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The Impact of Bancassurance Interaction on the Adoption Behavior of Green Production Technology in Family Farms: Evidence from China

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Abstract: In the context of increasingly severe resource and environmental constraints, accelerating family farms to take the path of green agricultural development is an urgent practical problem to be solved. The bancassurance interaction, an innovative form of financial support policy for agriculture, can effectively alleviate the risks and credit rationing problems faced by family farms in the operation process, provide new opportunities for green production of family farms, and is of great significance to promoting sustainable agricultural development. This study uses data from 564 planting family farms in Shaanxi Province to analyze the impact of the bancassurance interaction on adopting green production technology in family farms and its mechanism, paying particular attention to the heterogeneous effects of the family life cycle and family economic level. The results of this study show that the bancassurance interaction has a significant positive impact on the adoption of green production technology by family farms. Compared with agricultural credit and insurance, the effect of the bancassurance interaction on adopting green production technologies is more evident. The analysis of the impact mechanism shows that the bancassurance interaction can promote the adoption of green production technology in family farms through three channels: increasing investment in agricultural production, expanding the scale of land management, and strengthening exchanges of green technology. Among them, the effect of increasing agrarian production investment is the most pronounced. The heterogeneity analysis shows that the impact of the bancassurance interaction on the green production technology of family farms varies significantly according to the family life cycle and economic level. Family farms at the dependency stage and low-income level were more willing to adopt green production technologies driven by the bancassurance interaction. Therefore, it is necessary to continuously innovate the interaction mode between banks and insurance companies, rationally allocating agricultural production factors and combining the actual situation of each family farm to strengthen the leading role of the bancassurance interaction in adopting green production technologies and promoting high-quality agricultural development.

Keywords: bancassurance interaction; green production; family farm; production factor allocation; family life cycle; family economic level

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1. Introduction

"Green water and green mountains are golden mountains and silver mountains". Green agricultural development is vital for protecting the environment and alleviating resource scarcity. It is also an inevitable choice to meet people's growing needs for nutrition and health improvements [1]. However, due to the lack of awareness of the green development of producers in the agriculture sector, agrarian production presents a status quo that emphasizes quantity over quality, resulting in low land resource allocation efficiency, which impedes the progress of environmental protection and food safety. All regions place a high value on green agricultural development, insist on promoting the development of green technological innovation systems, prioritize conservation and protection over natural recovery, and continuously promote the transformation of green agricultural development. China's annual Central Committee Document No. 1 has mentioned relevant measures to promote green agricultural development for nine years. As a new agricultural business entity, family farms, with family members as the main labor force and agricultural income as the main source of family income, have the characteristics of professional farming, intensive production, and moderate scale, which can achieve a high rate of land output and resource utilization, promote the effective allocation of production factors, and are the main force to promote green production [2,3]. As a result, it is critical to focus on the significance of the adoption of green technology by family farm operators in improving the green use of land and accelerating the realization of comprehensive green development in agriculture [4].

Existing studies on green agricultural production are plentiful, with the majority of them relying on the Theory of Planned Behavior and the Norm Activation Model to discuss the influencing factors of green production behavior and efficiency, including internal and external factors. Internal factors primarily address the behavioral logic of green production through the lens of farmers' cognition or household capital endowment [5–7]. External factors mainly discuss the incentive effects of related factors on green production behavior, such as government regulations, financial subsidies, and market returns [8–10]. Rural finance effectively supports green and low-carbon agricultural development as a capital element to promote rural economic development and increase farmers' income. Agricultural credit and insurance are essential rural finance tools for effectively alleviating agricultural credit rationing, improving risk management, and positively impacting green agricultural production [11,12]. On the one hand, agricultural credit can help alleviate the financing constraints of new business entities, reallocate agricultural production factors, and increase farmer adoption of green production technologies [13,14]. On the other hand, agricultural insurance can encourage green production behaviors among agricultural producers by mitigating risks such as natural disasters in agricultural production, market price fluctuations, and technology adoption failures [15]. However, the rural credit business continues to face lending and repayment challenges due to a lack of collateral. Agricultural insurance has the effect of collateral to a certain extent. Strengthening the synergy between agricultural credit and agricultural insurance could benefit the supply side by allowing financial institutions to understand better farmers' repayment ability and increase their willingness to lend, thereby expanding the scale of rural credit [16,17]. Simultaneously, the collaboration between banking and insurance is beneficial in stabilizing demand-side income expectations, such as for farmers and promoting green production [18]. Family farms have a larger production scale and require more capital in the production process than smallholders. However, due to a lack of adequate collateral for family farms, there is a more urgent need for the "bancassurance interaction" model. Therefore, the "bancassurance interaction" development mechanism was formally proposed. Since then, insurance companies and credit-providing financial institutions have conducted pilot projects in various regions, and the operation modes are relatively affluent. The main model is innovative financial cooperation in which banks and other financial institutions use agricultural insurance contracts as collateral to provide formal agriculture-related credit while providing risk protection through agricultural insurance, an institutional arrangement to solve the financing constraints of farmers [19].

Most existing research focuses on the effects of agricultural credit and insurance on farmer income growth and production efficiency [20–22]. Some empirical studies have shown that agricultural credit and insurance can increase farmer income, but this positive effect is more pronounced among farmers in better economic circumstances. It has little effect on farmers' income and production in poor economic conditions, which may result in the "Matthew Effect" in farmer groups [23,24]. Some studies have also discussed the impact of agricultural insurance on agricultural production through agricultural loans [25,26]. Only a few scholars have investigated the impact of the bancassurance interaction on credit rationing and rural household income growth. The research findings have confirmed the incentive effect of the bancassurance interaction [27,28]. There is still a lack of discussion about the impact of the bancassurance interaction on adopting green technology in family farms and its mechanism. At the same time, whether the development of the bancassurance interaction mechanism is more conducive to adopting green agricultural technologies than the single development of agricultural credit or insurance remains to be verified. Using field survey data collected from family farms in the planting industry in Shaanxi Province, this paper examines the influence of agricultural credit, agricultural insurance, and bancassurance interactions on the adoption behavior of family farmers' green production technology. The influence mechanism of bancassurance interactions in adopting green production technology is discussed by using the mediation effect model. Based on the family life cycle and family economic level, this study also explores the heterogeneous impact and provides a theoretical foundation for the proposed targeted measures.

This paper contributes to the existing studies in the following aspects: First, it integrates bancassurance interactions and agricultural green technology adoption into a unified research framework in an exploratory manner. It focuses on systematically explaining the benefits of the bancassurance interaction beyond the single development of agricultural credit and agricultural insurance on the adoption of green production technology in family farms. On the one hand, it investigates the factors influencing the adoption behavior of green production technology from a new perspective and enriches the range of antecedents to the adoption of green production technology. On the other hand, it provides a theoretical basis for the scientific evaluation of the effects of the bancassurance interaction in supporting agriculture. Second, based on the Douglas production function, this paper uses production capital investment, land scale expansion, and technology exchange as mediating variables to verify the indirect influence of the bancassurance interaction on green production technology adoption in family farms, and deepen the understanding of the relationship between the bancassurance interaction and green production technology adoption behavior in family farms, research perspective is unique. Third, taking into account the perspective of the family life cycle and family economic level, we further identify differences in the paths of bancassurance interactions influencing green technology adoption behavior among family farmers, providing reference to precisely formulate policies for the sustainable development of the agricultural sector.

2. Theoretical Framework

2.1. The Direct Impact of the Bancassurance Interaction on Green Technology Adoption Behavior in Family Farms

Previous studies have addressed the relationship between the bancassurance interaction and green production technology adoption behavior less directly, mainly exploring the effects of agricultural insurance and credit on agricultural green production separately. On the one hand, some scholars have investigated the impact of agricultural insurance on agricultural production, finding that agricultural insurance spreads and transfers risk for agricultural production, increases expected returns on investment in agricultural production, and helps promote the adoption of green production technologies by farmers [29,30]. On the other hand, there is a growing body of research on the impact of agricultural credit on agricultural production [31,32], and which it is generally agreed that agricultural credit provides beneficial financial support for agricultural production and enhances farmers' investment in green production. As a financial support model that links agricultural insurance and credit, the bancassurance interaction has the dual effect of implementing risk management and alleviating financing constraints, which is more conducive to promoting sustainable agricultural development [33]. In the bancassurance interaction model, agricultural insurance not only effectively reduces the production risks of family farms and improves the ability of farmers to adopt green production technologies, but also provides financial compensation to farms after disasters, stabilizes farmers' income expectations, and promotes farmers' adoption of green production technologies [34]. At the same time, with the collateralization of agricultural insurance policies, agricultural credit increases the availability of financing for farmers, alleviating the problem of financial constraints in family farm production and increasing their adoption of green technologies [35]. To analyze the impact of the bancassurance interaction on family farms' green technology adoption behavior more intuitively, this paper draws on Liao to construct a theoretical model to explore further [36].

Family farmers have two main options for production: they can either continue with traditional technology or invest in and adopt green production technology by strengthening their exchange of knowledge and resources. Assuming that the probability of agricultural production is subject to risks such as natural disasters β. The scale of production is m mu. The yields per mu for traditional and green technology production are n_1, n_2, respectively, and the market prices are p_1,p_2, respectively. Traditional production costs are c, while green production costs are $g + c$ and more than traditional production costs as technological innovation. If a farmer borrows money, he needs to mortgage a fixed asset with a value of f. Assuming that farmers only need to borrow money when they have sufficient funds, according to the theory of maximizing producer utility, if agricultural production does not involve borrowing or insurance costs, the utility functions for choosing traditional and green technology production are U_a and U_b respectively:

$$U_a = (1 - \beta)mn_1p_1 - c + f \tag{1}$$

$$U_b = (1 - \beta)mn_2p_2 - c - g + f \tag{2}$$

When farmers have insufficient funds to expand their land or increase agricultural production investment for higher returns, they must apply for agricultural credit. Assuming that the farmer needs a loan amount l, the bank's interest rate is r. Currently, a fixed asset with a mortgage value of f is required for the loan. In the case of loans, the utility functions of choosing traditional technology production and green technology production are U_c and U_d respectively:

$$U_c = (1 - \beta)(mn_1p_1 + \pi_1) - c - l(1 + r) + (1 - \beta)f \tag{3}$$

$$U_d = (1 - \beta)(mn_2p_2 + \pi_2) - c - g - l(1 + r) + (1 - \beta)f \tag{4}$$

Formulas (3) and (4), π_1 and π_2, respectively, represent the income growth brought about by the expansion of the land management scale or the increase in agricultural production investment using traditional and green production technology.

Agricultural insurance is an essential means for farming producers to manage risk. Assume that the cost of purchasing agricultural insurance per mu for farmers is α, the amount of government subsidies is δ, and the insurance compensation rate is $\theta(0 < \theta < 1)$. When a farmer buys agricultural insurance, the utility functions for traditional technology production and green technology production are U_e and U_f respectively:

$$U_e = (1 - \beta)mn_1p_1 - c - \alpha m + \beta m\theta(\alpha + \delta) + f \tag{5}$$

$$U_f = (1 - \beta)mn_2p_2 - c - g - \alpha m + \beta m\theta(\alpha + \delta) + f \tag{6}$$

Guided by the government, the interactive cooperation between banks and insurance companies known as "bancassurance interaction", is a model that supports agricultural production. This model offers significant credit benefits to farmers who purchase agricultural insurance. It mainly uses producer agricultural insurance contracts as collateral for loans, which increases their willingness to borrow at lower interest rates [37]. Agricultural insurance thus helps manage production risk for farmers while reducing repayment risks for agricultural producers. Utilizing credit to promote the scale expansion of agricultural production, this approach achieves a win–win situation for farmers and financial institutions [17]. Therefore, with the bancassurance interaction, farmers do not need collateral when borrowing and the interest rate they pay is lower, set to $r_0(r_0 \leq r)$. The scale of land operations after borrowing is expanded to w. The utility functions of the two different production technologies for the family farmer are U_g and U_h, respectively:

$$U_g = (1-\beta)(mn_1p_1 + \pi_1) - c - l(1+r_0) + f - \alpha w + \beta w\theta(\alpha+\delta) \tag{7}$$

$$U_h = (1-\beta)(mn_2p_2 + \pi_2) - c - g - l(1+r_0) + f - \alpha w + \beta w\theta(\alpha+\delta) \tag{8}$$

According to the rational assumption, only when $U_h > U_g$, farmers will be more inclined to adopt green production technology. In the bancassurance interaction model, the utility difference between choosing green technology production and traditional technology is ΔU_1:

$$\Delta \mathrm{U}_1 = U_h - U_g = (1-\beta)(mn_2p_2 - mn_1p_1 + \pi_2 - \pi_1) - g \tag{9}$$

When $\Delta U_1 > 0$, $(1-\beta)(mn_2p_2 - mn_1p_1 + \pi_2 - \pi_1) > g$. Generally, the market price of green agricultural products is higher than ordinary products. With the adoption of green technology, most plants can also increase production and income. $mn_2p_2 > mn_1p_1$ and $mn_2p_2 > mn_1p_1$ are a fact [38]. g, as a green technology investment, has a longer payback cycle. Overall, in the bancassurance interaction model, the utility of adopting green technology production is far greater than traditional technology production. Only when natural disasters cause severe losses, so there is no harvest in the planting industry, the investment in green technology could be more effective, and the utility of choosing green production could be better than traditional production.

Agricultural credit helps alleviate financial constraints for agricultural producers, while agricultural insurance provides a safeguard for production. Therefore, what are the advantages of the bancassurance interaction model compared to the single development of agricultural credit and insurance? This study will use utility differences to reach further.

The effect difference between the bancassurance interaction and agricultural credit on the adoption of green technology by farmers is ΔU_2:

$$\Delta \mathrm{U}_2 = U_h - U_d = l(r - r_0) + \beta\theta w + \beta f - \alpha w \tag{10}$$

A large part of the agricultural insurance premium is government subsidies, so the actual agricultural insurance premium paid by farmers αw is less than the amount of loan collateral losses that may be caused by risks such as natural disasters. Thus, $\Delta U_2 > 0$, which indicates that the impact of the bancassurance interaction on farmers' green production behavior is more significant than the single impact of agricultural credit.

The utility difference between the bancassurance interaction and agricultural insurance is ΔU_3:

$$\Delta \mathrm{U}_3 = U_h - U_f = (1-\beta)\pi_2 - l(1+r_0) + \alpha(w-m)(\beta\theta - 1) \tag{11}$$

Formula (11), $l(1+r_0)$ represents the interest expense of agricultural credit, and $\alpha(w-m)(\beta\theta-1)$ is the difference between the agricultural insurance premium and the amount of insurance compensation when an agricultural disaster occurs. When the compensation rate θ is less than 1, $\alpha(w-m)(\beta\theta-1)$ is a negative value. Therefore, $(1-\beta)\pi_2$ is the maximum benefit of the bancassurance interaction model relative to the single development growth of agricultural insurance. The size of π_2 depends on the expansion performance of agricultural operations and farmers' ability to pay a premium for green products, which shows that the interaction between banks and insurance companies brings infinite possibilities to the benefits of green production. From a practical point of view, agricultural insurance premiums and bank interest account for a relatively small proportion of production costs. Bancassurance interactions can compensate these funds in the future by improving green production efficiency. The farmer must pay most agricultural insurance premiums and bank interests even during an agricultural disaster [39]. Based on the preceding analysis, the following hypotheses are proposed:

Hypothesis 1 (H1). *Bancassurance interaction positively affects family farmers' adoption of green production technology, and this joint promotion effect is greater than the single promotion effect of agricultural credit and agricultural insurance.*

2.2. The Indirect Impact of the Bancassurance Interaction on the Adoption of Green Technology in Family Farms

Capital input, land scale, and technological innovation are all essential factors in agricultural production, according to the Cobb–Douglas production function. Thus, this paper analyzes the impact of the bancassurance interaction on farmer adoption of green production technology from capital, land, and technology standpoint.

The capital invested in production is the most direct factor influencing technology adoption. The availability of agricultural loans in the bancassurance interaction model can increase farmers' financial support for long-term and short-term agricultural production investment [40]. For example, purchasing more eco-efficient production equipment and agricultural goods can lower the cost of green production while increasing farmers' willingness and ability to produce in a green manner. Moreover, agricultural credit can persuade farmers to purchase socialized services for specific product segments, promoting green production [41]. However, whether or not to buy social services is determined by the amount of available credit, the cost performance of social services, and farmers' risk tolerance [42,43]. Some farmers may prefer to buy their production inputs when credit is less available. Additionally, the incentives in agricultural loan terms can influence the scale of producers' operations and adoption of green production technologies to some extent. For instance, loans targeted toward green production can influence producers' ecological awareness and behavior [44]. Agricultural insurance can impact farmers' green production capital investment by reducing financial losses, increasing credit availability, and stabilizing market demand. First, agricultural insurance can assist farmers in reducing their financial risk. When crops are exposed to natural disasters, farmers will receive agricultural compensation, which can compensate for losses due to disasters and prevent underfunding of agricultural production inputs [45]. Second, effective risk management can assist farmers in obtaining funds for green production. When the farm has practical risk management measures, it will increase the financing availability of farmers, giving them more funds to invest in sustainable technologies [46]. Finally, managing farmers' resilience to risks such as natural disasters can improve producers' market prospects [47], mainly due to the increasing trust that most consumers have developed over time toward this product. Green products with stable prices, tastes, and efficacy can encourage consumers to purchase them regularly and increase farmers' confidence in green production. Therefore, the bancassurance interaction can boost farmers' confidence in green production and investment, increase their expected returns on production inputs, change the risk-averse mentality towards investment, effectively stimulate productive investment behavior among farmers, improve the adoption rate of green technologies, and promote a virtuous circle between the bancassurance interaction and agricultural green development [13,48].

Optimizing land resource allocation and promoting the moderate-scale operation of agricultural producers is conducive to the sustainable development of agriculture. On one hand, agricultural loans can influence the scale of land use and management of family farmers. When producers receive a large number of agricultural loans, they have more funds to invest in environmentally sustainable production, which can reduce the negative impact of agricultural production on the environment [49]. At the same time, the operation scale will impact farmers' ability to participate in the green agricultural product market. Large-scale farmers have more product marketing options, are better positioned to benefit from green agricultural products, and are more willing to invest in green production. In turn, the farmers' ability to access credit is hampered, thus limiting their investment in sustainable technologies. Furthermore, when some agricultural producers are under loan pressure, they may increase production efficiency by expanding the scale of land management to meet the repayment goal. To some extent, the increasing scale can reduce pesticide and fertilizer waste, indirectly promote green production behavior and improve land productivity [50,51]. On the other hand, agricultural insurance can effectively prevent losses caused by risks such as climate change and the spread of pests and diseases in green production [52]. Agricultural insurance is an important risk management tool that can assist farmers in mitigating the impact of various disasters and improving income expectations, allowing them to expand their operations and adopt environmental-friendly production techniques [53]. Furthermore, agricultural insurance can encourage business expansion by offering incentives such as financial subsidies to adopt sustainable production technologies [54]. Therefore, agricultural credit and insurance can collaborate in the bancassurance interaction to effectively promote the rational use of land and increase farmers' income and the quality and quantity of crop production.

Technology adoption and innovation are primarily driven by farmer technical training and professional communication. Agricultural credit can provide farmers with financial resources to improve their access to information and training on green production technologies. Favorable loan conditions, such as low-interest loans for green technologies, reduce farmers' debt burden. Farmers can use the funds to seek green technical help. Farmers can effectively increase their understanding and application of green production technologies and promote green technologies if they have more opportunities for green technology exchanges [55]. Agricultural insurance can encourage family farmers' technological innovation on both psychological and financial levels. At a psychological level, agricultural insurance effectively covers production risks, alleviates family farmers' concerns about new technology innovation and risk aversion psychology, overcomes farmers' psychological barriers to participating in green technology exchanges and using technology, and increases investment in sustainable production [56]. At a financial level, agricultural insurance can reduce financial losses from new technology adoption, cover agricultural production risks, encourage farmers to strengthen technical exchanges, innovate production technologies, and promote green and sustainable development [57]. In addition, agricultural insurance companies can help farmers with technical advice and the implementation of green production technologies. The bancassurance interaction promotes cooperation between banks and insurance companies to improve the production environment and communication atmosphere for green agricultural production [58]. Based on the preceding analysis, the following hypotheses are proposed:

Hypothesis 2 (H2). *Bancassurance interaction encourages family farmers to adopt green production technology by increasing capital investment in agricultural production.*

Hypothesis 3 (H3). *Bancassurance interaction encourages family farmers to adopt green production technology by adjusting the scale of land management.*

Hypothesis 4 (H4). *Bancassurance interaction encourages family farmers to adopt green production technology by strengthening green technology exchanges.*

Based on the above analysis, the theoretical framework of this study is shown in Figure 1.

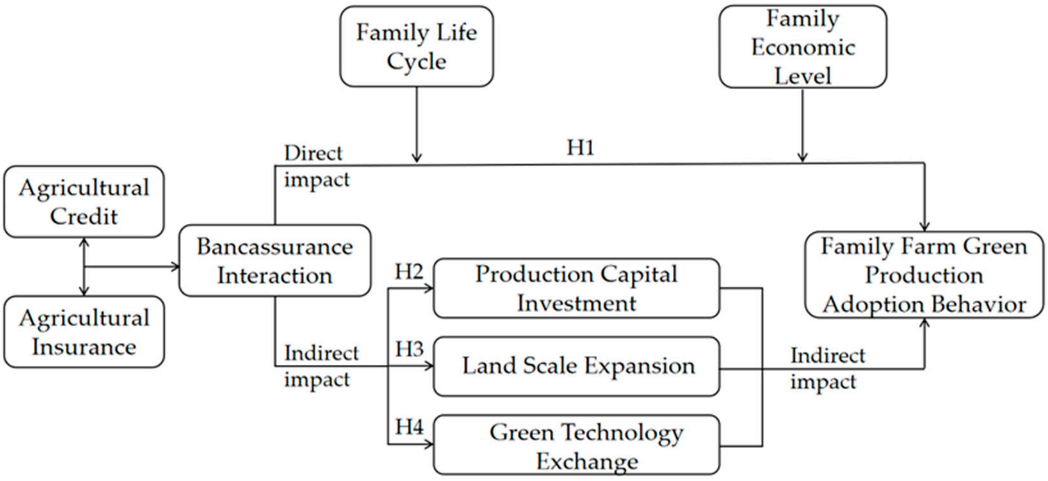

Figure 1. Theoretical analysis framework.

3. Materials and Methodology

3.1. Data Source

The data in this article come from a survey conducted by the project team in rural areas of Shaanxi Province in May 2022. Shaanxi is selected as the research area, primarily due to the uniqueness of its agricultural status. On the one hand, Shaanxi Province is a significant agricultural province, with over 100,000 registered family farms. The majority of agricultural products grown on family farms have distinct regional characteristics. As an effect, encouraging green production on family farms can effectively ensure the quality and features of agricultural products while also serving as a model. On the other hand, Shaanxi Province is a region with limited land and water resources. Most of this region's traditional agricultural production methods rely on chemical substances such as pesticides and fertilizers, and diffuse pollution is severe. Green production in Shaanxi Province significantly promotes the agricultural industry's long-term development. Furthermore, the Shaanxi Provincial Government highly emphasizes financial support for the green agricultural development strategy. Major financial institutions have launched green agricultural loans, insurance support, and "Internet +" rural financial services to encourage green agricultural production. Shaanxi Province has a relatively complete rural information system, a good policy environment, and a favorable enabling environment for financial development. It is a crucial pilot area for bancassurance interaction policies.

The project survey team used the random sampling principle to conduct field interviews with family farmers in 9 cities and 12 counties in Shaanxi Province, including Chunhua County and Xingping County in Xianyang City, Huangling County in Yan'an City, Yaozhou County in Tongchuan City, Fuping County in Weinan City, Lintong District and Zhouzhi County in Xi'an City, Luonan County in Shangluo City, Shiquan County in Ankang City, Hantai District in Hanzhong City, and Fengxiang County and Meixian County in Baoji City (Figure 2). Whether registration has been completed officially is the identification criteria for family farms. A total of 570 questionnaires were distributed, and 564 valid questionnaires were collected, thus the effective rate of the survey is 98.94% and a good sample representation. The sample's basic information is as follows: The family farm owners interviewed include 496 men (87.94%) and 68 women (12.06%). The average age is 48 years old. Education is generally at high school or higher, with high school education accounting for 35% and college education and above accounting for 22.3%. Married farmers make up 96.6% of the total. Farmers work in agriculture for an average of 21 years.

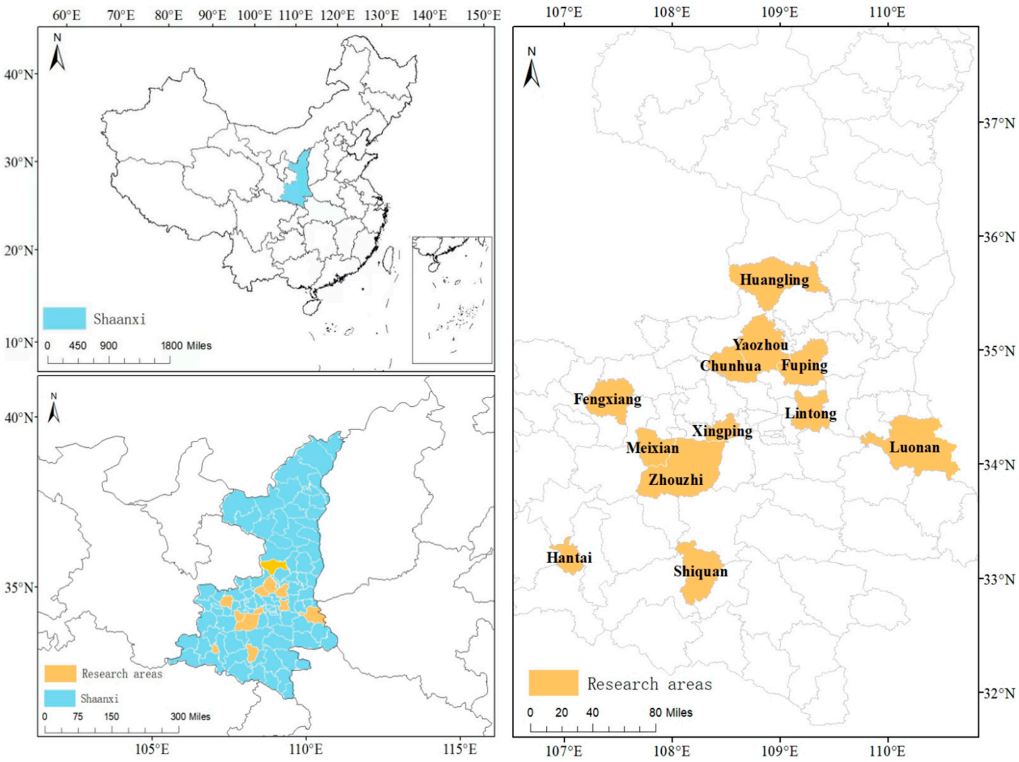

Figure 2. Research areas.

3.2. Variable Measurement

3.2.1. Dependent Variable

The dependent variable is green technology adoption behavior. The use of nine green technologies primarily measures family farmers' adoption of green technology during three stages of crop planting. It is divided into three phases: prenatal, middle, and postpartum. Farmers' adoption of new breed technology is primarily responsible for prenatal. Cultivation (deep plowing), fertilization (organic fertilizer instead of chemical fertilizer, soil testing, and formula fertilization technology), pesticide application (biological or physical pest and disease control technology), and irrigation are all part of production (water-saving irrigation technology). Post-production is primarily concerned with waste management, which includes plastic film recycling, waste recycling, and straw returning technology. Drawing on the approach of Willy [59], farmers' adoption of green technologies is used to gauge the extent of green technology adoption. Figure 3 shows the proportion of family farms implementing various levels of green production. The ratio of family farms that have not adopted green production technology is 0.35%, whereas the proportion of family farms using 5 and 6 technologies is the highest, at 18.26%, which means there is a huge space to improve the level of green production practices in family farms.

3.2.2. Independent Variables

The independent variable in this study is the bancassurance interaction. If the family farmer participates in the bancassurance interaction mode, the value is 1; otherwise, it is 0 [19]. The measurement indicators of agricultural credit and agricultural insurance are also set to measure the superiority of the bancassurance interaction model over agricultural credit and agricultural insurance. If the family farmer has access to agricultural loans, the value is 1; otherwise, it is 0. If the family farmer has agricultural insurance, the value is 1; otherwise, it is 0.

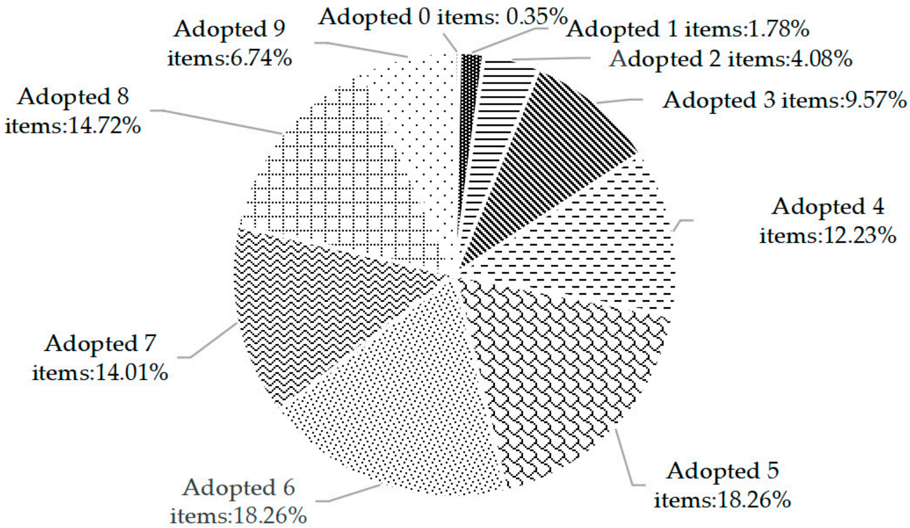

Figure 3. The proportion of family farms implementing different levels of green production.

3.2.3. Control Variables

Based on farmer behavior theory and drawing on relevant research findings [60–62], this study selected two control variables, personal characteristics and household characteristics, to examine the factors influencing the adoption behavior of green production technologies in family farms. Unique characteristics include the farmer's age, gender, and culture. Household characteristics include the number of the labor force, family financial professionals, whether the government supports industries, planting income, understanding of green development policies, sources of business information, and the frequency of natural disasters.

3.2.4. Adjusted Variables

The family life cycle and family economic level are used in this paper to analyze the heterogeneity of the effect of the bancassurance interaction on the adoption of green production technology.

The family life cycle. Family farmers at various stages of their lives have different perceptions and ideas about green products, which can influence their decision to adopt green production technologies. Derrick [63] argued that family life cycle stages should be defined depending on the purpose of the study and the availability of research data. Currently, farmers are generally under the age of 65, and their age shows a tendency to be younger. Therefore, the life cycle of a family farm is divided into four stages [64]. The first stage is the start-up period, in which the family farmer is young and has no children. This stage can also be referred to as the stabilization period, when there are no children to attend school or parents over 65. The second stage is dependency, in which the family farmer has children attending school but no parents over 65. The third stage is the burden period, which occurs when the family farmer has both children in school and an older adult over the age of 65 in the family. The fourth is the support period, during which the family farmer has no children in school but must support an older adult over 65.

Family economic level. Significant income disparities exist among family farms, so there is heterogeneity in green production technologies by the bancassurance interaction in the case of different household economic levels. This paper uses the total farm income of family farms as a measure and divides the economic level of farm households into three groups, according to the 0.33 and 0.66 quantile points to indicate low income, middle income, and high income [65].

3.2.5. Intermediary Variables

This paper examines the impact path of the bancassurance interaction on green production technology adoption from the standpoint of production factors allocation, focusing on production capital investment, land scale expansion, and green technology exchange.

Production capital investment. Family farmers' total expenditure on agricultural production inputs [66], including labor employment, agricultural machinery maintenance and fuel costs, seeds, irrigation, chemical fertilizers, pesticides, and mulch film.

Land scale expansion. The difference between the area of inflowing land and the area of outflowing land is referred to as net land transfers to family farms [67,68]. Because the transfer area of family farms is relatively large, the impact mechanism is measured using the logarithm of the functional area plus 1.

Green technology exchange. The level of participation of family farmers in agricultural green training and communication [69]. Table 1 displays the descriptive statistics for the variables.

Table 1. Variable assignment and descriptive statistics.

Variables	Definition	Mean	S.D.
Bancassurance interaction	No = 0; Yes = 1	0.213	0.41
Credit	No = 0; Yes = 1	0.516	0.5
Insurance	No = 0; Yes = 1	0.39	0.488
Green technology adoption	The number of green production adopted by family farms	5.649	1.994
Age	The actual age of the farmer	48.782	9.067
Gender	Female = 0; male = 1	0.879	0.326
Education	Years of education	11.174	2.849
Workforce	Total household labor force	3.014	1.134
Financial member	No = 0; Yes = 1	0.145	0.353
Government support	No = 0; Yes = 1	0.317	0.466
Planting income	Take the logarithm of the total planting income of the year plus 1	11.232	4.027
Green cognition	Very little = 1; less = 2; general = 3; More = 4; very much = 5	3.417	1.193
Business information	Very little = 1; less = 2; general = 3; More = 4; very much = 5	3.576	0.963
Natural disasters	Very infrequently = 1; less infrequently = 2; general = 3; more frequently = 4; very frequently = 5	3.225	1.341
Family life cycle	Start-up period = 1; Dependency period =2; Burden period = 3; Support period = 4	2.321	0.792
Family economic level	Total household agricultural income (million yuan)	108.210	231.387
Production capital investment	The logarithm of all productive expenditures plus 1	12.1	1.384
Land scale expansion	Take the logarithm after adding 1 to the net transferred land	3.934	1.674
Green technology exchange	Very infrequently = 1; less infrequently = 2; general = 3; more frequently = 4; very frequently = 5	4.316	1.189

3.3. Methodology

3.3.1. Ordered Probit Model

Regarding the study of green production technology adoption behavior, scholars more often use binary discrete Probit or Logit models. Since the dependent variable in this paper is the number of green production technology adoption by family farmers, which is an ordered multicategorical variable, it is more appropriate to use the order-probit model for estimation [70], and the basic regression model is as follows:

$$Y_i^* = \alpha_1 X_i + \beta_1 C_i + \varepsilon_i \tag{12}$$

Formula (12), Y_i^* is used as the latent variable of the ith family farmer's green production technology adoption behavior. X_i stands for the bancassurance interaction, agricultural credit, or agricultural insurance. C_i is a control variable. ε_i is a random disturbance item and obeys the logical distribution $E[\varepsilon_i|X_i] = 0$. Assuming that $r_1 < r_2 < r_3 < r_4 < r_5 < r_6 < r_7 < r_8 < r_9$ is an unknown cut point, and Y_i is the observable green production behavior of the ith farmer, then Y_i can be expressed by Y_i^* as follows:

$$Y_i = \left\{ \begin{array}{c} 0, Y_i^* \le r_1 \\ 1, r_1 < Y_i^* \le r_2 \\ 2, r_2 < Y_i^* \le r_3 \\ 3, r_3 < Y_i^* \le r_4 \\ 4, r_4 < Y_i^* \le r_5 \\ 5, r_5 < Y_i^* \le r_6 \\ 6, r_6 < Y_i^* \le r_7 \\ 7, r_7 < Y_i^* \le r_8 \\ 8, r_8 < Y_i^* \le r_9 \\ 9, Y_i^* > r_9 \end{array} \right\} \tag{13}$$

The probabilities of non-adoption to adoption of the nine green production technologies by family farmers in Equation (13) are as follows:

$$\begin{array}{c} P(Y_i = 0|X) = \Phi(r_1 - \alpha_1 X_i - \beta_1 C_i) \\ P(Y_i = 1|X) = \Phi(r_2 - \alpha_1 X_i - \beta_1 C_i) - \Phi(r_1 - \alpha_1 X_i - \beta_1 C_i) \\ P(Y_i = 2|X) = \Phi(r_3 - \alpha_1 X_i - \beta_1 C_i) - \Phi(r_2 - \alpha_1 X_i - \beta_1 C_i) \\ P(Y_i = 3|X) = \Phi(r_4 - \alpha_1 X_i - \beta_1 C_i) - \Phi(r_3 - \alpha_1 X_i - \beta_1 C_i) \\ P(Y_i = 4|X) = \Phi(r_5 - \alpha_1 X_i - \beta_1 C_i) - \Phi(r_4 - \alpha_1 X_i - \beta_1 C_i) \\ P(Y_i = 5|X) = \Phi(r_6 - \alpha_1 X_i - \beta_1 C_i) - \Phi(r_5 - \alpha_1 X_i - \beta_1 C_i) \\ P(Y_i = 6|X) = \Phi(r_7 - \alpha_1 X_i - \beta_1 C_i) - \Phi(r_6 - \alpha_1 X_i - \beta_1 C_i) \\ P(Y_i = 7|X) = \Phi(r_8 - \alpha_1 X_i - \beta_1 C_i) - \Phi(r_7 - \alpha_1 X_i - \beta_1 C_i) \\ P(Y_i = 8|X) = \Phi(r_9 - \alpha_1 X_i - \beta_1 C_i) - \Phi(r_8 - \alpha_1 X_i - \beta_1 C_i) \\ P(Y_i = 9|X) = 1 - \Phi(r_9 - \alpha_1 X_i - \beta_1 C_i) \end{array} \tag{14}$$

In Equation (14), Φ is the cumulative density function of the standard normal distribution. As with the binary Probit model, the order-probit model parameters will be estimated using the great likelihood estimation method.

3.3.2. Mediation Effect Model

The mediating effect model can be used to analyze the process and mechanism of independent variables affecting the dependent variable. Compared with regression analysis, mediation effect analysis can get more in-depth results. Therefore, to verify the mediating effects of production and operation investment, land operation scale, and green technology exchange in the interaction of bancassurance on the adoption of green production technology in family farms, this study refers to the mediating effect model proposed by Iacobucci [71], and uses the stepwise regression method to establish the models between independent variables, dependent variables, and mediating variables, respectively, and the mediation test is shown in Figure 4. The regression Equation are as follows:

$$Y_i = \alpha_1 X_i + \beta_1 C_i + \varepsilon_i \tag{15}$$

$$M_i = \alpha_2 X_i + \beta_2 C_i + \varepsilon_i \tag{16}$$

$$Y_i = \alpha_3 X_i + \alpha_4 M_i + \beta_3 C_i + \varepsilon_i \tag{17}$$

The mediators in Formulas (16) and (17) include production and operation investment, land management scale, and green technology exchange, and the rest of the variables are the same as in Formula (12). Equations (15) and (17) choose the order-probit model, and Equation (16) selects the model according to the type of mediating variables. Production and operation investment and land operation scale are continuous type variables, so OLS regression model is selected. Green technology exchange is a multicategorical variable, so the order-probit model is selected.

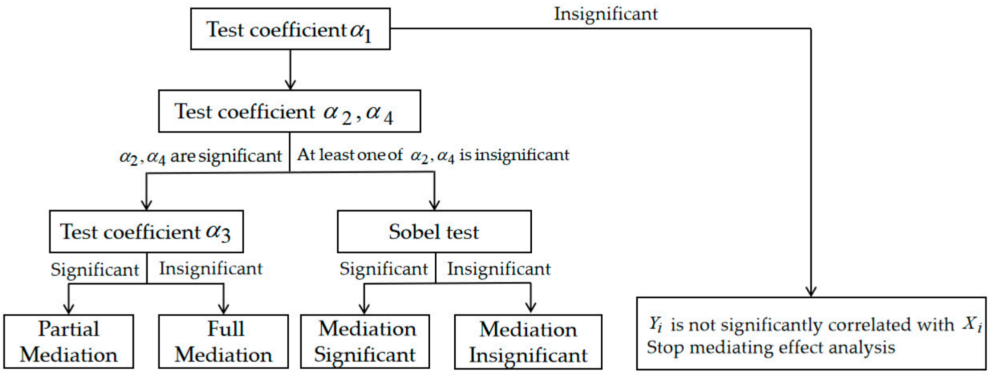

Figure 4. Intermediary effect stepwise regression method.

4. Results

4.1. The Impact of the Bancassurance Interaction on the Adoption of Green Production Technology

Before the benchmark regression model is tested, it is necessary to test whether the model constructed in this paper meets the basic assumptions of the linear model. First, this paper conducts a multicollinearity test on the model. The correlations between the variables are measured, and the empirical results show that although some explanatory variables are correlated, the correlation is basically below 0.5. In addition, in order to avoid problems such as unstable parameter estimation and unreliable model results caused by collinearity, this paper uses the variance inflation factor (VIF) to diagnose the collinearity of the model. The results show that the VIF value of each explanatory variable is between 1.06–2.92, the average value is 1.42, and the maximum value is also less than 10. According to the VIF test rule [72], it shows that the model does not have serious multicollinearity. Second, this paper uses the measured skewness and kurtosis to test for normal distribution, and the results of the study show that the absolute value of skewness of each variable is less than 3 and the absolute value of kurtosis is less than 10, indicating that the data are basically accepted as normally distributed [73]. Finally, this paper conducted a heteroskedasticity test by white test and BP test. The results of the study showed that the p-value did not pass the significance test and the hypothesis of homoscedasticity was accepted, indicating that there was no heteroscedasticity problem. In order to better mitigate the heteroskedasticity problem, robust standard errors are used in model tests in this paper to overcome the problem of possible heteroskedasticity in the regression.

Table 2 calculates the impact of farmers' participation in the bancassurance interaction, agricultural credit, and agricultural insurance on green production technology adoption. The empirical results show that the bancassurance interaction, agricultural credit, and agricultural insurance can all significantly promote family farmers' adoption of green production technology. The impact coefficients of the bancassurance interaction participation, agricultural credit participation, and agricultural insurance participation are 0.2676, 0.1547, and 0.2159, respectively, indicating that the bancassurance interaction has the most significant impact on family farmers' adoption of green production technology. It demonstrates that the benefits of the bancassurance interaction to green agricultural development are far greater than the respective development of agricultural credit and agricultural insurance. Agricultural credit funds agricultural green production, promoting farmer production scale expansion and technical exchanges. Agricultural insurance manages risk in green production and alleviates producers' concerns. Agricultural credit and insurance significantly impact family farmers' use of green production technology. The dual functions of agricultural credit and insurance have been fully enhanced under the bancassurance interaction mode. It can eliminate the risk of farmers lacking collateral and losing collateral due to possible improper production and management, dramatically improving farmers' green production utility. Therefore, H1 is confirmed.

Table 2. Empirical results of bancassurance interaction on family farmers' adoption of green production technologies.

Variables	Green Technology Adoption (1)	(2)	(3)
Bancassurance Interaction	0.2676 ** (0.1070)		
Credit		0.1547 * (0.0876)	
Insurance			0.2159 ** (0.0882)
Age	−0.0185 *** (0.0048)	−0.0175 *** (0.0048)	−0.0189 *** (0.0048)
Gender	0.0571 (0.1205)	0.0389 (0.1216)	0.0563 (0.1221)
Education	0.0477 *** (0.0152)	0.0491 *** (0.0153)	0.0462 *** (0.0152)
Workforce	0.0414 (0.0366)	0.0401 (0.0368)	0.0355 (0.0364)
Financial professionals	0.3738 *** (0.1304)	0.3635 *** (0.1301)	0.3762 *** (0.1321)
Government support	0.0158 (0.0928)	0.0379 (0.0928)	0.0294 (0.0925)
Planting income	0.0538 *** (0.0113)	0.0532 *** (0.0113)	0.0543 *** (0.0113)
Green cognition	0.1618 *** (0.0375)	0.1706 *** (0.0372)	0.1586 *** (0.0374)
Business information	0.1438 *** (0.0435)	0.1438 *** (0.0436)	0.1456 *** (0.0436)
Natural disasters	−0.0062 (0.0336)	−0.0008 (0.0341)	−0.0145 (0.0337)
N	564	564	564

Note: ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively, and the standard errors are in brackets.

Demographic characteristics, such as the age and education level of farmers, significantly impact the adoption of green production technologies. Among them, age has a significant negative impact on green production technology adoption, possibly due to older farmers' higher risk tolerance and slower acceptance of new things. Their level of education can influence farmers' ability to learn green technology. However, family characteristics, family financial professionals, annual household planting income, green cognition, and business information sources all positively affect green production technology adoption.

4.2. Endogenous Problem Handling

Considering the possible endogeneity of the bancassurance interaction on the adoption behavior of green production technology in family farms due to omitted variables or reverse causality, the endogeneity problem can be better solved by combining instrumental variables and conditional mixed process (CMP) estimation method for an ordered Probit model with endogenous variables [74]. Therefore, this paper adopts the CMP estimation method and uses "the frequency of communication between family farms and bank and insurance company staff" as the instrumental variable in the regression analysis with reference to the research of Xu [75]. The main considerations are as follows: First, the more exchanges between family farms and staff of banks and insurance companies, the easier it is to affect the interaction and participation of family farms in banking and insurance. Second, the frequency of communication between family farms and bank and insurance staff does not directly affect the adoption of agricultural green technology production, which meets the requirements for instrumental variables. The results of the study are shown in Table 3. The results of the first stage indicate that the frequency of communication with bank and insurance company staff significantly affects family farm bancassurance interaction participation, satisfying the requirement of the relevance of the instrumental variable. The results of the second stage regression indicated that after correcting for the endogenous problem, the bancassurance interaction still positively promoted green production technology adoption behavior in family farms. The mixed regression insig_2 values were significant and the likelihood ratio passed the test, indicating that the model estimates were significant. The auxiliary estimation parameter atanhrho significant can indicate that there is a significant correlation between the two joint cubic equations, and joint estimation using the CMP mixed process is more effective than separate estimation. In addition, since CMP cannot test the weak instrumental variables problem, in order to further verify the validity of the instrumental variables, reference is made to Chyi [76], with the help of the weak instrumental variables test for linear models. The results show that the weak instrumental variable test F-statistic is 24.264, which is much greater than 10, rejecting the hypothesis of weak instrumental variables and confirming the necessity of the endogeneity test.

Table 3. Endogenous test results.

Variables	The First Stage: Bancassurance Interaction	The Second Stage: Green Technology Adoption
Bancassurance interaction		1.4095 *** (0.3757)
Frequency of communication with bank and insurance company staff	0.0778 *** (0.0158)	
Control variables	Controlled	Controlled
Insig_2	−0.9233 *** (0.0297)	
atanhrho	−0.5323 ** (0.2084)	
F-value	24.264	
N	564	

Note: ***, ** indicate significance at the 1%, 5% levels, respectively, and the standard errors are in brackets.

4.3. Robustness Test

4.3.1. PSM Test

Endogeneity may exist between the bancassurance interaction and family farms' green production technology behavior. Hence, the Propensity Matching Score method (PSM) can solve the problems of selection bias and bidirectional causality caused by sample self-selection because there may be endogeneity between the bancassurance interaction and the green production technology behavior of family farms. Therefore, this study employs five matching methods to examine the average treatment effect of the bancassurance interaction, agricultural credit, and agricultural insurance on family farms' green production technology behavior. The average value of five methods was used for analysis. As shown in Table 4, the bancassurance interaction can positively affect the adoption behavior of green production technology in family farms using k-nearest neighbor matching, caliper matching, K-nearest neighbor matching within the caliper, kernel matching, and sample matching methods. The impact effect before matching is 0.5518, and the net result after matching is 0.5729.

Similarly, under the test of five matching ways, agricultural credit and insurance play an important role in promoting the adoption of green production technology in family farms. After matching, the net effect of agricultural credit and agricultural insurance is 0.3065 and 0.4838, respectively, smaller than the effect of the bancassurance interaction. The robustness of H1 is confirmed.

Table 4. PSM test results.

Matching Method	Bancassurance Interaction		Credit		Insurance	
	ATT	T	ATT	T	ATT	T
Before matching	0.5518 *** (0.2040)	2.70	0.2780 * (0.1677)	1.66	0.4712 *** (0.1711)	2.75
K-nearest neighbor matching (k = 4)	0.5934 *** (0.2040)	2.63	0.3790 ** (0.1858)	2.04	0.3751 ** (0.1882)	1.99
Caliper matching	0.5907 *** (0.2258)	2.62	0.3802 ** (0.1860)	2.04	0.3751 ** (0.1882)	1.99
K-nearest neighbor matching within caliper	0.5343 *** (0.2032)	2.63	0.2883 * (0.1707)	1.69	0.4856 *** (0.1731)	2.80
Kernel matching	0.5841 *** (0.2020)	2.89	0.3065 * (0.1688)	1.82	0.4838 *** (0.1706)	2.84
Spline matching	0.5620 *** (0.2000)	2.81	0.3125 * (0.1738)	1.80	0.4663 *** (0.1767)	2.64
Average after matching	0.5729	-	0.3333	-	0.4371	-

Note: ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively, and the standard errors are in brackets.

4.3.2. A Multi-Attribute Decision Support System Approach Based on the Logit Model

The decision-support system (DSS) models are systematic approaches that assist and support users in making decisions, helping agricultural producers analyze influencing factors and make appropriate decisions based on the actual situation [77,78]. Domain analysis and modeling of decision support to assist in the development of DSS are in great demand, and an effective approach is needed to assist in this effort. This paper presents a multi-attribute decision support approach based on the Logit model, proposes relevant elements of a decision support system, explores the correlations among the features of the decision system, and compares the degree of correlation so that the decision-influencing factors can be rated. Specifically, this paper selects 17 optimization elements affecting decision-making in eight categories based on intrinsic and extrinsic factors supporting green production decision-making in family farms. On the one hand, based on the theory of planned behavior, the capital endowment of family farms (including human capital, natural capital, physical capital, and social capital) and farmers' green cognition are selected as intrinsic factors to explore the internal behavioral logic of family farms' green production decisions [79,80]. On the other hand, based on the normative activation model, financial support policy regulation and market orientation are selected as the extrinsic environmental factors to discuss the incentive influences on green production decisions of family farms [81,82]. Columns (1) to (3) of Table 5 present the empirical results of the impact of internal and external factors on the adoption behavior of green production technology in family farms under the case of financial support indicators represented by the bancassurance interaction, agricultural credit, and agricultural insurance, respectively. From the internal factors, human capital, physical capital, and green perceptions are all crucial factors influencing family farms' decision-making, among which green perceptions have the most significant influence among the internal factors. From the external factors, financial support and binding government regulation can positively influence family farm production decisions. Among them, the role of financial support is the most significant. Overall, financial factors have a non-negligible role among the internal and external factors that influence the decision of green production technology in family farms. Compared to the three different financial support factors, the most significant role of the bancassurance interaction in promoting green production technology decisions of family farms verifies the necessity of this paper's research and confirms hypothesis 1 again.

Table 5. Empirical results of multi-attribute decision support system method based on logit model.

Elements	Variable Category	Variables	Green Technology Adoption (1)	(2)	(3)
Internal Elements	Human Capital	Farmers' health status	−0.1281 (0.1174)	−0.1399 (0.1171)	−0.1281 (0.1177)
		Cultural level	0.1118 *** (0.0273)	0.1134 *** (0.0274)	0.1091 *** (0.0273)
		Number of farm-owned laborers	0.0890 * (0.0505)	0.0841 * (0.0502)	0.0928 * (0.0507)
	Natural Capital	Owned arable land area	−0.0035 (0.0041)	−0.0032 (0.0041)	−0.0044 (0.0041)
	Physical Capital	Family farm farming income	0.0851 *** (0.0202)	0.0842 *** (0.0201)	0.0842 *** (0.0201)
		Value of owned agricultural machinery	0.0892 *** (0.0223)	0.0886 *** (0.0225)	0.0924 *** (0.0222)
	Social Capital	Join a professional farmers' cooperative	0.2377 (0.1566)	0.2638 * (0.1561)	0.2441 (0.1561)
		Join the family farm alliance	−0.0859 (0.1791)	−0.0774 (0.1789)	−0.1001 (0.1791)
	Green Awareness	Farmers' knowledge of green production	0.2675 *** (0.0706)	0.2824 *** (0.0707)	0.2665 *** (0.0705)
External Elements	Financial Support	Bancassurance interaction	0.4155 ** (0.1856)		
		Credit		0.2761 * (0.1504)	
		Insurance			0.3783 ** (0.1556)
	Government Regulation	Incentive regulation (subsidies)	0.0046 (0.0701)	−0.0004 (0.0702)	−0.0122 (0.0698)
		Binding regulation (punishment)	0.1445 ** (0.0659)	0.1453 ** (0.0661)	0.1421 ** (0.0659)
	Market Orientation	Reactive market orientation (consumer demand)	−0.0864 (0.1031)	0.1377 (0.0992)	−0.0823 (0.1032)
		Pioneering market orientation (green development future expectations)	0.1408 (0.0991)	0.1377 (0.0992)	0.1481 (0.0992)
Statistical test		Log likelihood	−1099.9864	−1100.8095	−1099.5336
		LR chi2	127.93	126.28	128.83
		Prob > chi2	0.0000	0.0000	0.0000
		Pseudo R2	0.0550	0.0542	0.0553
		N	564	564	564

Note: Table 5 measures the variance inflation factor (VIF) for the explanatory variables, and the test results are in the range of 1.01–2.89, with a mean VIF of 1.40, all of which are less than 10, indicating that there is no problem of multicollinearity between the variables. In addition, ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively, and the standard errors are in brackets.

4.4. Heterogeneity Analysis

The direct effect of the bancassurance interaction on the adoption of green production technologies in family farms was verified in the previous section. However, the above results only reflect the average effect across the whole sample and do not reflect the differences between groups. Family farms at different family life cycle stages and family income levels differ in capital accumulation, demographic structure, risk preferences, and their production goals and factor inputs to the farm. Therefore, this paper analyzes the heterogeneity of the effects of the bancassurance interaction on adopting green production technologies in family farms by grouping them according to the family life cycle and economic level.

4.4.1. Grouped by Family Life Cycle

The stage of the family is an essential factor affecting agricultural producers' decision-making. According to the results in Table 6, the bancassurance interaction and agricultural insurance positively impact the adoption of green production technology behavior of family farmers only during the dependency period. The impact of other stages is insignificant.

One possible explanation is that family farms accounted for a large proportion of the group during the dependency period. Most of these family farms are young, with a strong acceptance and cognitive ability for new things. The primary source of burden for family farms during the dependency period is only the children. At this time, the family farm has a large labor force, and the farmer's parents can help take care of the grandchildren and run the farm, significantly reducing the farmer's burden. The farmer's business is expanding compared to the start-up period, and they have enough energy to work hard and are eager to produce new varieties of agricultural products. As a result of the promotion of the bancassurance interaction, the adoption of green production technology can be improved. Furthermore, when the coefficient values of the bancassurance interaction and agricultural insurance are compared, the positive impact of the bancassurance interaction on farmers' green production technology is still more significant than that of agricultural insurance during the dependency period.

Table 6. Heterogeneity Analysis Results: Family Life Cycle.

Variables	Start-Up Period	Dependency Period	Burden Period	Support Period
Bancassurance Interaction	0.1712 (0.2627)	0.4823 *** (0.1620)	0.0104 (0.1926)	0.3468 (0.4281)
Credit	0.1000 (0.2630)	0.1862 (0.1322)	0.1071 (0.1612)	0.1685 (0.4305)
Insurance	0.2018 (0.2615)	0.2784 ** (0.1253)	0.0569 (0.1664)	0.4249 (0.3883)
N	77	267	182	38

Note: ***, ** indicate significance at the 1%, 5% levels, respectively, and the standard errors are in brackets.

4.4.2. Grouped by Family Economic Level

The results of the effect of the bancassurance interaction on the adoption behavior of green production technology in family farms under different household economic situations are shown in Table 7. When the economic condition of the family farm is at the low-income level, there is a significant positive effect of the bancassurance interaction on the adoption behavior of green production technology. The effect of agricultural credit on green production technology adoption behavior was more important when the economic condition of family farms was at the middle-income level. When the family farm's economic condition was at a high-income level, agricultural insurance positively affected green production technology adoption behavior. This result indicates that the bancassurance interaction policy is more susceptible to the low-income level. It proves that the bancassurance interaction has a more significant effect on income generation for low-income groups, thus promoting the adoption of green production techniques among low-income groups. The less pronounced effect of the bancassurance interaction on the adoption of green production technologies in the middle-income and high-income groups may stem from the fact that the middle-income and high-income groups have fewer financing constraints than the low-income groups, and the bancassurance interaction provides more access to credit for the low-income groups, thus affecting green agricultural production.

Table 7. Heterogeneity Analysis Results: Family Economic Level.

Variables	Low-Income Level	Middle-Income Level	High-Income Level
Bancassurance Interaction	0.3741 * (0.1940)	0.1843 (0.1882)	0.2699 (0.1801)
Credit	0.2140 (0.1553)	0.2895 * (0.1632)	0.1250 (0.1480)
Insurance	0.2075 (0.1611)	0.0971 (0.1510)	0.2785 * (0.1548)
N	191	183	190

Note: * indicate significance at the 10% levels, and the standard errors are in brackets.

4.5. Mechanism Analysis

Based on the direct impact of the bancassurance interaction on the adoption of green production technology in family farms, this study continues to explore the indirect impact mechanism of the bancassurance interaction on the adoption of green production technology in family farms from three perspectives: production capital investment, land scale expansion, and green technology exchange (Table 8). First, the interaction of bancassurance has a significant positive impact on agricultural production capital investment. After controlling the direct impact of the bancassurance interaction on farm green production technology behavior, the investment in agricultural production funds plays a vital role in promoting green production technology adoption in family farms. This shows that farmers will increase their capital investment in agricultural production after participating in the bancassurance interaction. The higher the investment in productive capital, the greater the adoption of green production technology. It shows that participating in the bancassurance interaction can increase the investment in agricultural production funds, thereby increasing the adoption of green production technology. H2 was validated. Second, the bancassurance interaction can have a significant positive impact on landscale expansion. After controlling the impact of the bancassurance interaction on green production technology, land scale expansion can also significantly impact green production technology adoption. It shows that land scale expansion is mediating in promoting green production technology adoption via the bancassurance interaction. H3 has been confirmed. Finally, the interaction of bancassurance can positively promote farmer green technology exchange. Green technology exchange can encourage farmers to adopt green production technology by including the bancassurance interaction variable. It shows that the bancassurance interaction can strengthen communication between farmers and other producers or professional technicians through financial support and risk protection, as well as increase the frequency of farmers' participation in technical training, thereby increasing the level of green technology adoption. H4 thus is validated. Furthermore, the ratio of the mediation effect of the three mediator variables to the total product was calculated in this study, and the calculation formula is: $\alpha_2\alpha_4/\alpha_1$. Therefore, the intermediary effects of production capital investment, land scale expansion, and green technology exchange accounted for 31.25%, 7.98%, and 9.53%, respectively. It shows that the indirect impact of the bancassurance interaction on adopting green production technology is dominated by production capital investment, green technology exchange, and land scale expansion.

Table 8. Mediating Effect Results.

Variables	Production Capital Investment	Green Technology Adoption	Land Scale Expansion	Green Technology Adoption	Green Technology Exchange	Green Technology Adoption
Bancassurance Interaction	0.6638 *** (0.1307)	0.1856 * (0.1108)	0.3355 ** (0.1580)	0.2462 ** (0.1092)	0.1931 * (0.1086)	0.2453 ** (0.1080)
Production capital investment		0.1260 *** (0.0336)				
Land scale expansion				0.0637 ** (0.0307)		
Green Technology Exchange						0.1321 *** (0.0441)
Age	−0.0191 *** (0.0083)	−0.0163 *** (0.0048)	−0.0024 (0.0076)	−0.0184 *** (0.0048)	−0.0062 (0.0052)	−0.0179 *** (0.0047)
Gender	−0.1722 (0.1713)	0.0797 (0.1212)	−0.0615 (0.1829)	0.0597 (0.1196)	0.1201 (0.1365)	0.0431 (0.1231)
Education	0.0817 *** (0.0207)	0.0379 ** (0.0152)	0.1032 *** (0.0223)	0.0413 *** (0.0152)	0.0546 *** (0.0183)	0.0405 *** (0.0154)
Workforce	0.0515 (0.0582)	0.0351 (0.0372)	−0.0516 (0.0538)	0.0448 (0.0369)	0.0282 (0.0442)	0.0366 (0.0367)

Table 8. *Cont.*

Variables	Production Capital Investment	Green Technology Adoption	Land Scale Expansion	Green Technology Adoption	Green Technology Exchange	Green Technology Adoption
Financial professionals	0.2309 (0.1583)	0.3501 *** (0.1311)	0.0999 (0.1642)	0.3691 *** (0.1298)	0.6262 *** (0.1283)	0.3060 ** (0.1313)
Government support	−0.0171 (0.1209)	0.0195 (0.0931)	−0.0570 (0.1299)	0.0202 (0.0931)	0.1572 (0.1029)	0.0039 (0.0929)
Planting income	0.0306 * (0.0166)	0.0508 *** (0.0114)	0.1707 *** (0.0199)	0.0433 *** (0.0124)	0.0164 (0.0117)	0.0521 *** (0.0114)
Green cognition	0.0678 (0.0455)	0.1550 *** (0.0375)	0.0965 * (0.0511)	0.1563 *** (0.0376)	0.2376 *** (0.0414)	0.1339 *** (0.0383)
Business information	0.1201 ** (0.0578)	0.1308 *** (0.0439)	0.0204 (0.0656)	0.1430 *** (0.0438)	0.1417 *** (0.0519)	0.1267 *** (0.0437)
Natural disasters	−0.0565 (0.0446)	0.0006 (0.0333)	−0.0477 (0.0473)	−0.0033 (0.0334)	0.1050 *** (0.0367)	−0.0191 (0.0343)
N	564	564	564	564	564	564

Note: ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively, and the standard errors are in brackets.

5. Discussion

The comprehensive promotion of green agricultural production technologies is essential to protect the ecological environment and achieve high-quality agricultural development. Promoting the adoption of green production technologies requires the extensive participation of new agricultural business entities such as family farms. Previous studies have explored further factors influencing the adoption of green production technologies, but few scholars have focused on the impact of bancassurance interactions. The main contributions of this paper are as follows:

First, it was found that the bancassurance interaction positively influence family farms' green production technology adoption behavior. Credit constraints are a common problem that farmers face in developing countries. Adverse selection and moral hazard due to information asymmetry in credit markets are important causes of credit constraints [83]. Agricultural producers face the dual constraints of high collateral value and high interest rates in lending. Financial institutions face high default risk, making it more difficult for agricultural producers to obtain loans from the credit market [84]. To alleviate the constraints in the rural credit market, a reasonable loan model has been designed from the perspective of agricultural producers to reduce the problems of credit default and information asymmetry. The first products combining insurance and agricultural credit were introduced in Peru, and since then, the application of the bancassurance interaction has been promoted in developing countries. Using agricultural insurance policies as collateral to solve the problem of credit rationing in rural areas and improve farmers' risk tolerance has an essential impact on agricultural production. The results of this paper provide strong support for using the bancassurance interaction for the green production of family farms. In addition, other scholars have separately explored the impact of agricultural insurance and agricultural credit on agricultural green production, which is supported in this paper. In line with the previous studies [85,86], this paper finds that both agricultural insurance and agricultural credit can positively influence the green production technology of family farms. This paper compares the magnitude of the utility generated by the bancassurance interaction, agricultural insurance, and agricultural credit at the theoretical and empirical levels. It finds that the impact of the bancassurance interaction on the adoption of green production technology in family farms is much more significant than the utility entailed by the development of agricultural insurance or agricultural credit alone, which again confirms the necessity of bancassurance interaction policy implementation, complementing existing studies.

Second, capital investment, land scale expansion and technology exchange are essential in influencing the adoption of green production technologies on family farms through the bancassurance interaction. The bancassurance interaction is a "stabilizer" for agricultural production, as it not only underwrites the income of family farms, but also provides more production capital, effectively increasing confidence in productive investment. It has been shown that when family farms are sure to have more income in the future, they will increase their agricultural inputs and thus promote green production technologies [87,88]. In the final analysis, the bancassurance interaction fundamentally solves the contradiction between "capital for profit" and "risk aversion," and its existence is conducive to improving farmers' expected returns and the stability of agricultural production, thus bringing into play their advantages in terms of management capacity, economies of scale, and technological level to allocate factor inputs rationally. This contradiction is conducive to improving farm owners' expectations of the profitability and stability of agricultural production, so that they can take advantage of their management capabilities, economies of scale, and technology and allocate their factor inputs rationally. Therefore, regardless of whether it is done to increase capital investment, expand the land scale, or strengthen technology exchange, the interaction between banks and insurance can effectively promote family farms' green technology adoption behavior. The research reveals that capital investment has a significant influence on the relationship between bancassurance interaction and the adoption of green production technology by family farms. This suggests that the bancassurance interaction facilitates green production-related investments in agriculture by improving credit accessibility for family farms, which ultimately leads to an increase in the adoption of green production technologies. Therefore, this finding highlights the primary impact of the bancassurance interaction on promoting sustainable agricultural practices and emphasizes its crucial role in supporting green agricultural development policies.

Finally, there is some heterogeneity in the impact of the bancassurance interaction on adopting green production technologies in family farms under different family life cycle stages and economic levels. On the one hand, family farms allocate their financial resources differently. They are influenced to produce stage changes in agricultural input due to the stage changes in the family life cycle. In existing studies, the family life cycle is also often considered an important factor influencing production decisions in farm households [89]. Wu [90] showed that the financial burden of the birth of a farmer's child gradually increases during the dependency period. In addition, the increased time spent on childcare causes farmers to increase their agricultural input by making agricultural production the main source of the household economy. Therefore, family farms in the dependency period are more likely to be influenced by bancassurance interactions than those in other family life cycle stages, bringing more benefits to green agricultural production. On the other hand, due to the severe information asymmetry in the credit market, the economic level of households affects the availability of loans for family farms, and most financial institutions are more willing to lend funds to farmers with higher levels of economic development to avoid the risk of default through qualification checks [91]. This phenomenon results in lower household economic level farms having less access to lending opportunities and thus cannot increase investment in agricultural green production. The emergence of the bancassurance interaction has addressed this challenge for low-income family farms. Meanwhile, agricultural insurance reduces production risk for low-income households and protects the farm's repayability [46,92]. Agricultural credit, using agricultural insurance policies as collateral, eases credit rationing for farms and effectively contributes to increasing income for low-income family farms. Therefore, the impact of the bancassurance interaction on the green development of low-income family farms is more evident [57]. Overall, capturing the family farm life cycle stage and family economic level to maximize the advantages of the bancassurance interaction is essential for promoting sustainable agricultural development.

This paper also has limitations: First, this study only investigates and analyzes family farms in Shaanxi Province. The sample coverage needs to be increased, and adding more provinces for comparative analysis would make the study more enjoyable. The project team plans to research other areas to expand the study's sample size. Second, the article analyzes only one year's worth of data, which does not allow for a dynamic understanding of the impact of the interaction between banking and insurance and may cause problems due to the lag in effect. The study will continue to follow up on family farmers to reflect on and address rural realities more scientifically and accurately.

6. Conclusions and Policy Implications

This paper analyzed the impact and mechanism of the bancassurance interaction, agricultural credit, and agricultural insurance on the green production technology adoption behavior of 564 planting family farms in Shaanxi Province. We examined the mediating effect of agricultural production investment, land scale expansion and green technology exchange in the influence of the bancassurance interaction on green production technology adoption behavior. This study also analyzed the heterogeneous impact of the bancassurance interaction on the adoption behavior of green production technology in family farms under family life cycle and economic levels. The results of the study are as follows: First, the bancassurance interaction, agricultural credit, and rural insurance all have a positive effect on the family farm adoption of green production technology. The promotion effect of the bancassurance interaction is greater than that of agricultural credit and insurance. The conclusion remains unchanged after using the PSM method and the multi-attribute decision support system method based on the logit model for the robustness test. Second, increasing agricultural production investment, expanding land management scale, and increasing green technology exchanges are effective ways for the bancassurance interaction to promote green production technology adoption in family farms. The intermediary effect of agricultural production investment is the most visible among them, while the effect of land scale expansion is the weakest. Third, heterogeneity analysis shows that the bancassurance interaction has a heterogeneous impact on family farms with varying family life cycles and economic levels. Among them, the bancassurance interaction is more visible for family farms' green production behavior during the dependency period. Simultaneously, the positive contribution of the bancassurance interaction on green technology adoption is more significant for low-income level family farms.

The research results reveal that the bancassurance interaction can significantly promote the green production transformation of new business entities such as family farms. Therefore, this study puts forward the following policy recommendations: First, the cooperation between banks and insurance companies must be strengthened while innovating the bancassurance interaction model. Based on the individualized capital needs of agricultural producers in various regions, flexible incentive policies for green loans and green insurance products will encourage investment in green production. Simultaneously, use modern technology to improve the risk management and supervision system, develop scientific and practical risk assessment methods, and improve agricultural insurance's risk prevention and control capabilities. Second, the synergistic effect of the bancassurance interaction and production factor allocation must be maximized to enhance the adoption of green production by new agricultural business entities. Increase financial support for new agricultural business entities, create various incentive mechanisms such as capital and technology, promote output at a moderate scale, and enhance land use efficiency. At the same time, expand green production technology communication channels. Exchange meetings on green technology can be organized regularly by the government, farmers' cooperatives, or family farm alliances to share green production technology and management experience. In addition, stakeholders must fully use Internet information technology platforms, such as Tik Tok and WeChat, to strengthen the publicity and promotion of green production technology, and to improve family farmers' awareness and recognition of green production. Farmers must also be encouraged to focus on green production, and family farmers in the dependency period and with low-income levels should be given special attention.

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