Does off-farm employment affect farmers’ adoption of green control techniques?

RESEARCH ARTICLE

Lili Yu\textsuperscript{a}, Yaqi Wang\textsuperscript{b}, Hongling Xie\textsuperscript{b}, Xue Yao\textsuperscript{c} and Bei Liu\textsuperscript{d,\textsuperscript{\textdagger}}

\textsuperscript{a}Associate Professor, \textsuperscript{b}Student, College of Economics, Qufu Normal University, Yantai Road 80, Rizhao, Shandong, P.R. China

\textsuperscript{c}Ph.D, School of Economics & Management, Beijing Forestry University, Qinghua East Road 35, Haidian District, 100083 Beijing, P.R. China

\textsuperscript{d}Ph.D, Institute of Agricultural Economics and Development, Chinese Academy of Agricultural Sciences, Zhongguancun South Street 12, Haidian District, 100081 Beijing, China

Abstract

Actively encouraging farmers to adopt green control techniques (GCT) is an important measure for achieving sustainable agricultural development and ensuring global food security. Based on microsurvey data covering 912 households in Henan and Shandong Provinces, this paper uses a binary probit model to explore the effect of off-farm employment on the adoption behavior of farmers’ GCT and the mechanism of the effect. The study finds that off-farm employment has a capacity accumulation (CAP) effect and a crowding-out (CROWD) effect on farmers’ GCT adoption behavior. Additionally, the CROWD effect generally exceeds the CAP effect, making off-farm employment unfavorable for farmers’ adoption of GCT. Further analysis finds that off-farm employment has a positive effect on the adoption of GCT by farmers based on agricultural income, and as the distance from off-farm employment increases, the positive effect is greater. In contrast, off-farm employment has a negative effect on rural households whose main income is nonagricultural income, and with the increase in the distance from off-farm employment, its negative effect gradually increases. On this basis, to promote green prevention and control techniques for diseases and insect pests, we should focus on farmers whose main income is agricultural, enhance their CAP effect, and guide farmers whose main income is nonagricultural to transfer out of their land. While enriching research on GCT, this paper also provides an empirical basis and policy reference for how to better promote GCT during the period of rapid development of off-farm employment.

Keywords: capacity accumulation effect, crowding-out effect, degree of off-farm employment, distance from off-farm employment, green control techniques

JEL-codes: Q12; Q16

\textsuperscript{\textdagger} Corresponding author: liubeiyi23@163.com
1. Introduction

The use of chemical pesticides has made a great contribution to solving the problem of global food security. However, the long-term large and inefficient use of chemical pesticides has also led to a series of negative effects, such as increased agricultural production costs, frequent agricultural product quality and safety incidents, and reduced biodiversity (Khan et al., 2021). To address these effects, the United States, Denmark, Japan and other developed countries have taken the lead in launching integrated pest management (IPM) programs, obtaining good results in the control of chemical pesticides, research and development, and the promotion and application of green plant protection techniques.

China is a major producer and consumer of agricultural products worldwide. The quality and safety of agricultural products are not only related to the health of domestic consumers but also affect the quality of agricultural products worldwide to some extent. For a long period of time, due to the need to increase production and value, farmers have arbitrarily increased the amount and frequency of chemical pesticide use and shortened the interval, which has had an increasingly serious negative impact on the quality and safety of China’s agricultural products, the safety of the ecological environment, and the safety of agricultural production. Therefore, the Chinese government is committed to promoting the Chinese practice of IPM–green control techniques (GCT). GCT has become an effective way to realize a reduction in and substitution of chemical pesticides and the sustainable management of pests and diseases due to their excellent technical attributes, such as resource savings, environmental friendliness, and human and animal safety. Since the concept of “public plant protection and green plant protection” was first proposed at the National Plant Protection Conference in 2006, the central government and local governments at all levels have vigorously promoted the implementation of GCT by strengthening organizational support, policy support, scientific and technological support, and publicity guidance. However, in reality, farmers’ GCT adoption rate is still low, and the coverage rate of the green prevention and control of major crop diseases and insect pests is only 27.2% (Niu et al., 2022). In 2022, the Ministry of Agriculture and Rural Affairs formulated the “Action Plan for Healthy Chemical Pesticides by 2025”, proposing the goal of “striving to achieve a coverage rate of green prevention and control techniques for major crop diseases and insect pests of more than 55%”. How to quickly and effectively promote the application of China’s green prevention and control techniques is still a key issue of concern for the academic community.

At the same time, due to the seasonal characteristics of agricultural production, to maximize income, farmers have begun to look for new employment methods, and off-farm employment has risen rapidly in China. According to the “2021 Migrant Workers Monitoring Survey Report” by the National Bureau of Statistics, China’s rural migrant labor force reached 171 million in 2021, an increase of 2.13 million or 1.3% over the previous year. Off-farm employment has gradually become an important way of production and life for rural residents. Not only has off-farm employment broken through the single social structure of rural residents as agricultural producers, but also accompanied by the continuous expansion of the scale of off-farm employment, the production mode, income mode and investment behavior of rural households have also undergone profound changes.

Studies have confirmed that off-farm employment improves household well-being (Ma et al., 2021, 2022a; Rajkhowa and Qaim, 2022), improves the efficiency of production technology or equipment use (Ma et al., 2022b; Zheng et al., 2021), enhances land use efficiency (Zhao et al., 2021; Zhou et al., 2020) and has other positive significance. Therefore, how does off-farm employment affect farmers’ GCT adoption behavior? Existing research suggests that the factors affecting farmers’ GCT adoption include mainly household characteristics (Yu et al., 2021), the resource endowment (Gao et al., 2019b), human cognitive characteristics (Gao et al., 2017), technical characteristics (Zhang et al., 2023), and subjective normative factors (Niu et al., 2022). There are few studies based on the perspective of off-farm employment.

Theoretically, off-farm employment will have both positive and negative impacts on the farmers’ adoption of GCT. On the one hand, off-farm employment can bring nonagricultural income to farmers, increase the
overall income of families, and enhance the ability of farmers to pay for technology and resist risks (Barasa et al., 2023). At the same time, off-farm employment will also broaden farmers’ information acquisition channels and improve their technical awareness and awareness of agricultural product quality and safety (Addai et al., 2023), thereby promoting farmers’ technology adoption. This paper calls this phenomenon the capacity accumulation (CAP) effect. On the other hand, off-farm employment will transfer part of the family labor force to off-farm employment, and there will be a shortage of labor and shortened working hours for farmers’ agricultural production and operations (Aikaeli et al., 2022), which is not conducive to farmers’ technology adoption. This paper calls it the crowding-out (CROWD) effect. Therefore, the direction of the impact of off-farm employment on farmers’ GCT adoption behavior is uncertain, and the relationship between the two is an empirical issue that needs to be resolved.

In addition, the impact of off-farm employment on farmers’ GCT adoption behavior is affected by differences in the degree of off-farm employment and the distance from off-farm employment. First, the proportion of nonagricultural production time to the total labor time or the proportion of nonagricultural income to the total household income of rural households is different, and the degree of off-farm employment is also different (Lu et al., 2022; Xu, 2018). Farmers with a low degree of off-farm employment have a high degree of dependence on and attention to agriculture and will make full use of off-farm employment to alleviate the information constraints, capital constraints, and risk constraints of agricultural production (Saini et al., 2022). Off-farm employment may exert a greater CAP effect on them. Farmers with a high degree of off-farm employment will marginalize and sideline agriculture, resulting in a reduction in the input of production factors such as time, capital, and labor for agricultural production (Lang et al., 2022), and off-farm employment may exert a greater CROWD effect on them. Second, farmers may have off-farm employment in their own township, or they may have off-farm employment across townships or counties. The location of off-farm employment is different, as is the distance from off-farm employment. For farmers who are close to off-farm employment, returning home to live and work is convenient. Such farmers can flexibly arrange their off-farm employment time and take into account both agricultural and nonagricultural work, and they tend to use off-farm employment to support agricultural production. Off-farm employment may exert a greater CAP effect on them (Endiris et al., 2021). On the other hand, farmers who have a long distance from off-farm employment find it inconvenient to return home to live and work, and they face problems such as poor circulation of agricultural information and high costs of returning home (Ahmad et al., 2020). Off-farm employment may exert a greater CROWD effect on them.

Accordingly, to compensate for the shortcomings of existing research noted above, this article analyzes in depth the following questions: Does off-farm employment have an impact on farmers’ GCT adoption? Does off-farm employment have a CAP effect and a CROWD effect on farmers’ GCT adoption behavior? Are there any heterogeneities in the issues above due to the degree of off-farm employment and the distance from off-farm employment?

Specifically, based on microsurvey data covering 912 households in Henan and Shandong provinces, this paper uses a binary probit model to explore the impact of off-farm employment on farmers’ GCT adoption behavior. Then, it divides the CAP effect and CROWD effect of off-farm employment to explore the path of the impact of off-farm employment on farmers’ GCT adoption behavior. On this basis, based on the differences in the degree of and distance from off-farm employment, this paper explores the heterogeneous impact of off-farm employment on farmers’ GCT adoption behavior under different degrees and distances.

Compared with the literature, the contributions of this paper are mainly reflected in the following aspects: The first contribution is in terms of the research perspective. Based on the perspective of off-farm employment, this paper explores the impact of off-farm employment on farmers’ GCT adoption behavior. Doing so not only expands the boundary of research on the factors affecting farmers’ GCT adoption behavior but also has important implications for the continuous promotion of GCT popularization.
The second contribution is in terms of the mechanism. This paper verifies the CAP effect and CROWD effect of off-farm employment and comprehensively evaluates their role in farmers’ GCT adoption behavior, deepening the literature.

The third contribution is in terms of the content of research. This paper not only explores the effect of off-farm employment on farmers’ GCT adoption behavior and the mechanism of this effect but also explores the heterogeneous impact of different off-farm employment levels and off-farm employment distances on farmers’ GCT adoption behavior. Doing so not only deepens the content of research but also presents new empirical evidence, which provides a reference for the formulation of GCT promotion policies.

The rest of the paper is structured as follows: The second section develops the theory and hypotheses. The third section covers the materials and methods, including the data sources, variable selection, descriptive statistics and model setting. The fourth section presents the results and discussion. The fifth sections conducts the mechanism test. The sixth section performs the heterogeneity analysis. The seventh section draws the conclusions and policy recommendations.

2. Literature review and hypotheses

2.1. The overall effect of off-farm employment on the GCT adoption behavior of farmers

According to the theory of farmers’ behavioral choice, farmers’ GCT adoption refers to their behavior of deciding whether to accept and actually use production techniques to maximize their utility on the basis of considering their own factor endowment and combining it with actual agricultural development. The GCT adoption behavior of farmers is subject to the factor endowment of farmers. Factor endowment theory believes that the cultivation and function of farm household factor endowments are closely related to their off-farm employment status (Li et al., 2022).

On the one hand, as a way to accumulate farmers’ factor endowment, off-farm employment promotes farmers’ GCT adoption through the CAP effect. Specifically, the first way is through access to information. Information access is an important factor affecting farmers’ GCT adoption (Baiyegunhi et al., 2018). Off-farm employment is conducive to broadening farmers’ information acquisition channels and improving their information acquisition capabilities (Alemarychu et al., 2018), thereby enhancing farmers’ perceived usefulness and ease of use of GCT and having a positive impact on farmers’ GCT adoption behavior. The second way is through access to funds. Abundant funds allow farmers to pay for technology input costs, and they encourage farmers to adopt new technologies (Araral et al., 2020). The nonagricultural income obtained from off-farm employment can not only ease farmers’ financial constraints in the GCT adoption process but also diversify families’ income sources and enhance their risk resistance (Huang et al., 2022), thus promoting GCT adoption. The third way is through the accumulation of social capital. Social capital can effectively compensate for the shortage of government technology promotion services and reduce technical learning and use costs (Gao et al., 2019b). In addition, off-farm employment can expand farmers’ communication scope, enhance their social circle, and promote the accumulation of social capital (Chi, 2022), thus improving their enthusiasm for GCT adoption.

On the other hand, although off-farm employment has shown absolute advantages in promoting farmers’ income and increasing social capital, it can greatly improve the factor endowment and thus break through the constraints that act as boundaries of farmers’ GCT adoption as much as possible. However, off-farm employment will also have a CROWD effect that causes labor transfer and aggravates the loss of the agricultural labor force, thus inhibiting farmers’ GCT adoption. The main reason is that off-farm employment is the result of farm households’ allocation of household resource endowments between agricultural and nonagricultural sectors with the goal of maximizing household income (Stark and Bloom, 1985). First, from the perspective of the gender structure of farmers engaged in agriculture, in general, high income from
off-farm employment will attract a large number of young or male farmers to engage in off-farm employment, while most of the labor force engaged in agricultural production among family members will be elderly people or women (Egger et al., 2021). The overall quality of the agricultural labor force will be reduced, which is not conducive to farmers’ GCT adoption. Second, from the perspective of the agricultural labor requirements for learning and using GCT, GCT is a complex technology set and not only require high labor input but also have strict operational requirements. Thus, more agricultural labor time must be consumed (Kabir and Rainis, 2015; Pereira et al., 2017). Under the condition of a constant family time endowment, the increase in the opportunity cost of farming brought by off-farm employment will lead farmers to compress their agricultural production inputs, transfer their agricultural labor, and only invest in the labor and labor time necessary to maintain basic agricultural production (Araujo et al., 2018; Jin et al., 2022), which is also unfavorable for farmers’ GCT adoption.

The analysis above shows that off-farm employment has multiple influences on farmers’ GCT adoption behavior, and the final impact is related to the dominance of the CAP effect and the CROWD effect generated by off-farm employment. If the CAP effect produced by off-farm employment is greater than the CROWD effect, the total effect will promote farmers’ GCT adoption. If the CROWD effect produced by off-farm employment is greater than the CAP effect, the total effect will inhibit farmers’ GCT adoption. On this basis, this paper proposes the following hypothesis:

H1-1: If the CAP effect is dominant, then off-farm employment will have a positive impact on farmers’ GCT adoption behavior.
H1-2: If the CROWD effect is dominant, then off-farm employment will have a negative impact on farmers’ GCT adoption behavior.

2.2. The heterogeneity of the impact of off-farm employment on farmers’ GCT adoption behavior

At this stage, the comparative efficiency of China’s agriculture is low, and high-capacity farmers face higher opportunity costs in agricultural production. Occupational choices make high-capacity farmers mainly focus on nonagricultural income and even withdraw from agricultural production (Schmidt et al., 2017). Therefore, for rural households with nonagricultural income as the main source, their labor quality is relatively high, and they often choose technical or mental industries (Zhang et al., 2021), which are characterized by long nonagricultural hours, inflexible time and high wage rates, resulting in squeezed agricultural time. At the same time, in view of the disadvantages of the low return rate, high uncertainty and long cycle of agricultural investment, farmers with off-farm employment who have marginalized and sidelined agriculture will invest funds in nonagricultural sectors. The CROWD effect of off-farm employment is obvious. In addition, the shift in the focus of employment leads farmers who mainly rely on nonagricultural income to oftentimes value only the security function of agricultural land and often choose extensive agricultural management (Deng et al., 2018). The CAP effect of off-farm employment is not obvious. Therefore, the CROWD effect of off-farm employment on rural households with nonagricultural income is greater than the CAP effect, which hinders GCT adoption.

For rural households whose main income is agricultural, on the one hand, while off-farm employment can enhance the information acquisition ability of farmers, the nonagricultural income brought by off-farm employment can also alleviate the financial constraints of farmers and improve their ability to invest in agriculture, which has an obvious CAP effect (Dzanku, 2018). On the other hand, agricultural production has strong seasonality, and off-farm employment is more likely to fill slack time and achieve full employment (Xu et al., 2019). Therefore, farmers whose main income is from agriculture often choose purely physical industries with lower requirements, which are characterized by unstable jobs and relatively low wage rates. Although off-farm employment occupies part of the agricultural production time of farmers, they still rely on agricultural income as their main source of income, and the CROWD effect of off-farm employment is not obvious. Therefore, the CAP effect of off-farm employment is greater than the CROWD effect on...
farmers whose income is mainly from agriculture, thus promoting their GCT adoption. Therefore, this paper proposes the following hypothesis:

H2: The effect of off-farm employment on GCT adoption is positive for farmers whose income is mainly agricultural income and negative for farmers whose income is mainly nonagricultural income.

In addition to the characteristics of farmers themselves, changes in the distance from off-farm employment have an impact on the process of agricultural technology adoption. In general, the root cause of the long-distance off-farm employment of rural households is that the economic development level of the place of employment is high, there are many employment opportunities, and higher wage income can be obtained.\(^1\) For farmers with off-farm employment whose main income is from agriculture, an increase in the distance from off-farm employment will not only broaden their horizons and give them the courage to try new things but also exercise their ability to acquire, learn and master new technologies, which has a significant impact. The CAP effect is more conducive to farmers’ GCT adoption. For farmers with off-farm farmers whose main source of nonagricultural income is off-farm employment, long-distance off-farm employment provides conditions for them to choose jobs with more stability and higher wages. Their quality of life is improved, which will lead to nonagricultural income. Most farmers ignore the basic status of agricultural income, neglect land management, and even leave their land unused or abandoned, or they even transfer out their original land. At the same time, as the distance from off-farm employment increases, the commuting time and commuting costs of farmers increase, and the opportunity cost of farming increases accordingly, resulting in a lag in farmers’ attention to new techniques, having a significant CROWD effect, which is not conducive to farmers’ GCT adoption behavior. Therefore, this paper proposes the following hypothesis:

H3: With an increase in the distance from off-farm employment, the positive effect of off-farm employment on the GCT adoption behavior of farmers whose main income is from agriculture increases, and the negative effect of off-farm employment on the GCT adoption behavior of farmers whose main income is from nonagricultural income will also increase greatly.

3. Materials and methods

3.1. Data sources

Henan and Shandong Provinces were selected for this field study for several reasons. First, Henan and Shandong are major agricultural provinces in China, with agricultural populations of 47.64 million and 39.44 million, respectively, accounting for 49.8% and 39.4% of the total population of their provinces, respectively. The total output values of agriculture, forestry, animal husbandry, related side occupations and fishery in Henan and Shandong account for 6.9 and 8.4% of China’s total output value in these sectors, ranking second and first, respectively.\(^2\) They also rank second and third in grain output among 31 provinces in China.\(^3\) Second, both provinces face serious challenges concerning pest control (Gao et al., 2020). Third, 85.1% of rural households in Henan Province had off-farm employment behavior in 2014, and the number of migrant workers was increasing.\(^4\) Moreover, Shandong Province is experiencing rapid growth and a high

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\(^1\) The 2019 Migrant Workers Monitoring Survey Report shows that the average monthly income of farmers with off-farm employment across townships but not across counties and off-farm employment across counties is 4427 yuan, and the average monthly income of farmers with off-farm employment in the township is 3500 yuan. Even though long-distance employment will incur necessary accommodation fees, farmers with off-farm employment still choose long-distance employment to obtain higher wage income.

\(^2\) Source: China Rural Statistical Yearbook-2018, available online at http://navi.cnki.net/KNavi/YearbookDetail?pcode=CYFD&pykm=YMCTJ&hb=


degree of off-farm employment among farmers, and the province has many rural workers, accounting for 25\% of the total population.\(^5\)

The survey was conducted in two stages. The first stage was a preliminary investigation. In October 2018, we randomly selected 20 households in each province to conduct household interviews. Based on the results of this preliminary investigation, the deficiencies in the questionnaire were improved. The second stage was the formal survey. From January to March 2019, the survey was carried out by combining stratified sampling and random sampling. The specific sampling method is as follows. First, all the counties in each province were sorted based on regional GDP and divided into three categories: high, medium, and low. Three counties were randomly selected from each category. Then, three townships were randomly selected from each sampled county, and three villages were randomly selected from each sampled township. Finally, six rural households were randomly selected from each sampled village. Therefore, the sample covered 18 counties, 54 townships, 162 villages and 972 rural households. Considering the farmers’ limited education, on one hand, the questionnaire survey used the method of one-on-one household interviews. The interviewees were the household heads of the sample farmers, and the interviewers were graduate students and senior undergraduate students who were previously trained. On the other hand, the questionnaires used corresponding pictures to enable the interviewees to accurately select the answer items. A total of 972 questionnaires were distributed, and 912 valid questionnaires were finally obtained after excluding those that were missing key information, those that were completed in a nonstandard manner and those with obviously wrong answers. The effective response rate of the questionnaires was 93.83%.

3.2. Variables

**Dependent variable: farmers’ GCT adoption behavior (GCT)**

Considering that GCT is a complex technology set, incorporating the actual popularization of GCT in the research area, we selected insecticidal lamps, color plate trapping, bait traps, insect net control, biological pesticide, the artificial release of natural enemies, disease-resistant varieties, and deep plowing irrigation to eliminate borers. These various GCT subtechniques were displayed to farmers through pictures. If a farmer adopted one or more of these subtechniques, \(GCT\) equals 1 and 0 otherwise.

**Main independent variable: off-farm employment (off-farm)**

To investigate the comprehensive impact of off-farm employment on farmers’ GCT adoption behavior, this paper uses \(off-farm\) to represent the off-farm employment of farmers. If a sample farmers had off-farm employment behavior, \(off-farm\) takes the value of 1 and 0 otherwise.

**Mechanism variables**

(1) Capability accumulation effect (CAP). Based on the theoretical analysis above, to measure the CAP effect, this paper constructs an evaluation index based on three dimensions: the number of information acquisition channels, financial status and social capital. Among these dimensions, information acquisition channels mainly include 5 traditional channels (government departments, television, radio, newspapers and magazines, and relatives and friends) and 5 modern channels (Internet information technology-based computers, WeChat public accounts, agricultural apps and mobile client news, and bus and subway advertisements) (Parmar et al., 2019). Thus, in the question, the results of multiple choices by farmers in the above information channels are selected as the proxy variable of the number of information acquisition channels. Deposits are the most important component of assets (Mao et al., 2019). Thus, we select the current household bank deposit

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amount of farmers in the questionnaire as the proxy variable of financial status. Social networks are the main way to accumulate social capital (Nan and Ouyang, 2020). Thus, in the questionnaire, the total amount of gift money that farmers spend among relatives, neighbors and friends is selected as the proxy variable of social capital. Moreover, we use a weighting method that combines the factor analytic and entropy methods (Gao et al., 2019a) to obtain the index of the CAP effect, which is expressed as CAP.

(2) Crowding-out effect (CROWD). Under the condition of constant household resource endowment, the more family members are engaged in off-farm employment and the longer hours they work, the less labor and time inputs will be used for agricultural production and operation, which indicates a greater crowding-out effect brought by off-farm employment (Deng et al., 2018). Therefore, this paper selects “proportion of nonagricultural labor force in household labor force” and “proportion of nonagricultural employment days in household employment days” as the proxy variables of the crowding-out effect, which is expressed as CROWD.

Control variables

Drawing on relevant research, this paper selects control variables covering four aspects: household head characteristics, resource endowment characteristics, technical characteristics and exogenous characteristics. They are gender (GEN), age (AGE), educational level (EDU), risk preference (RISK), the planting scale (SCA), types of crops (CS), the labor force (LAB), cultivated land fragmentation (FRA), perceived ease of use (PEU), perceived usefulness (PU), cooperative participation (CP), technical training in agriculture (TRA) and the region dummy variable (PRO). Among them, GEN takes the value of 1 for male and 0 for female. RISK is measured by the average (log) of family members’ lottery spending over the past year. AGE, EDU, SCA, CS, LAB and FRA are measured by the actual age of the head of household, years of education, actual arable land area, number of crops planted, actual number of household workers, and number of household arable land plots. For PEU, we asked farmers to use a 5-point Likert scale to score the following items and obtain the average: “I think GCT is easy to operate”, “I can easily master the operation of GCT after training”, and “In the process of using GCT, I can easily get help from technical instructors and others”. For PU, we asked farmers to use a 5-point Likert scale to score the following items and obtain the average: “I think GCT can reduce the use of pesticides”, “I think GCT can increase income”, and “I think GCT is conducive to sustainable agricultural development”. Both CP and TRA take the value of 1 for yes and 0 for no. In addition, for PRO, if the sample farmers are from Henan Province, the value is 1; if the sample farmers are from Shandong Province, the value is 0.

3.3. Descriptive statistics

As shown in Table 1, 238 of the 912 households surveyed in this study (26.1%) had adopted GCT, which is consistent with the low GCT adoption rate in China. In total, 796 farmers were engaged in off-farm employment, accounting for 87.28% of farmers, indicating that off-farm employment behavior has become a common phenomenon in China’s rural areas, which is consistent with reality. Furthermore, among the 796 households with off-farm employment, the households whose agricultural income accounted for more than 50% of the total household income in the current year were set as agricultural income-based households (AOFs), and those whose agricultural income accounted for less than 50% of the total household income in the year were set as nonagricultural income-based households (NOFs). Among them, 524 were classified as NOFs, accounting for 57.46%, indicating that farmers have a high degree of off-farm employment.

In addition, compared with full-time farmers (FFs), a higher proportion of male householders were engaged in off-farm employment and expressed a higher perceived ease of use and perceived usefulness of GCT. AOFs had a larger farmland scale and a higher likelihood of joining cooperatives and receiving technical training than FFs and NOFs. Compared with FFs and AOFs, NOFs were younger and better educated and
<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Farmer GCT adoption behavior (GCT)</strong></td>
<td>yes=1, no=0</td>
<td>0.266 (0.439) 0.190 (0.392) 0.412 (0.492) 0.198 (0.399)</td>
</tr>
<tr>
<td><strong>Off-farm employment (off-farm)</strong></td>
<td>yes=1, no=0</td>
<td>0.873 (0.333) – – –</td>
</tr>
<tr>
<td><strong>Capacity accumulation effect (CAP)</strong></td>
<td>Weighted by the weighting method combining factor analysis and the entropy method</td>
<td>0.664 (0.301) 0.232 (0.384) 0.571 (0.330) 0.809 (0.163)</td>
</tr>
<tr>
<td><strong>Crowding-out effect (CROWD)</strong></td>
<td>non-agricultural labor force as a share of the household labor force</td>
<td>0.490 (0.126) – 0.310 (0.114) 0.670 (0.137)</td>
</tr>
<tr>
<td></td>
<td>non-agricultural employment days as a share of household employment days</td>
<td>0.525 (0.206) – 0.341 (0.201) 0.710 (0.211)</td>
</tr>
<tr>
<td><strong>Gender (GEN)</strong></td>
<td>male=1, female=0</td>
<td>0.556 (0.411) 0.446 (0.454) 0.556 (0.413) 0.667 (0.436)</td>
</tr>
<tr>
<td><strong>Age (AGE)</strong></td>
<td>Actual age of head of household</td>
<td>54.082 (9.881) 60.259 (9.898) 54.272 (9.453) 47.716 (8.401)</td>
</tr>
<tr>
<td><strong>Education level (EDU)</strong></td>
<td>The actual years of education of the head of household</td>
<td>7.083 (2.904) 5.060 (2.500) 7.136 (2.166) 9.052 (2.730)</td>
</tr>
<tr>
<td><strong>Risk preference (RISK)</strong></td>
<td>Use a five-point Likert scale to obtain values</td>
<td>2.006 (1.016) 1.552 (0.890) 1.908 (1.041) 2.557 (1.075)</td>
</tr>
<tr>
<td><strong>Planting scale (SCA)</strong></td>
<td>Farmer’s actual farmland area</td>
<td>6.272 (3.605) 5.166 (2.731) 8.504 (4.001) 5.147 (2.415)</td>
</tr>
<tr>
<td><strong>Types of crops (CS)</strong></td>
<td>The number of crops planted</td>
<td>2.671 (1.090) 3.401 (0.904) 3.107 (0.991) 1.506 (1.027)</td>
</tr>
<tr>
<td><strong>Labor force (LAB)</strong></td>
<td>The number of rural household laborers</td>
<td>3.435 (1.429) 3.129 (1.022) 3.790 (1.461) 3.387 (1.174)</td>
</tr>
<tr>
<td><strong>Fragmentation degree of cultivated land (FRA)</strong></td>
<td>Number of farmland plots</td>
<td>2.555 (1.026) 2.629 (0.924) 2.585 (1.000) 2.523 (1.058)</td>
</tr>
<tr>
<td><strong>Perceived ease of use (PEU)</strong></td>
<td>Use a five-point Likert scale to obtain values</td>
<td>2.741 (1.158) 2.026 (1.078) 3.007 (1.144) 3.191 (1.073)</td>
</tr>
<tr>
<td><strong>Perceived usefulness (PU)</strong></td>
<td>Use a five-point Likert scale to obtain values</td>
<td>3.28 (1.263) 2.705 (1.302) 3.430 (1.198) 3.706 (1.204)</td>
</tr>
</tbody>
</table>
had a higher risk preference. However, there were no significant differences in the number of laborers or the degree of farmland fragmentation among the three types of farmers.

3.4. Model specification

First, since farmers’ GCT adoption behavior is a discrete variable, to identify the impact of off-farm employment on farmers’ GCT adoption behavior, this paper uses a binary probit model for empirical research. The model is set as follows:

\[ GCT_i = \alpha + \lambda_{\text{off-farm}} + \sum \gamma_j X_j + \eta_i; \quad \begin{cases} GCT_i = 1 & \text{if } GCT_i > 0 \\ GCT_i = 0 & \text{otherwise} \end{cases} \]  

(1)

In the formula, \( i \) represents farmers; \( GCT_i \) is an unobservable latent variable; \( GCT_i \) is an observed binary value variable representing the GCT adoption behavior of farmer \( i \); \( \lambda \) is the estimated coefficient; \( X_j \) represents the control variables (including GEN, AGE, EDU, RISK, SCA, CS, LAB, FRA, PEU, PU, CP, TRA and PRO); \( \gamma_j \) is the estimated coefficient; \( \alpha \) is the constant term; and \( \eta_i \) is the residual term subject to a normal distribution.

4. Results and discussion

4.1. Benchmark regression results

Table 2 reports the regression results of the impact of off-farm employment on farmers’ GCT adoption behavior. The core explanatory variable off-farm employment (off-farm) has a significant negative impact on farmers’ GCT adoption behavior (GCT) at the 1% level, indicating that off-farm employment has a negative impact on farmers’ GCT adoption behavior. The reason may be that the main groups participating in off-farm employment are mainly young and middle-aged people, making most of the labor force engaged in agricultural production among family members consist of elderly people. Compared with young people, elderly people are more rigid in their thinking and still retain traditional agricultural production habits. Thus, they have a negative attitude toward the adoption of GCT (Gao et al., 2017; Li et al., 2021). At the same time, farmers who participate in off-farm employment spend much time obtaining nonagricultural income, ignoring agricultural operations to a certain extent and thus greatly reducing the possibility of adopting GCT (Jin et al., 2022). The results above show that the CROWD effect of off-farm employment is greater than the CAP effect, which also preliminarily supports the expectations of H1-2.

In addition, from the estimation results of the control variables, educational level (EDU), risk preference (RISK), the planting scale (SCA), the labor force (LAB), perceived ease of use (PEU), perceived usefulness (PU), cooperative participation (CP) and technical training in agriculture (TRA) significantly and positively affect farmers’ GCT adoption behavior, while age (AGE) and the degree of cultivated land fragmentation (FRA) significantly and negatively affect farmers’ GCT adoption behavior. Gender (GEN) has no significant effect on farmers’ GCT adoption behavior. The reasons are as follows. First, the higher the educational level of farmers is, the more advanced their concepts and vision, the more comprehensive their understanding of...
new techniques such as GCT, and the more likely they are to adopt new techniques such as GCT (Gonzaga et al., 2019). At the same time, the greater the risk tolerance of farmers is, the more optimistic they will be when viewing the expected benefits brought by GCT adoption, and they will make scientific and reasonable planning for agricultural production and operations, thus taking a positive attitude toward the adoption of GCT (Yu et al., 2021). Second, the expansion of the planting scale and the increase in the number of laborers are prerequisites for farmers to carry out large-scale operations. Doing so not only increases the dependence of farmers on agricultural production but also increases the proportion of farmers’ agricultural production income, thus stimulating their motivation to adopt GCT (Li and Li, 2023). Third, when farmers think that GCT is simple and useful, their willingness to adopt them is higher. At the same time, joining cooperatives can provide farmers with production materials, procurement services, credit guarantees, and technical guidance, which for farmers reduces the risk of GCT adoption. Therefore, joining cooperatives is conducive to promoting the occurrence of farmers’ GCT adoption behavior (Gao et al., 2017). Fourth, GCT has high requirements in terms of time, capital and labor input. Therefore, both male and female household heads are more cautious about whether to adopt GCT, which leads to the nonsignificant impact of gender on farmers’ GCT adoption (Rezaei et al., 2014).

4.2. **Endogeneity analysis**

Since there may be omitted variables in the model that affect both off-farm employment and farmers’ GCT adoption behavior, off-farm employment is associated with the residuals of the model. Therefore, to alleviate possible endogeneity problems, this paper further uses the instrumental variable two-stage least squares method (IV-2SLS) to test the model.

In terms of IV selection, we refer to the research of Xu et al. (2022) and select the off-farm employment ratio of districts and counties with a lag of one period (Non-employ) as the IV of off-farm employment.

<table>
<thead>
<tr>
<th>Variable</th>
<th>(I)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>GCT</strong></td>
</tr>
<tr>
<td>off-farm</td>
<td>$-0.521^{***}$ (0.261)</td>
</tr>
<tr>
<td>GEN</td>
<td>0.091 (0.053)</td>
</tr>
<tr>
<td>AGE</td>
<td>$-0.108^{*}$ (0.025)</td>
</tr>
<tr>
<td>EDU</td>
<td>0.223* (0.132)</td>
</tr>
<tr>
<td>RISK</td>
<td>0.142** (0.068)</td>
</tr>
<tr>
<td>SCA</td>
<td>0.018* (0.011)</td>
</tr>
<tr>
<td>CS</td>
<td>0.027 (0.128)</td>
</tr>
<tr>
<td>LAB</td>
<td>0.023** (0.042)</td>
</tr>
<tr>
<td>FRA</td>
<td>$-0.078^{**}$ (0.022)</td>
</tr>
<tr>
<td>PEU</td>
<td>0.081** (0.035)</td>
</tr>
<tr>
<td>PU</td>
<td>0.143** (0.045)</td>
</tr>
<tr>
<td>CP</td>
<td>0.246*** (0.078)</td>
</tr>
<tr>
<td>TRA</td>
<td>0.315*** (0.111)</td>
</tr>
<tr>
<td>PRO</td>
<td>0.166 (0.106)</td>
</tr>
<tr>
<td>Observations</td>
<td>912</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.422</td>
</tr>
</tbody>
</table>

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively. The robust standard errors are in parentheses. The same applies to Table 3.
reasons are as follows. On the one hand, the level of off-farm employment at the district and county levels has an important impact on farmers’ decision-making with regard to off-farm employment, and off-farm employment is consistent. Due to the convenience of geographical distance and the rapid flow of information, farmers’ choice of off-farm employment behavior is often affected by the proportion of off-farm employment in the county in the previous period. Thus, choosing this indicator as an IV meets the correlation requirement. On the other hand, off-farm employment in the lag period is a predetermined variable for the GCT adoption behavior of farmers in the current period. The value of the off-farm employment level in the previous period has been given in advance, and theoretically, it will not affect the random error term of the current period. Therefore, for the current period, the GCT adoption behavior of farmers has no direct impact. The regression results are shown in Table 3.

The first-stage regression results show that the impact of the one-period lag of the proportion of off-farm employment in districts and counties on off-farm employment is significantly positive at the 1% level, which indicates that the IV meets the condition of correlation. At the same time, the F statistics obtained by the K-Prk Lagrange multiplier (LM) test and the K-Prk Wald test are both much greater than 10, which reflects the effectiveness of the IV selection in this paper through the weak IV test and the unidentification tests. The second-stage regression results show that the estimated coefficient of off-farm is significantly negative at the 1% level. This result indicates that after considering endogeneity problems, off-farm employment still has a negative impact on farmers’ GCT adoption behavior, which further supports the benchmark regression robustness of the results.

5. Mechanism test

The research conclusions above show that off-farm employment has a negative impact on farmers’ GCT adoption behavior. So, how does off-farm employment affect farmers’ GCT adoption behavior? According to the previous theoretical analysis, off-farm employment has a CAP effect and a CROWD effect on farmers’ GCT adoption behavior. Therefore, this paper adopts a two-step method. First, it examines whether there is a CAP effect and a CROWD effect on off-farm employment. On this basis, we compare and analyze the effect and size of the CAP effect and CROWD effect of off-farm employment on farmers’ GCT adoption behavior.

The results reported in columns (1)–(3) of Table 4 show that the estimated coefficients of the impact of off-farm employment on the CAP effect and the CROWD effect are significantly positive at the 1, 5 and 1%

| Table 3. Endogeneity analysis |
|-------------------------------|-------------------|-------------------|
| **Variable**                  | **Stage 1 regression** | **Stage 2 regression** |
|                               | **off-farm**       | **GCT**           |
| Non-employ                    | 0.064*** (0.036)   |                   |
| off-farm                      |                   | −0.532*** (0.222) |
| Control variables             | YES               |                   |
| Observations                  | 912               | 912               |
| $R^2$                         | 0.041             | 0.542             |
| Kleibergen-Paap rk LM Statistics | 155.084*** (0.000) |               |
| Kleibergen-Paap rk Wald F Statistics | 99.753 (10.380) |               |
level, respectively, indicating that off-farm employment has a significant CAP effect and CROWD effect. This result is consistent with the expected results of the theoretical analysis.

Second, this paper further verifies the effects of the CAP effect and the CROWD effect of off-farm employment on farmers’ GCT adoption behavior and compares these effects on farmers’ GCT adoption behavior in terms of the size of the effects. The model is set as follows:

\[ GCT_i = \alpha + \delta \text{CAP}_i + \theta \text{CROWD}_i + \sum \gamma_i X_i + u_i \]  

(2)

In the formula, \( \text{CAP}_i \) and \( \text{CROWD}_i \) represent the proxy variables of the capacity accumulation effect and the crowding-out effect of rural household \( i \)’s off-farm employment, respectively; \( \delta \) and \( \theta \) represent their estimated coefficients, respectively; \( \alpha \) the meaning of the other variables are the same as those in equation (1). Notably, due to the different dimensions and fluctuation ranges of the proxy variables, to clarify whether the impact of off-farm employment on farmers’ GCT adoption behavior is greater, we must determine whether the CAP effect or the CROWD is more important. In this paper, the method of standardizing the estimated coefficients \( \delta \) and \( \theta \) is used to compare the relative size of the impact of the CAP effect and the CROWD effect on farmers’ GCT adoption behavior.

The estimation results in columns (4)–(6) of Table 4 show that the estimated coefficient of the CAP effect on farmers’ GCT adoption behavior is significantly positive at the 1% level. This result indicates that the CAP effect of off-farm employment positively affects farmers’ GCT adoption behavior. The reason is that the higher the capacity accumulation effect index is, the more farmers can obtain GCT-related information through various channels, the more abundant the funds, and the richer the social capital, which has a positive impact on their GCT adoption behavior (Baiyegunh et al., 2018). At the same time, the estimated coefficient of the CROWD effect on farmers’ GCT adoption behavior is significantly negative at the 10% and 5% level. This result indicates that the CROWD effect of off-farm employment has a negative impact on farmers’ GCT adoption behavior. The reason is that the higher the proportion of the nonagricultural labor force in the household labor force and the more nonfarm employment hours, the less labor and time farmers spend on agricultural production, and the impact on their GCT adoption behavior is more negative (Jin et al., 2022).

---

Table 4. The path of the impact of off-farm employment on farmers’ GCT adoption behavior: Analysis based on the CAP effect and the CROWD effect

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CAP</td>
<td>CROWD1</td>
<td>CROWD2</td>
<td>GCT</td>
<td>GCT</td>
<td>GCT</td>
</tr>
<tr>
<td>off-farm</td>
<td>0.311***</td>
<td>0.357***</td>
<td>0.343***</td>
<td>0.162***</td>
<td>-0.556*</td>
<td>-0.432**</td>
</tr>
<tr>
<td></td>
<td>(0.159)</td>
<td>(0.214)</td>
<td>(0.052)</td>
<td>(0.054)</td>
<td>(0.288)</td>
<td>(0.202)</td>
</tr>
<tr>
<td>CAP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.162***</td>
<td>-0.556*</td>
<td>-0.432**</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(0.054)</td>
<td>(0.288)</td>
<td>(0.202)</td>
</tr>
<tr>
<td>CROWD1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.432**</td>
<td>-0.432**</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(0.202)</td>
<td>(0.202)</td>
<td></td>
</tr>
<tr>
<td>CROWD2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.432**</td>
<td>-0.432**</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(0.202)</td>
<td>(0.202)</td>
<td></td>
</tr>
<tr>
<td>Control variables</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Observations</td>
<td>796</td>
<td>796</td>
<td>796</td>
<td>796</td>
<td>796</td>
<td>796</td>
</tr>
<tr>
<td>R²</td>
<td>0.367</td>
<td>0.339</td>
<td>0.400</td>
<td>0.508</td>
<td>0.407</td>
<td>0.457</td>
</tr>
</tbody>
</table>

---

6 The estimated value of the parameter is adjusted by using the ratio of the independent variable to the standard deviation of the dependent variable. The specific formula is as follows: regression coefficient × (standard deviation of the independent variable/standard deviation of the dependent variable).
Furthermore, this paper uses the method of standardizing the estimated coefficients to compare the relative impact of the CAP effect and the CROWD effect on farmers’ GCT adoption behavior. The standardized regression coefficients of the CAP effect and the CROWD effect are 0.111, −0.160 and −0.203, respectively, and the absolute value of the latter is greater than that of the former. These results indicate that the CROWD effect of off-farm employment on farmers’ GCT adoption behavior exceeds the CAP effect. That is, off-farm employment has a negative impact on farmers’ GCT adoption behavior. This again corroborates the robustness of the baseline regression.

6. Heterogeneity analysis

This paper examines the heterogeneous impact of off-farm employment on farmers’ GCT adoption behavior based on two aspects, different degrees and different distances, and it uses the method of cross-item regression for analysis.

6.1. The heterogeneous effects of off-farm employment on farmers’ GCT adoption behavior under different degrees

To compare the heterogeneous impact of off-farm employment on farmers’ GCT adoption behavior at different degrees, this paper divides off-farm employment households into agricultural income-based households (AOFs) and nonagricultural income-based households (NOFs), and then the interaction items with off-farm employment were included in the model, and the regression results are shown in Table 5.

From the estimation results in column (1), the estimated coefficient of off-farm × AOFs is significantly positive at the 5% level, indicating that off-farm employment has a positive impact on the adoption of GCT by farmers whose income is mainly from agriculture. That is, for households whose main income is from agriculture, off-farm employment has a more obvious CAP effect on households’ GCT adoption behavior. From the estimation results in column (2), the estimated coefficient of off-farm × NOFs is significantly negative at the 10% level. This result indicates that for rural households whose main income is nonagricultural income, off-farm employment has a negative impact on the adoption of GCT by farmers whose income is mainly from nonagricultural work. That is, for rural households with nonagricultural income as their main income, off-farm employment has a more obvious CROWD effect on farmers’ GCT adoption. The reason is that farmers whose main income is from agriculture are highly dependent on agriculture and are more inclined to use the funds and information obtained from off-farm employment for agricultural production to increase the income brought by agricultural production. Therefore, off-farm employment has a more obvious CAP effect on GCT adoption behavior (Li et al., 2022). On the other hand, the employment focus of rural households with nonagricultural income has shifted, and they often choose extensive agricultural management, which leads to off-farm employment having more of a CROWD effect on their GCT adoption behavior (Deng et al., 2018). Hypothesis 2 is confirmed.

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7 According to the descriptive statistical analysis in Table 1, the standard deviation of the dependent variable GCT adoption behavior is 0.439, and the standard deviations of the independent variables capacity accumulation effect index, proportion of nonagricultural labor force in household labor force and proportion of nonagricultural employment days in household employment days are 0.301, 0.126 and 0.206, respectively. According to the regression results of Model 2, the coefficients of the variables capacity accumulation effect index, proportion of nonagricultural labor force in household labor force and proportion of nonagricultural employment days in household employment days are 0.162, −0.556 and −0.432, respectively. Therefore, the standardized regression coefficients of the capacity accumulation effect index, proportion of nonagricultural labor force in household labor force and proportion of non-agricultural employment days in household employment days are 0.162×(0.301/0.439)=0.111, −0.556×(0.126/0.439)=−0.160 and −0.432×(0.206/0.439)=−0.203, respectively. To save space, the regression coefficient standardization process below is omitted, and only important results are presented.
Table 5. The heterogeneous impact of off-farm employment on farmers’ GCT adoption behavior at different degrees

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GCT</td>
<td>GCT</td>
</tr>
<tr>
<td>off-farm×AOF</td>
<td>0.136** (0.238)</td>
<td></td>
</tr>
<tr>
<td>off-farm×NOF</td>
<td>-0.053* (0.222)</td>
<td></td>
</tr>
</tbody>
</table>

Control variables
Observations 796 796
R² 0.427 0.399

Table 6. The heterogeneous impact of off-farm employment on farmers’ GCT adoption behavior under different distances

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AOFs</td>
<td>GCT</td>
<td>GCT</td>
<td>NOFs</td>
<td>GCT</td>
<td>GCT</td>
</tr>
<tr>
<td>off-farm×within the township</td>
<td>0.108** (0.067)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>off-farm×outside township but within the county</td>
<td>0.125** (0.078)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>off-farm×outside the county</td>
<td></td>
<td>0.133** (0.077)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>off-farm×within the township</td>
<td></td>
<td>-0.091** (0.007)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>off-farm×outside township but within the county</td>
<td></td>
<td></td>
<td>-0.100* (0.009)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>off-farm×outside the county</td>
<td></td>
<td></td>
<td></td>
<td>-0.102** (0.005)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Control variables
Observations 272 272 272 524 524 524
R² 0.330 0.302 0.375 0.412 0.360 0.408

6.2. The heterogeneous impact of off-farm employment on farmers’ GCT adoption behavior under different distances

To compare the heterogeneous impact of off-farm employment on farmers’ GCT adoption behavior under different distances, this paper divides farmers with off-farm employment into those with agricultural income and those with nonagricultural income and then divides them based on the employment distance of the household head. Specifically, we divide these farmers based on whether their off-farm employment is within the township, outside the township but within the county and outside the county. Then, off-farm employment and its interaction items are included in the model. The regression results are shown in Table 6.

Judging from the estimation results in columns (1)–(3), for off-farm×within the township, off-farm×outside township but within the county, and off-farm×outside the county, the estimated coefficients are all significantly positive at the 5% level, and the standardized regression coefficients gradually increase. These results indicate that for rural households whose main income is from agriculture, with the increase in the distance from...
off-farm employment, off-farm employment has a greater impact on farmers’ GCT adoption. The positive effect of behavior increases. Judging from the estimation results in columns (4)-(6), for off-farm × within the township, off-farm × outside township but within the county, and off-farm × outside the county, the estimated coefficients of rural households are significantly negative at the 5, 10 and 5% level, respectively, and the absolute value of the standardized regression coefficient gradually increases. These results indicate that for rural households whose main income is nonagricultural income, with the increase in the distance from off-farm employment, the negative effect of off-farm employment on farmers’ GCT adoption behavior increases. The reason is that compared with working at a business located within the township, working at a business located outside the township or outside the county will enable AOFs to experience more new things, acquire new knowledge and abilities, and apply them to agriculture. Thus, the CAP effect is more obvious (Endris et al., 2021). However, for NOFs, the increased distance from off-farm employment and increased nonagricultural income shifts their focus further away from agriculture. Thus, the CROWD effect is more obvious (Ahmad et al., 2020). Hypothesis 3 is confirmed.

7. Conclusions and policy recommendations

Actively encouraging farmers to adopt GCT is an important measure for achieving sustainable agricultural development and ensuring global food security. Based on microsurvey data covering 912 households in Henan and Shandong Provinces, this paper uses a binary probit model to explore the effect of off-farm employment on farmers’ GCT adoption behavior and the mechanism of this effect. Additionally, based on the degree of and distance from off-farm employment, the heterogeneous impact of off-farm employment on farmers’ GCT adoption behavior is discussed. The study finds that off-farm employment has a CAP effect and a CROWD effect on farmers’ GCT adoption. Furthermore, the CROWD effect generally exceeds the CAP effect, making off-farm employment unfavorable for farmers’ GCT adoption. Further analysis finds that off-farm employment has a positive effect on the GCT adoption behavior of farm households mainly based on agricultural income, and as the distance from off-farm employment increases, its positive effect is greater. In contrast, off-farm employment has a negative effect on farm households whose main income is nonagricultural income, and with the increase in the distance from off-farm employment, the negative effect gradually increases.

Compared with the literature on off-farm employment and farmers’ GCT adoption behavior, this paper incorporates the two into a unified analysis framework, which not only opens up new ideas and perspectives for exploring farmers’ GCT adoption behavior but also enriches and improves the research on off-farm employment. Based on the capacity accumulation effect and crowding-out effect of non-agricultural employment, this paper further clarifies the mechanism behind the effect of non-agricultural employment on farmers’ GCT adoption behavior so that the findings and conclusions of the paper have more reliable policy implications. This article has the following policy implications:

First, the adoption of GCT by farmers whose main income is from agriculture should be further promoted, and a new situation in the adoption of GCT should be formed. On the one hand, infrastructure construction, such as 5G and the Internet of Things, should be strengthened in rural areas. Additionally, comprehensive information on GCT adoption experience and skills for farmers whose income is mainly from agriculture should be provided so that they can fully understand the effects and advantages of GCT, thereby improving their self-awareness of GCT adoption and stimulating their enthusiasm for GCT adoption. On the other hand, the government should strengthen the demonstration effect and driving role of farmers with agricultural income as the mainstay, cultivate a group of talent that understands and loves agriculture and understands and masters GCT knowledge, and inject strong momentum into the adoption of GCT by farmers.

Second, the government should broaden the channels of off-farm employment, ensure that farmers whose main income is from agriculture obtain sustained and stable off-farm employment income, and enhance
their CAP effect. On the one hand, the government should promote the standardized construction of the rural off-farm employment market, set up township employment service centers, standardized part-time job markets, provide more information and opportunities for off-farm employment for farmers whose main income is from agriculture, and ensure that they can quickly transition during the slack period to off-farm employment. On the other hand, it should focus on industrial employment, implement the “one county, one industry” project to strengthen counties and enrich people, and actively develop and expand rural industries to provide more off-farm employment opportunities for farmers whose income is mainly from agriculture to further enhance the CAP effect of off-farm employment.

Third, the government should guide the transfer of farmland from off-farm income-based farmers to agricultural income-based farmers, laying a resource base for the popularization of GCT. On the one hand, it should improve the farmland transfer market mechanism, guide the orderly transfer of land management rights, and develop moderate-scale agricultural operations, such as summarizing the local experience of combining small fields with large fields. On the premise of farmers’ willingness, the government should gradually solve the problem of fragmentation in combination with farmland construction and land consolidation, expand the scale of land management of farmers whose main income is from agriculture, and provide a resource base for them to adopt GCT. On the other hand, it should further improve the construction of the labor market for migrant workers, strengthen the guarantee for migrant workers to work in cities, help rural households with nonagricultural income to truly settle down in cities and towns, and provide stable income for rural households with nonagricultural income as their main source so that they have no worries about the future, thus enhancing their willingness to transfer out their farmland.

Of course, this paper still has certain limitations. In recent years, the new generation of information technology has widely penetrated all walks of life, and the cross-integration of “agriculture + new generation information technology” has become an important development trend (Zheng and Ma, 2023). Whether the use of information technology enhances the “capacity accumulation effect” or “crowding out effect” of non-farm employment on farmers’ GCT adoption behavior? This remains to be further answered. In addition, due to the limitations of the survey data, this paper analyzes only farmers in Henan and Shandong Provinces, but it remains to be seen whether the research conclusions can be consistently drawn in other parts of China. Moreover, GCT represents a complex set of technologies. In this paper, whether “farmers adopt any one or more of the GCT subtechnologies” is set to mean only that farmers have GCT adoption behaviors, and GCT is not further divided into different subtechnologies. In view of this shortcoming, future studies can further subdivide GCT into different subtechnologies according to technical characteristics on the basis of expanding the sample size to improve the research accuracy regarding farmers’ GCT adoption behavior.

References


