019 2FE	2007–2014 2FE	2015–2019 2FE	2007–2014 2FE	2015–2019 2FE
CO^{atou}	− 0.001	− 0.004**						
	(0.001)	(0.002)						
$lnCO^{apro}$			− 0.042***	− 0.003				
			(0.01)	(0.006)				
$lnCO^{mixa}$					− 0.070***	− 0.042**		
					(0.024)	(0.019)		
CO^{aint}							0.0003	− 0.00001
							(0.000)	(0.000)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F test	22.26***	29.77***	21.95***	20.36***	24.66***	26.16***	16.33***	25.91***
Hausman test	6.73	19.33***	37.86***	17.30**	60.08***	25.93***	5.04	2.75
Province fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.907	0.941	0.914	0.935	0.912	0.937	0.907	0.936
Observations	248	155	248	155	248	155	248	155

Figures in parenthesis are robust standard error. ***, **, and * indicate significance at the 1%, 5%, and 10% levels

performance of agricultural products processing enterprises and thus reduced this impact. Table 9 shows that the convergence of planting and breeding industry ($\ln CO^{mixa}$) always has significant poverty reduction effects, which is worth continuing to promote. The estimated coefficient of CO^{aint} was positive before 2015 and became negative after 2015. This means its poverty reduction effect gradually emerged in the later stage, although its coefficient was not significant from a statistical point of view. This may be due to the late start of agricultural e-commerce. With the relevant training provided by the government, rural residents have gradually become familiar with e-commerce platforms such as Taobao, and master e-commerce sales skills in recent years. So, the poverty reduction effect is gradually emerging.

Then, we estimate the poverty reduction impact of rural industry convergence in different regions. The western, central, and eastern regions of China contain 12, 8, and 11 provincial administrative regions, respectively. Their geographical environment is very different. The eastern part of China is coastal, the central part is flat, and the western part is mountainous and inland.

After China's provincial panel data are divided into three groups, the sub-regional data become long panel data. The number of cross sections ($N=12$, 8 or 11) is less than the number of time series ($T=13$). To eliminate the possible heteroscedasticity between groups and the correlation between groups at the same time, we use the panel-corrected standard error (PCSE) estimator to get a more robust estimation result.

The regression results are shown in Table 10. The estimated coefficient of CO^{atou}, $\ln CO^{mixa}$ and CO^{aint} is all negative and passes the statistical significance test at the 1% level in columns (1), (7) and (10), indicating the convergence of agriculture and tourism, the convergence of planting and breeding industry and the convergence of agriculture and internet industry have significantly reduced rural poverty in western of China. The estimated coefficient of $\ln CO^{apos}$ is negative and pass the statistical significance test at the 5% level in columns (5). It means the convergence of agriculture and processing industry has significantly reduced rural poverty in central of China.

Rural industry convergence has the greatest impact on the western region. The possible reason is that the western region is suitable for the development of rural industry convergence. More importantly, the poor people are in great need of local jobs brought about by convergence. Because before that, they were often forced to leave their hometowns and family to find jobs in economically developed cities in the central and eastern regions. The convergence of agriculture and processing industry has played a major role in rural poverty reduction in central China owing to the relatively flat terrain in the central region. Agricultural product processing companies are more suitable for building factories. In addition, the central region is China's main grain producing area, and it is more suitable to drive the rural poor to out of poverty by fully integrating and linking agriculture and processing industries.

5 Discussion

Existing research believes that although the development of agriculture is very beneficial to poverty reduction, the synergies between agriculture and other sectors are also the important rural development strategy to alleviate rural poverty (Kay, 2009; Shan et al., 2017). This article provides evidence for this view. After several major land system reforms and agricultural technology revolution, China's agriculture has developed rapidly. By the end of

Table 10 Heterogeneous analysis in different regions of China

Variables	(1) West PCSE	(2) Central PCSE	(3) East PCSE	(4) West PCSE	(5) Central PCSE	(6) East PCSE	(7) West PCSE	(8) Central PCSE	(9) East PCSE	(10) West PCSE	(11) Central PCSE	(12) East PCSE
CO^{atou}	− 0.002***	− 0.002	− 0.000 1									
	(0.001)	(0.002)	(0.001)									
$lnCO^{apro}$				− 0.012	− 0.019**	− 0.001						
				(0.008)	(0.009)	(0.007)						
$lnCO^{mixa}$							− 0.052***	0.005	− 0.034			
							(0.016)	(0.019)	(0.021)			
CO^{aint}										− 0.002***	− 0.002	− 0.000 1
										(0.001)	(0.002)	(0.001)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.904	0.891	0.925	0.904	0.898	0.925	0.908	0.890	0.928	0.904	0.891	0.925
Wald	203 27***	3906***	178102****	62415***	3532***	216999***	8471***	3127***	351517***	20327***	3906***	178102***
Observations	156	104	143	156	104	143	156	104	143	156	104	143

Figures in parenthesis are robust standard error. ***, **, and * indicate significance at the 1%, 5%, and 10% levels

2000, the food and clothing problem of most of the population had been solved. However, the income of farmers is low. Many young, educated rural laborers migrate to urban areas to increase their income and welfare (Van der Ploeg & Jingzhong, 2010). While other rural population who remain in the countryside find it difficult to escape poverty. In the past ten years, the Chinese government has adopted industry convergence as the latest rural development strategy to revitalize the rural economy and give rural residents opportunities to increase income. Rural industry convergence is a creative path to achieve synergy between agriculture and related sectors. This article quantitatively analyzes its poverty reduction effect. Based on Chinese provincial panel data from 2007 to 2019, this article finds that rural industry convergence between agriculture and related sectors has positive effects on rural poverty reduction. Rural local employment has played a key role as a bridge. Rural industry convergence promotes the development of various types of industries based on agriculture in rural areas. It eliminates the dual economic structure of urban and rural areas and ensures rural residents can have employment opportunities without leaving their hometowns to cities. For example, many rural Chinese women who always stay in the countryside to take care of the elderly and children have obtained more income channels from convergence. Multiple job holdings help them escape poverty. The poverty reduction effect of rural industry convergence is more significant in the western China. Because employment is more important to the poor in western rural areas. China's western economy is relatively backward, and there are few job opportunities. In the past, the local population had to travel long distances to the central and eastern regions to increase income. Local employment from rural industry convergence can greatly reduce transportation costs and the high cost of living in the cities. Moreover, it will not cause geographic separation between family members. These have greatly increased the welfare of the rural residents.

In addition, previous studies mainly focused on the convergence phenomenon of the information and communication industry from the perspective of the enterprise perspective response to future opportunities and challenges (Bröring, 2010; Curran et al., 2010; Duysters & Hagedoorn, 1998). Little attention has been paid to the phenomenon of rural industry convergence based on agriculture. Except for the research on the convergence of agriculture and tourism based on cases (Shen et al., 2019; Chen et al., 2020), other types are rarely involved. This article divides the rural industry convergence into four categories according to their characteristics and quantitatively compares their poverty reduction effects. The empirical results show that the poverty reduction effects of each type of convergence are different in different periods and regions. When rural industry convergence is used as a rural development strategy, the government must fully consider the environment of industrial development, and the characteristics of regional resource endowments (Wang et al., 2018). Like the views of other scholars, policymakers need to take active measures to ensure rural economic growth that benefits the poor. (Angeles et al., 2021; Haggblade et al., 2010). The new business formats generated by convergence require the villagers to add a lot of new knowledge. It is very necessary for the government or enterprises to provide targeted training. The convergence of agriculture and processing industry can provide a large number of stable jobs to nearby villagers, but its poverty reduction effect has been affected by world trade frictions in recent years. Therefore, creating a good trade environment is an important responsibility of the government. From a regional perspective, despite the western China is relatively backward in economic development, it is far away from industrial pollution. Not only the scenery is beautiful, but also the agricultural products are rich. The comparative advantages of the western region enable the healthy development of most types of rural industry convergence, so the poverty reduction effect in the western region is very significant. The endowment advantages of flat terrain and the main agricultural production areas make the poverty reduction effect of the convergence of agriculture and processing industry in central China very significant.

6 Conclusions and implications

This paper quantitatively analyzes the effect of industry convergence between agriculture and related sectors on rural poverty based on China's provincial panel data. The main findings can be summarized as follows: (1) The convergence of agriculture and tourism (ATOU), the convergence of agriculture and processing industry (APOS), the convergence of planting and breeding industry (MIXA) have positive and significant effects on rural poverty reduction. The convergence of agriculture and the internet industry (AINT) has a positive effect on poverty reduction, but it fails the statistical significance test. (2) Rural Local employment has played an important role as a bridge in the impact of rural industry convergence on poverty reduction. ATOU and MIXA mainly reduce rural poverty by increasing the number of rural self-employed population. APOS alleviates rural poverty by increasing the number of employees in companies, which means APOS provides more jobs. (3) Based on the heterogeneous analysis of the periods, we find that the poverty reduction effects of ATOU and AINT improved in the later period. MIXA's poverty reduction effect has always been very significant. Possibly affected by international trade frictions in recent years, the effect of APOS becomes insignificant in the later period. (4) Rural industry convergence has the greatest impact on rural poverty in the western region by reason that ATOU, MIXA and AINT all have a significant poverty reduction impact. APOS only has a significant impact on poverty alleviation in the central China.

Based on the above conclusions, we propose the following policy implications: (1) Rural industry convergence is a pro-poor rural development strategy. Most types of convergence play positive roles in poverty alleviation. The government should support the development of rural industry convergence. As we all know, China has eliminated absolute poverty by the end of 2020 and has made a great contribution to global poverty reduction. China's practical experience in rural areas can inspire other countries in the world that want to develop rural economies and alleviate rural poverty. In addition to promoting the development of agriculture, they should also support the convergence of agriculture and related sectors to further reduce rural poverty. (2) Rural local employment is an important factor in poverty reduction in rural areas. While the government is guiding the development of rural industry convergence through policies, the government should provide various assistance such as training for villagers to participate in it. By increasing the probability of villagers starting their own businesses or obtaining employment opportunities, the effect of poverty alleviation can be enhanced. (3) The government must fully consider the endowment advantages of different rural areas and choose the appropriate type of rural industry convergence to support. For example, in rural areas with superior agricultural scenery and close to cities, the convergence of agriculture and tourism should be supported. In villages with the advantages of famous and high-quality agricultural products, the convergence of agriculture and the internet industry should be supported to help farmers connect with external markets.

This article uses China as an example to quantitatively verify the rural poverty reduction effect of agriculture and other sectors at a macro level. However, whether this conclusion is universal in the world still needs data from more countries to verify. In the next step, we will try to collect data from more countries to explore the relationship between industry convergence and poverty reduction.

7 Data availability statement

The data are available upon reasonable request from readers.

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Declarations

Conflict of interest The authors declare no conflict of interest.

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