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The Symbiotic Mechanism of the Influence of Productive and Transactional Agricultural Social Services on the Use of Soil Testing and Formula Fertilization Technology by Tea Farmers

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Abstract: In this investigation, we analyze data from 929 tea farmers across Shanxi, Sichuan, and Anhui provinces to elucidate the impact of productive and transactional agricultural social services on farmers' adoption of soil testing and formula fertilization technology. Our perspective centers on the farmers' standpoint and the underpinning mechanisms of these influences. Our findings delineate several key points: Both transactional and productive socialized services exert a positive influence on farmers' decisions to adopt green production technologies, with the impact of productive socialized services being more pronounced than their transactional counterparts. The enthusiasm and the scale of adoption for green production technologies among farmers are positively impacted by both types of socialized services, a conclusion robust even when potential endogeneity and other statistical biases are corrected using IV Probit. The influence mechanism of transactional and productive social services operates symbiotically, primarily fostering trust, enhancing farmers' tea price expectations and industry cognition, driving positive social evaluations, and motivating speculative behavior among farmers. Transactional and productive socialization services show varying propensities in promoting the adoption of soil testing and formula fertilization technology, depending on the farmers' type, endowments, and income levels. Involvement in these agricultural socialization services enables farmers to bolster their income, improve technical proficiency and information-gathering capabilities, jointly participate in market competition, reduce market risks, and enhance their recognition and choice of green production technologies. This appears to be a crucial catalyst for the successful promotion of greener development and transformation within agriculture and rural areas.

Keywords: transactional agricultural socialization service; productive agriculture socialization service; farmers; technology of soil testing and formula fertilization

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1. Introduction

Chemical fertilizers constitute a pivotal component in modern agricultural production. Economically, their employment amplifies crop yield and augments productivity per unit of land, thereby bolstering global food security [1]. However, in terms of sustainability, despite their necessity for soil nutrient replenishment and crop growth, their overuse and misuse can precipitate environmental degradation and biodiversity loss. As per the National Bureau of Statistics, China's agricultural fertilizer usage surged from 41.46 million tons in 2000 to 51.912 million tons in 2021, marking an average annual growth rate of 1.2%. Amid such a context, there is increasing acknowledgment of the environmental challenges incumbent upon traditional agricultural practices and an amplified focus on transitioning towards sustainable "green" methodologies. Soil testing and formula fertilization technology represent such a green approach, contributing significantly to nutrient utilization optimization, productivity enhancement, and the mitigation of non-point source agricultural pollution [2]. In response to this trend, the Ministry of Agriculture unveiled the "Zero-Growth Action Plan for Fertilizer Use by 2020", advocating for the active promotion of soil testing and formula fertilization technology to refine farmers' fertilization techniques and accomplish fertilizer reduction. However, despite its promise, the adoption rate of this fertilizer reduction technology among farmers stands at a mere 30%. Thus, there is a pressing need to hasten the promotion and application of soil testing and formula fertilization technology to augment fertilizer utilization efficiency and enable cost savings and increased income in agricultural production [3].

The extant literature, both domestic and international, provides substantial evidence elucidating the factors that impact farmers' adoption of soil testing and formula fertilization technologies, from a conventional economic viewpoint. This comprehensive review focuses on the following key aspects: Firstly, at the individual farmer level, cognition plays a pivotal role in the decision to adopt soil testing and formula fertilization technologies. As posited by the Theory of Planned Behavior, several cognitive components—including farmers' perception of technology's ease-of-use and perceived utility [4], their attitudes, subjective norms, perceived behavioral control [5], market normative perception [6], technological awareness, environmental awareness, and risk awareness—significantly influence their behavioral intentions [7,8]. In essence, farmers' propensity to adopt these technologies is directly correlated to their perceived ease of mastering these, the associated risk factor, and market demand. A simplified understanding of the technology, reduced risk, and heightened market demand augments the potential benefits, thereby increasing the likelihood of adoption. Secondly, resource endowment emerges as a crucial determinant influencing the farmers' adoption of soil testing and formula fertilization technologies. The familial possession of the factors of production, such as land, capital, and labor, are intrinsically linked to the farmers' production practices and behavioral choices. The magnitude of land management, the degree of fragmentation [9], and the quality of cultivable [10] land pose limitations on technology adoption. Conversely, labor mobility [11], human capital, and livelihood capital [12], under particular circumstances, can catalyze the adoption of soil testing and formula fertilization technologies amongst rural households. Furthermore, non-physical resource endowments, notably social capital [13] and information transmission [14], exert direct and indirect influences on farmers' production behaviors. Moreover, government policies, encompassing technology promotion initiatives and subsidy programs, are vital in shaping the adoption of soil testing and formula fertilization technologies among farmers [8,15]. As rational actors in the market, farmers' trust in policies plays a critical role, with subsidy provision effectively boosting technology adoption. Notably, green production technologies bring about positive externalities, and their beneficial environmental impact can be challenging to quantify in terms of market prices. As such, government regulations, the diffusion and promotion of precision agriculture technologies [16], and well-structured technology promotion measures exert a substantial influence on the uptake of soil testing and formula fertilization technologies among farmers [17].

In the face of accelerating urbanization, industrialization, and information technology advancement, China's rural labor structure has increasingly exhibited traits of aging, feminization, and part-time employment. This shift presents small-scale farmers with an array of new challenges in the realm of agricultural production. More tasks are becoming progressively difficult, impractical, or economically inefficient for individual households to carry out [12]. For small-scale farmers, achieving advanced production technology and specialization is a crucial pathway towards scaling management practices, adopting green production technologies, and promoting sustainable development and modernization in agriculture. Current academic research on agricultural socialization services primarily encompasses the construction of its system model, guidance in land scaling management [18], the promotion of improvements in agricultural technical efficiency and production efficiency [19], and the crucial linkage between small farmers and modern agriculture [20]. Moreover, several scholars have investigated the effects of agricultural socialization services on farmers' green production practices [2], including the adoption of reduced fertilizer use and biopesticide technologies.

Despite the wealth of research conducted on agricultural socialization services, there is a notable paucity of investigations into the different types of such services. The majority of studies tend to emphasize enhancing production efficiency [21], often neglecting the significant role of transaction services. Additionally, very few studies have explored the impact of agricultural socialization services on green production technologies, specifically soil testing and formula fertilization. The inquiry into and discussion of the underlying impact mechanisms have remained largely theoretical, devoid of empirical methods and data validation. From a research perspective [22], some investigations have been conducted from a family and land transfer standpoint. However, studies probing the mechanisms from a farmer's perspective are noticeably limited. Lastly, in using the entropy method to measure agricultural socialization services, some scholars may overlook the importance of the indicators themselves, leading to potential bias in the results. Consequently, it becomes crucial to delve into the impact of transactional and productive social services on the adoption of soil testing and formula fertilization technology from a farmer's perspective, making it a worthwhile avenue to explore further.

This study offers marginal contributions to the existing body of literature in several key ways: Firstly, it deepens the understanding of the transactional and productive social service model in the context of agricultural socialization services and their influence on the adoption of soil testing and formula fertilization technology. While the previous literature has largely focused on the role of productive socialization services in scale management and the improvement of agricultural technical efficiency, our work employs micro-farmer data to examine the understudied impact of these services on the adoption of soil testing and formula fertilization technology. Secondly, we adopt the coefficient of variation method to gauge the extent of agricultural productive and transactional socialized services. Prior research often lacks a comprehensive examination of farmers' utilization of different agricultural socialized services. By recognizing the endogeneity problem and applying the instrumental variable method, we enhance the precision of our estimation results, demonstrating that the usage of agricultural socialized services bears a direct and economically significant impact on farmers' adoption of soil testing and formula fertilization technology. Thirdly, our study offers novel insights into the mechanisms underlying the adoption of green fertilization technology within the agricultural socialized service mix, particularly from the farmers' perspective. We identify and examine the influencing pathways of trust, price expectation, industry cognition, social evaluation, and speculative behavior among farmers, providing empirical evidence for these mechanisms. Our results indicate a symbiotic relationship between the influence mechanisms of transactional and productive socialized services. Transactional socialized services create favorable market conditions while productive socialized services impart necessary knowledge and skills, thus collectively promoting the adoption of soil testing and formula fertilization technology among farmers. Lastly, we account for heterogeneity by discussing the impact of transactional and productive agricultural socialization services on the adoption of soil testing and formula fertilization technology across different types of farmers, endowments, and incomes. Our results provide nuanced insights that could inform the formulation of differentiated policy approaches.

2. Theoretical Analysis and Research Hypothesis

Agricultural socialization services refer to the comprehensive provision of efficient, high-quality public welfare and business services for agriculture throughout the entire production cycle. Consistent with the division of labor theory [22], two main categories of these services are identified: services aimed at enhancing production efficiency and services intended to improve transaction efficiency. Services focused on production efficiency strive to infuse modern production factors into agriculture in a market-oriented manner through dedicated service organizations. This allows for the integration of agriculture with modern production factors, leading to a transformation in the agricultural development model and enhanced resource allocation and output efficiencies. These services primarily encompass agricultural supply, machinery, infrastructure, technology extension, and financial services. Conversely, services targeting transaction efficiency work toward facilitating the deepening of the agricultural division of labor and scale management. Key examples include services for agricultural product sales, logistics, information [23], trading markets, and land transfers. By delegating certain agricultural production and management tasks initially performed by individual farmers to professional organizations and institutions, these services strive to achieve increased efficiency, cost-effectiveness, and quality. The integration of agricultural social service organizations is expected to foster the adoption of modern agricultural technology among farmers [24]. This study's research mechanism is illustrated in Figure 1, and, based on this background, Hypothesis 1 is proposed:

H1: *Transactional and productive social services significantly enhance farmers' adoption of soil testing and formula fertilization technology.*

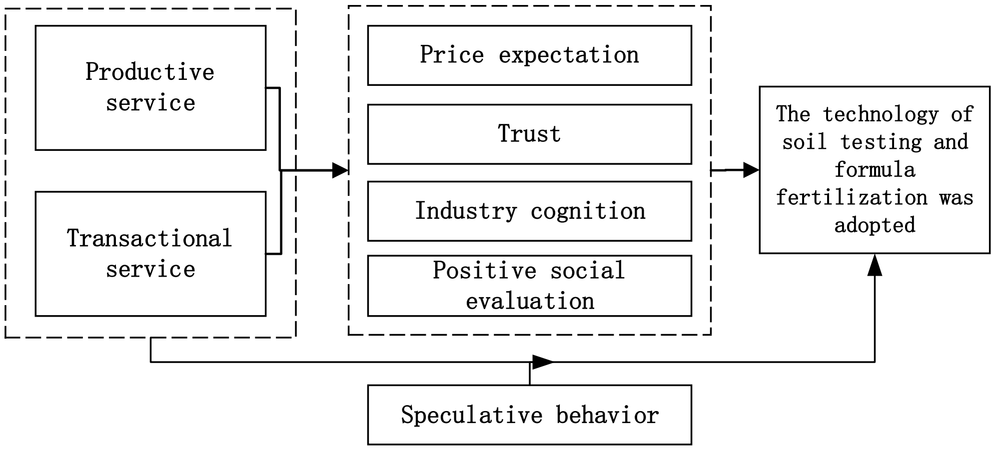

Figure 1. Mechanism diagram of the influence of agricultural socialized service mix on the adoption of soil testing and formula fertilization technology by farmers.

Furthermore, price expectations are defined as a farmer's prediction of the future sales price of their tea crop, which may be influenced by various factors such as market trends, supply and demand dynamics, and economic forecasts [25]. According to the rational behavior theory and the innovation diffusion theory, higher expected prices infer a higher anticipated return on investment, thus rationalizing the initial costs of novel technology [26]. Specifically, an anticipated increase in prices linked with a "green premium"—the elevated price of products manufactured using green technologies—directly incentivizes farmers to adopt such technologies. Transactional social services aid farmers in accessing markets, including those willing to pay higher prices for green products [27]. If farmers lack access to such markets, they will not benefit from rising price expectations. On the other hand, productive social services provide farmers with the requisite knowledge and skills to adopt green technologies and produce premium crops that meet market standards. They can also assist farmers in securing financial services for initial investments in green technologies. However, the influence of expected price increases may be restricted if farmers lack access to essential credit or insurance to manage the risks associated with these investments [28]. Therefore, Hypothesis 2 is put forth:

H2: *Improved farmers' price expectations for agricultural products can amplify the positive impact of transactional and productive social services on their adoption of soil testing and formula fertilization technology.*

Secondly, the concept of industry cognition is considered, which is a cognitive variable encapsulating a farmer's knowledge, comprehension, and perception of the tea industry. It includes their awareness of industry trends, processes, regulations, challenges, opportunities, and market dynamics, all of which can affect their decision-making processes, strategic planning, and engagement in the industry. Following the principles of social cognitive theory [29], farmers who perceive a shift in the industry towards increased sustainability and greener practices may be more inclined to invest in relevant technologies. This awareness can enhance their receptiveness towards both transactional social services, such as financial assistance and market access for green products, and productive social services, like green technology education and training. It is also likely that farmers will adopt novel technologies if they are cognizant of the growing consumer demand for green-produced products. These farmers may employ transactional social services to access these burgeoning markets [30]. Further, farmers with a vision for transitioning agriculture toward sustainable practices, who can also accurately grasp the supporting policies for sustainable agricultural development, will be willing to learn via productive social services and explore new market and financial opportunities offered by the transactional social services. This leads to the formulation of Hypothesis 3:

H3: *Farmers' understanding of the future development of the tea industry can significantly enhance the positive impact of transactional and productive socialization services on their adoption of soil testing and formula fertilization technology.*

Thirdly, the psychological variable of trust is discussed, which generally denotes a belief or confidence in the reliability, competence, or strength of an individual, system, or entity [31]. It is subjective in nature and can be shaped by past experiences, personal views, and relationships. It can apply to a farmer's trust in industry stakeholders, processes, or systems, which in turn influences their willingness to partake in specific activities or actions [32]. As per the social capital theory [33], farmers who trust the organizations providing services, such as government agencies, NGOs, or private companies, are more likely to perceive these services as beneficial and reliable. Productive social services allow farmers to appreciate the role and advantages of technology in agricultural practices, thereby bolstering their trust in soil testing and formula fertilization technologies. Transactional social services, which often connect farmers to markets, will lead to a greater likelihood of farmers adopting these technologies if they believe that a market exists for the products they cultivate using soil-testing and formula fertilization techniques. This could be the belief that consumers are willing to pay a premium for green products, or that such products will become the standard in the future. Lastly, farmers are more inclined to embrace change if they trust that they will receive the necessary support, be it financial, technical, or educational, to adopt new technologies. This understanding leads to the proposition of Hypothesis 4:

H4: *Trust can significantly enhance the positive impact of transactional and productive social services on farmers' adoption of soil testing and formula fertilization technology.*

Fourthly, we examine the notion of positive social evaluation, an aspect underpinned by the social capital theory [33]. Positive social evaluation refers to an individual's perceived social standing or acceptance within their community or society. This perception can serve as a robust driving force for behavior change, including the adoption of innovative technologies or practices. If implementing soil testing and formula fertilization methodologies is viewed positively by a farmer's community or society, these individuals may be motivated to employ these strategies to enhance their social status [32]. Additionally, the influence that farmers exert on one another and the potential for learning from peers suggests that if some begin adopting green technologies and subsequently receive positive social feedback, others may follow. This could instigate a positive feedback loop, where the uptake of green technology becomes socially normative. Furthermore, the wider market and consumer base can exert influence on farmers. Should consumers exhibit a preference for goods produced using green methodologies, and this preference becomes known to farmers (possibly through increased prices or labeling systems), farmers may be enticed to adopt these practices to meet market demands and bolster their reputation amongst consumers. Transactional and productive social services can equip farmers with the necessary resources, skills, and knowledge to incorporate these technologies and can help amplify the societal benefits of soil testing and formula fertilization technology. Hence, we propose Hypothesis 5:

H5: *Farmers' quest for positive social evaluation can invigorate transactional and productive social services, thereby promoting the adoption of soil testing and formula fertilization technologies.*

Lastly, we consider the role of speculation. Grounded in the equity theory [34], speculation typically involves decision-making based on the anticipated future outcomes, often with insufficient information or analysis. When farmers speculate about the adoption of green production technologies, they may disregard critical considerations such as the technology's compatibility with their specific agricultural conditions, associated costs, and potential risks [35]. Ill-informed decisions can result in adverse outcomes and diminish the positive effects of transactional and productive social services. Furthermore, speculation might redirect farmers' resources (including time, money, and energy) to alternative production or marketing endeavors. Farmers could potentially invest in unproven or trending technologies without adequately assessing their viability or potential benefits, which could obstruct the effective implementation of soil-testing and formula fertilization technology and limit the positive impact of social services. Speculative behavior often reflects a short-term mindset and a pursuit of rapid gains. Green production technologies typically demand long-term commitment, and changes in agricultural practices and investments require time to take effect. If farmers engage in speculation, they may be less open to the adoption process, resulting in the inconsistent or incomplete integration of green technologies. Farmers indulging in speculative behavior may undertake excessive financial or operational risks without thoroughly evaluating the potential consequences. Should these risks materialize, they might lead to financial losses or negative experiences, deterring farmers from the further adoption of soil testing and formula fertilization techniques. Lastly, speculation might hinder opportunities for collaboration and knowledge sharing among farmers. Farmers may become overly focused on individual speculative activities, overlooking the collective learning and exchange of experiences facilitated by the transactional and productive social services [36]. This isolation can limit the dissemination of valuable insights and lessons learned, consequently reducing the positive impact of agricultural socialization services on the adoption of soil testing and formula fertilization methodologies by farmers. Therefore, we propose Hypothesis 6:

H6: *The speculative behavior of farmers could attenuate the positive influence of transactional and productive socialization services on the adoption of soil testing and formula fertilization technology.*

3. Data Source, Variable Selection, and Descriptive Statistics

3.1. Data Source

The empirical data used in this study were collected from a questionnaire survey of tea farmers in geographical indication areas of Shaanxi, Sichuan, and Anhui provinces, conducted from July to August 2020. To maintain the sample's randomness, the research team utilized a four-stage random sampling approach, initially selecting 1–3 counties randomly in each province. These counties were then subdivided into three gradients based on the average income level of the tea growers in each county, labeled as high income, middle income, and low income. Within each gradient, three townships (towns) were selected at random, followed by the random selection of 2–3 villages within each township. Each village randomly distributed 15–20 questionnaires to the tea farmers, which were followed by one-on-one interviews. In total, the research team distributed 980 questionnaires that primarily included information on farmers' demographic and family backgrounds, soil testing, formula fertilization, and social services. Upon the exclusion of outliers and incomplete data, 929 valid questionnaires were obtained, constituting an effective rate of 94.80%.

3.2. Selection of Variables

1. Dependent variable: The primary dependent variable in this research is the farmers' adoption of soil testing and formula fertilization technologies. In this study, the survey questionnaire was designed such that areas where a farmer's soil testing and formula fertilization technology were adopted were assigned a value of 1, indicating adoption, while areas with no adoption were assigned a value of 0, indicating non-adoption. Moreover, referencing the extant literature [15], we segmented the level of adoption of soil testing and formula fertilization technologies into adoption enthusiasm and adoption scale. The degree of enthusiasm for technology adoption was gauged by asking farmers about their "willingness to adopt formula fertilization technology in the tea cultivation process" and assigning a value from 1–5, ranging from "very unwilling" to "very willing". The scale of technology adoption was quantified by enquiring about "the area in which tea farmers employ formula fertilization technology in soil testing". As crucial agents in the adoption of green technologies, farmers' decisions and the degree of technology adoption are instrumental in advancing green agricultural transformation.

2. Independent variable: The extent of the use of productive and transactional social services. Given the diverse attributes of these services, farmers' utilization of social services can be multifaceted. In this study, farmers were asked whether they had utilized services such as product sales intermediation, land circulation, professional sales markets, organic fertilizer logistics, and internet sales. The coefficient of variation method was employed to calculate the weighted average of these five services to represent the extent of the use of transactional social services. Similarly, questions were posed about the use of "agricultural technology training services, fertilizer supply services, fertilization services, land reclamation services, agricultural insurance services", with the coefficient of variation method again applied to compute the weighted average of these five services to depict the extent of the use of productive social services. The coefficient of variation method can mitigate bias in the weighting outcomes due to variations in the functions, attributes, and effects of each sub-service.

The coefficient of variation method is an objective weighting method used to measure the variation degree of each observation index in a sample. If the degree of variation in a sub-service is larger, it indicates that the unbalance of the use effect of the service is stronger [37], and a greater weight is assigned to it. First, calculate the coefficient of variation V_j per seed service:

$$V_j = S_j / U_j \tag{1}$$

In the Formula (1), S_j is the standard deviation of the j $(j = 1, \ldots, 5)$ indicator, and U_j is the mean of the j indicator. Secondly, the variation coefficient obtained in (1) is normalized to obtain the weight W_j of each sub-service in the agricultural socialization service:

$$W_j = V_j / \sum_{j=1}^{n} V_j \tag{2}$$

Finally, the weights of each sub-service are added up respectively to obtain the weights of the productive service and the transactional service. In this paper, Stata17.0 software was used to analyze the selected sample data via the coefficient of variation method, and the regression results were shown in Table 1.

3. Control Variables. To minimize potential confounding effects in this study, we included several control variables based on the extant literature [19]. These encompass several factors both at the level of the individual household head (including gender, age, education level, and health status) and at the household level of tea farmers (total household population, total land area, number of tea garden plots, the proportion of tea income per capita in the total household income, participation in cooperatives, and the distance from home to the market). The robustness of the results was further confirmed by controlling for different variables during the regression process.

Table 1. Usage degree of transactional and productive social services.

Target Layer	Primary Index	Secondary Index	Coefficient of Variation	Secondary Index Weight
The use degree of agricultural socialized services	Transactional social service usage	Have you used the service of product sales intermediary	0.8209	0.2021
		Have you used the land transfer service	1.0247	0.2523
		Use the professional sales market has not	0.3901	0.0960
		Have you used organic fertilizer logistics service	0.8913	0.2194
		Have you used the Internet to sell your services	0.9352	0.2302
	The use degree of productive social services	Have you used agricultural training services	0.7113	0.1143
		Have you used agricultural supply service	2.5792	0.4144
		Use fertilizer service has not	1.1919	0.1915
		Have you used the plowing service yet	1.0961	0.1761
		Have you used farm insurance services	0.6459	0.1038

4. Mechanism Variables. (1) Mediating variables: The farmers' price expectations were assessed by asking tea farmers whether they believed that "the price of their tea would increase after adopting green fertilization technology" compared to before its adoption. Positive responses would suggest that farmers expect green fertilization technology to increase the price of their tea, thereby promoting technology adoption. The question "Do you believe that green production is the future development trend of the tea industry from the perspective of quality improvement and environmental protection?" served to gauge farmers' industry cognition. This understanding of industry trends, processes, regulations, challenges, opportunities, and market dynamics can significantly influence their decision-making and strategic planning. Positive industry cognition, particularly in the context of the perceived necessity for green production, could promote technology adoption. The statement "Most people in society are trustworthy" was used to measure the trust variable, with the assumption being that farmers who trust the agents providing social services are more likely to adopt the green production technology suggested or supported by these agents. The query "Do you believe that you could gain more reputation/social recognition by adopting green production technology?" was designed to capture positive social evaluation, reflecting the often-significant role that social and cultural dynamics play within farming communities. (2) Modulating variable: The statement "Others can achieve the same or even higher income through opportunistic behavior" was used to represent farmers' speculative behavior. Excessive or uninformed speculation could undermine the positive impact of transactional and productive social services on farmers' technology adoption.

3.3. Descriptive Statistics

To examine the correlation between agricultural social services and farmers' adoption of soil testing and formula fertilization technology, before the formal regression, the correlation coefficient (Pearson) [38] between variables was calculated using Stata17.0. The correlation of transactional and productive social services with price expectation, industry cognition, trust, positive social evaluation, and speculative behavior are depicted in

Tables 2 and 3. The absolute values of the correlation coefficients among all variables are less than 0.8, indicating the absence of multicollinearity. Significant positive correlations were observed between transactional and productive social services and the technological adoption of soil testing and formula fertilization. These were also positively correlated with price expectation, industry cognition, trust, and positive social evaluation, as well as with the technology adoption decision. However, a negative correlation was found between farmers' speculative behavior and the technology adoption decision, which is in line with the theoretical conclusions postulated in this paper.

Table 2. Correlation coefficient analysis of transactional social services.

	Technology Adoption Decision	Transactional Service	Price Expectation	Industry Cognition	Trust	Positive Social Evaluation	Speculative Behavior
Technology adoption decision	1						
Transactional service	0.079 **	1					
Price expectation	0.088 ***	0.166 ***	1				
Industry cognition	0.066 **	0.174 ***	0.097 ***	1			
Trust	0.057 *	0.171 ***	−0.063 *	0.278 ***	1		
Positive social evaluation	0.071 **	0.161 ***	−0.140 ***	0.182 ***	0.497 ***	1	
Speculative behavior	−0.0120	0.191 ***	0.0270	0.231 ***	0.370 ***	0.164 ***	1

Note: *, **, and *** respectively indicate significance at the level of 10%, 5%, and 1%.

Table 3. Analysis of correlation coefficients of productive services.

	Technology Adoption Decision	Productive Service	Price Expectation	Industry Cognition	Trust	Positive Social Evaluation	Speculative Behavior
Technology adoption decision	1						
Productive service	0.065 **	1					
Price expectation	0.088 ***	0.181 ***	1				
Industry cognition	0.066 **	0.092 ***	0.097 ***	1			
Trust	0.057 *	0.130 ***	−0.063 *	0.278 ***	1		
Positive social evaluation	0.071 **	0.147 ***	−0.140 ***	0.182 ***	0.497 ***	1	
Speculative behavior	−0.0120	0.126 ***	0.0270	0.231 ***	0.370 ***	0.164 ***	1

Note: *, **, and *** respectively indicate significance at the level of 10%, 5%, and 1%.

Table 4 shows the descriptive statistics of variables in this paper. It can be seen from the table that in the tea planting process of the geographical indication area, farmers' technology selection rate of soil testing and formula fertilization reached 77.5%, the average enthusiasm of farmers for technology adoption was 1.2274, and the average adoption scale reached 6.13 mu. The average use degree of transactional and social services was 0.3638 and 0.2741, respectively. The average use degree of transactional social services was 8.97% higher than that of productive social services. There is room for improvement of farmers' enthusiasm in adopting technology.

Table 4. Descriptive statistics of variables (Sample size: 929).

Variable	Variable Declaration	Mean Value	Standard Deviation
Selection of soil testing technology for formula fertilization	If the adopted area of soil testing and formula fertilization technology is >0, a value of 1 indicates that it is adopted, and 0 indicates that it is not adopted.	0.7750	0.418
Enthusiasm for technology adoption	1 Very reluctant, 2 less willing, 3 more willing, 4 more willing, 5 very willing	1.2274	3.2971
Technology adoption scale	Adopted area, unit: Mu (Mu is a traditional Chinese unit)	6.1304	4.4568
Independent variable			
Transactional social service usage	Calculated via the coefficient of variation method, the results are shown in Table 1 above, unit: %	0.3638	0.249
The use degree of productive social services	Calculated via the coefficient of variation method, the results are shown in Table 1 above, unit: %	0.2741	0.117
Intermediate variable			
Price expectation	Compared with before the adoption of green fertilization technology, the price of their own tea increased after the adoption of 1 very disagree, 2 more disagree, 3 general, 4 more agree, 5 very agree	3.9247	0.766
Industry cognition	From the perspective of quality improvement and environmental protection, you think green production is the future development trend of the tea industry. 1 Strongly disagree, 2 strongly disagree, 3 general, 4 strongly agree, 5 strongly agree	3.4349	0.822
Trust	Most people in society can be trusted. 1 Strongly disagree, 2 strongly disagree, 3 general, 4 strongly agree, 5 strongly agree	3.0065	0.970
Positive social evaluation	Can you gain more reputation/social recognition by adopting green production technology? 1 Strongly disagree, 2 strongly disagree, 3 general, 4 strongly agree, 5 strongly agree	3.2357	0.877
Regulating variable			
Speculative behavior	Others can earn as much or more by being opportunistic. 1 Strongly disagree, 2 strongly disagree, 3 general, 4 strongly agree, 5 strongly agree	3.4489	0.708
Instrumental variable			
The number of social service subjects obtained by farmers per capita	Number of social service providers around/Number of family farmers, unit: per	0.1178	0.110
Household head level			
gender	0 women, 1 man	0.8848	0.319
age	2020 minus year of birth, unit: years	58.2982	10.260
Educational level	1 Illiterate, 2 primary school, 3 junior high school and secondary school, 4 High school, 5 junior College, 6 bachelor, 7 master	3.3638	0.923
Health status	1 can not take care of themselves, 2 long-term chronic diseases can take care of themselves, 3 weak and minor diseases, 4 healthy, 5 Very healthy	3.9279	0.865
Family level			

Table 4. *Cont.*

Variable	Variable Declaration	Mean Value	Standard Deviation
Family population	Unit: Person	3.8062	1.698
Total land area	Unit: Mu (Mu is a traditional Chinese unit)	15.5431	20.729
Number of plots of tea garden	Unit: block	5.3617	5.901
The per capita proportion of tea income in total household income	Proportion of tea income in total household income/Number of households, unit: %	0.1220	0.1460
Whether to participate in cooperatives	Participate in 1, not 0	0.3046	0.460
Distance from home to market	Unit: Li (Li is a traditional Chinese unit)	3.2980	7.499
Whether to work part-time or not	If the number of part-time workers is greater than 0, a value of 1 indicates part-time employment, and 0 indicates no part-time employment	0.4374	0.2573
Scale of income share	If the per capita proportion of tea income in total household income is higher than the average, the value of 1 indicates high agricultural income, and if it is lower than the average, it is 0	0.4729	0.3369
Tea land scale	Tea garden area/number of plots, unit: Mu (Mu is a traditional Chinese unit)	0.5002	0.4909

The average price expectation is 3.9247, indicating that most farmers agree that the adoption of new technology will help increase the price of their own tea. The average values of industry cognition, trust, and the pursuit of positive social evaluation were 3.4349, 3.0065, and 3.2357, respectively, indicating that a large proportion of tea farmers recognized that tea using green production technology would be more favored by the market, and farmers' trust in all parties was at a medium level, as they valued their own reputation more. They hope to obtain more social recognition by adopting green production technology; the average value of farmers' speculative behavior was 3.4489, and the average value of the number of social service subjects per farmer was 0.1178, indicating that the number of social service subjects provided for farmers in this region was relatively small.

According to the information at the level of the household heads, the heads of the rural households in the survey area are mainly male, accounting for 88.48%, and the average age is 58.2 years old. Most of the heads of households have less than 12 years of education and their health status is average, which indicates that the phenomenon of rural population aging and low education level is obvious. According to the household characteristics' information, the population size of the tea farmer family is mostly 3–4 people, the average land area is 15.5 mu, the number of tea plots and the scale of tea plots are more than 5, the land is relatively fragmented, the per capita proportion of tea income in the total household income reaches 12.2%, and 47.29% of the farmers' income proportion is higher than the average. The tea farmers who participated in the cooperative accounted for 30.46%, and the average distance from home to the market was about 3.29 li.

4. Methodology

4.1. Probit Model

Since the technology adoption decision of tea farmers is a binary dummy variable, the binary Probit model is used for regression analysis. The model is constructed as follows:

$$p(Y_i = 1|S) = F(S, \beta) = F(\beta_0 + \beta_1 S_{im} + \sum_{i=2}^{n} \beta_i Z_i) \quad (3)$$

In the formula, Y_i is the dependent variable "whether tea farmers adopt soil testing and formula fertilization technology"; S_{im} represents the agricultural socialization services, and m ranges from 1 to 2, respectively representing the transactional socialization services and productive socialization services. S is the independent variable vector that affects the technology adoption decision of tea farmers. β is the coefficient estimation vector of the independent variable, β_0 is the constant term, β_1 and β_i are the coefficients to be estimated of both the core explanatory variable and the control variable, respectively.

In addition, the enthusiasm of technology adoption and the scale of technology adoption were estimated using the OLS model, and the model construction was the same as the first step of the stepwise regression method below.

4.2. Intermediate Effect Model

Inspired by the work of Baron et al. [39], a stepwise regression model is initially constructed to test the mediating effect of the transactional and productive social services on technology adoption, specifically whether they stimulate adoption by shaping farmers' price expectations, fostering positive social evaluation, cultivating trust, and improving industry cognition. Additionally, in recognition of the potential oversight of mediating effects via the stepwise regression method, the Bootstrap method is deployed for the further verification of the existence, magnitude, and proportion of the mediating effect within the overall effect, thereby enhancing the statistical validity.

$$Y_i = c_1 S_{im} + \beta_1 Z_i + \varepsilon_1 \tag{4}$$

$$M_{in} = a S_{im} + \beta_2 Z_i + \varepsilon_2 \tag{5}$$

$$Y_i = c_2 S_{im} + b M_{in} + \beta_3 Z_i + \varepsilon_3 \tag{6}$$

In the formula, Y_i represents the binary dummy variable of whether farmers adopt the soil testing formulation technology; S_{im} represents the agricultural socialization services; m ranges from 1 to 2, respectively representing the transactional socialization services and productive socialization services; M_{in} is the intermediary variable; and n ranges from 1 to 3, respectively representing farmers' price expectation, industry cognition, trust, and pursuit of positive social evaluation. Z_i is the control variable; a, b, c_1, c_2 and β_1, β_2, β_3 are the coefficients to be estimated; ε_1, ε_2, ε_3 are the random disturbance terms.

4.3. Regulatory Effect Model

In addition to the above four intermediary mechanisms, this paper further discusses the regulating effect of farmers' speculative behavior. By referring to the existing literature [40], the following model is constructed to verify whether farmers' speculative behavior will reduce the positive effect of the transactional and productive social services on farmers' adoption of soil testing and formula fertilization technology and test the regulating effect.

$$Y_i = d_0 + d_1 S_{im} + d_i U_i + d_3 S_{im} U_i + \varepsilon_4 \tag{7}$$

In the formula, d is the coefficient to be estimated, S_{im} is the same as above, and U_i represents the adjustment variable. In this paper, the significance of coefficient d_3 of the interaction term $S_{im} \times U_i$ is used to determine whether the adjustment effect exists.

5. Empirical Results and Analysis

5.1. Influence of Transactional and Productive Social Services on the Adoption of Soil Testing and Formula Fertilization Technology

1. Impact of Transactional Social Services on the Adoption of Soil Testing and Formula Fertilization Technology. The decision to adopt the technology in this study is represented by a binary dummy variable, therefore, the binary Probit model was adopted and Stata17.0 software was used for regression analysis. Models (1) and (2) in Table 5 illustrate the effect

of transactional social service use on the adoption of soil testing and formula fertilization technology by households. The Probit-estimated marginal effect and the corresponding robust standard error are presented in the table. Model (1), which only takes into account the household head level variables, demonstrates that transactional social service usage significantly enhances the adoption of soil testing and formula fertilization technology, with each unit increase in usage degree augmenting the probability of technology adoption by 0.44 units. In Model (2), which further controls for household-level variables, the coefficient increases by 0.03, meaning each unit rise in the degree of transactional social service usage augments the probability of technology adoption by 0.47 units. These results underline that transactional social services, by offering benefits such as agricultural product sales, logistics, agricultural information services, trading market services, and land circulation, furnish evidence for the adoption of soil testing and formula fertilization technology, in line with the findings of previous studies [9,41].

Table 5. Effects of transactional and productive social services on the adoption of soil testing and formula fertilization.

Variable	Model (1)	Model (2)	Model (3)	Model (4)
Transactional social services	0.4399 **	0.4740 **		
	(2.3683)	(2.4802)		
Productive socialized service			0.6705 *	1.5326 ***
			(1.7103)	(3.4142)
gender	−0.1201	−0.1145	−0.1096	−0.0991
	(−0.8148)	(−0.7601)	(−0.7442)	(−0.6535)
age	0.0066	0.0064	0.0063	0.0061
	(1.3940)	(1.2888)	(1.3363)	(1.2353)
Educational level	0.0689	0.0954 *	0.0680	0.0921 *
	(1.3877)	(1.8796)	(1.3674)	(1.8096)
Health status	0.2277 ***	0.1935 ***	0.2226 ***	0.1882 ***
	(4.1051)	(3.3792)	(4.0204)	(3.2780)
Total family population		0.0269		0.0328
		(0.7843)		(0.9545)
Total land area		−0.0016		−0.0015
		(−0.6919)		(−0.6475)
Number of plots of tea garden		0.0245 **		0.0261 **
		(2.2607)		(2.3978)
The per capita proportion of tea income in total household income		−0.3661		−0.2831
		(−0.9459)		(−0.7297)
Whether to participate in cooperatives		−0.3220 ***		−0.5013 ***
		(−3.0734)		(−4.2539)
Distance from home to market		0.0247 ***		0.0265 ***
		(2.8262)		(2.9941)
Constant term	−0.7886 *	−0.8691 *	−0.7854 *	−1.0737 **
	(−1.7412)	(−1.8090)	(−1.7161)	(−2.1931)
Pseudo R^2	0.0249	0.0505	0.0222	0.0561
Prob > chi2	0.0002	0.0000	0.0005	0.0000

Note: N = 929, *, **, and *** respectively indicate significance at the level of 10%, 5%, and 1%. The same below.

2. Impact of Productive Social Services on the Adoption of Soil Testing and Formula Fertilization Technology. The estimated results and directions in Models (3) and (4) are akin to those in Models (1) and (2). Notably, for productive social services, each unit increase in the degree of productive social service usage results in a 1.5 times increase in the probability of technology adoption, upon adding the family-level control variables. This empirical evidence underlines the pivotal role of transactional social services in transforming agricultural development models and enhancing farmers' resource allocation efficiency and factor output efficiency. It further indicates that productive social services have a greater impact

on farmers' technology adoption decisions compared to the transactional social services. Combining the results from Part 1 and Part 2 validates Hypothesis 1.

3. Control Variables. Considering the household head, their education level and health status significantly positively influences technology adoption. Greater levels of education and superior health status improve the understanding and learning capacities for new technologies, thus enhancing the probability of adopting soil testing and formula fertilization technology. From a household perspective, the number of plots in the tea garden and proximity to the market are positively correlated with technology adoption. A larger number of plots provide farmers the opportunity to trial new technologies and diversify production. More plots may result in higher total yields, offsetting the initial costs of soil testing and formula fertilization technology. As production escalates, the cost per unit output decreases, making new technology adoption more economically feasible. Being situated closer to markets lessens transportation expenses, reduces post-harvest losses, and enables farmers to respond more promptly to the market demand. If there is a burgeoning demand for sustainably produced tea, market proximity provides farmers rapid access to market information, thereby facilitating technology adoption. Participation in cooperatives, conversely, negatively influences technology adoption, which might be attributed to insufficient cooperative publicity, substandard operations, and the failure of relevant leaders to provide pertinent information and material resources, resulting in a diminished trust in cooperatives, consequently lowering the likelihood of technology adoption.

5.2. Impact of Transactional and Productive Social Services on Adoption of Soil Testing and Formula Fertilization Technology

The prior analysis discussed the probability effect of the usage degree of both transactional and productive social services on farmers' adoption decision of soil testing and formula fertilization technology. However, the intensity of technology adoption by farmers also varies, which is manifested in the disposition towards and the scale of technology adoption. As delineated in Table 6 this study uses both the enthusiasm for technology adoption and the scale of technology adoption as proxy variables for adoption intensity to examine the relationship between transactional and productive social services and the intensity of farmers' adoption of soil testing and formula fertilization technology. As the variable in question is not binary, the Ordinary Least Squares (OLS) method is employed for estimation, which is consistent with the relevant literature. In Table 6, for the sake of enhancing the robustness of the results, we also controlled for factors at both the household head and household levels. The dependent variable of Models (1) through (4) is technology adoption enthusiasm. The outcome of Model (2) indicates that for each unit increase in the usage degree of transactional social services, farmers' enthusiasm for technology adoption escalates by 0.99 units, demonstrating statistical significance. This underscores that the utilization of transactional social services can indeed augment the zeal of farmers to adopt technology. Such services can enhance the economic feasibility of the technology and indirectly endorse the adoption of green technology by amplifying farmers' market access and ensuring an equitable transaction process. In Model (4), when the intensity of the usage of productive social services rises by one unit, the enthusiasm of farmers in adopting technology increases by 1.9 units. This increase in propensity to adopt technology is nearly twice that of transactional social services, highlighting that productive social services, which are directly related to farmers' agricultural production, are met with higher regard and a more positive attitude. The dependent variable of Models (5) through (8) is the scale of technology adoption. Using Model (6) and (8) as examples, in Table 6, the usage of transactional social services can prompt a synchronous increase in the marginal effect of farmers' technology adoption area by 1.74 units. Meanwhile, the utilization of productive social services can induce a corresponding increase in the marginal effect of farmers' technology adoption area by 4 units. This effect is significant, suggesting that both transactional and productive social services can stimulate the expansion of the scale of adoption of soil testing and formula fertilization technology by farmers. As a result, this promotes the efficiency of adoption of soil testing and formula fertilization technology and advances green development in agriculture.

Table 6. Effects of transactional and productive social services on the adoption of soil testing and formula fertilization technology.

Variable	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)
	Enthusiasm for Technology Adoption				Technology Adoption Scale			
Transactional social services	1.0388 ***	0.9884 ***			2.6999 ***	1.7440 **		
	(6.6269)	(6.2672)			(3.3216)	(2.3086)		
Productive socialized service			1.7781 ***	1.9040 ***			7.7595 ***	4.0015 **
			(5.2930)	(5.0963)			(4.4883)	(2.2541)
gender	0.0389	0.0265	0.0644	0.0542	1.1552 *	0.8848	1.2576 **	0.9559
	(0.3190)	(0.2180)	(0.5238)	(0.4419)	(1.8048)	(1.4985)	(1.9761)	(1.6193)
age	0.0036	0.0043	0.0031	0.0034	−0.0122	−0.0044	−0.0129	−0.0062
	(0.9086)	(1.0439)	(0.7837)	(0.8185)	(−0.5903)	(−0.2249)	(−0.6266)	(−0.3153)
Educational level	0.2017 ***	0.1929 ***	0.2001 ***	0.1966 ***	0.1040	0.2120	0.0512	0.2123
	(4.7784)	(4.5459)	(4.6858)	(4.6003)	(0.4798)	(1.0526)	(0.2364)	(1.0539)
Health status	0.0897 *	0.0999 **	0.0831 *	0.0934 *	1.0857 ***	0.7280 ***	1.0624 ***	0.7159 ***
	(1.8972)	(2.0677)	(1.7422)	(1.9197)	(4.4426)	(3.1613)	(4.3686)	(3.1084)
Total family population		−0.0354		−0.0248		0.4181 ***		0.4343 ***
		(−1.2713)		(−0.8848)		(3.1477)		(3.2715)
Total land area		0.0048 **		0.0055 ***		0.0876 ***		0.0887 ***
		(2.4560)		(2.8140)		(9.5322)		(9.6865)
Number of plots of tea garden		−0.0166 **		−0.0153 **		0.1520 ***		0.1550 ***
		(−2.4804)		(−2.2749)		(4.7146)		(4.7963)
The per capita proportion of tea income in total household income		−0.0795		0.0600		2.3575		2.5756
		(−0.2399)		(0.1799)		(1.4925)		(1.6321)
Whether to participate in cooperatives		0.0703		−0.1464		1.3400 ***		0.8869 *
		(0.7917)		(−1.4817)		(3.1235)		(1.8855)
Distance from home to market		−0.0052		−0.0036		−0.0247		−0.0229
		(−0.9624)		(−0.6675)		(−0.9153)		(−0.8501)

Table 6. *Cont.*

Variable	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)
	Enthusiasm for Technology Adoption				Technology Adoption Scale			
Constant term	1.6432 ***	1.7783 ***	1.5701 ***	1.6429 ***	−1.4219	−4.5933 **	−2.3448	−4.9626 **
	(4.2636)	(4.4055)	(3.9966)	(3.9868)	(−0.7175)	(−2.3936)	(−1.1754)	(−2.5517)
adj. R^2	0.072	0.080	0.056	0.067	0.039	0.186	0.049	0.186

Note: *, **, and *** respectively indicate significance at the level of 10%, 5%, and 1%.

5.3. Addressing Endogenous Issues

The decision to use agricultural socialized services is primarily driven by farmers, and some immeasurable variables, such as risk attitude and the acceptance of novelty, which might impact both the independent and dependent variables, leading to omissions in the variable selection within the model. Moreover, the needs of agricultural operation and production might lead farmers or households to demand agricultural socialization services, creating reverse causality and consequently biasing the estimation results. In consideration of these factors, this paper selects the number of social service entities per farmer (i.e., the number of social service entities in the vicinity divided by the number of family farmers) as an instrumental variable. Theoretically, this instrumental variable is intimately connected with the agricultural social services—absent of any social service entities, farmers would be unable to access the relevant services. However, the per capita number of agricultural social service entities available to the farmers in a household bears no direct relationship with the green production behavior of farmers. This aligns with the correlation and exogeneity requirements for the instrumental variables. The selected control variables in Table 7 are consistent with those mentioned previously. The results still indicate that both transactional social services and productive social services significantly promote the adoption of soil testing and formula fertilization technology by farmers, with the promotional likelihood of productive social services still surpassing that of transactional services. This reaffirms the core conclusion stated earlier. Furthermore, the F-statistics of 115.27 and 37.33 in the first stage are both greater than 10, dismissing the weak instrumental variable hypothesis and establishing the validity of the instrumental variables. After utilizing the instrumental variable model (IV Probit) to address potential endogeneity, the results remain robust, offering additional validation for Hypothesis 1.

Table 7. Estimation results of instrumental variable method (IV Probit).

Variable	Model (1)	Model (2)
Transactional social services	0.5486 **	
	(0.254)	
Productive socialized service		2.7443 **
		(1.309)
Householder control variable	Yes	Yes
Household control variable	Yes	Yes
Constant term	−0.8898 *	−1.3398 **
	(0.483)	(0.561)
F	115.27	37.33
Prob > chi2	0.0000	0.0000

Note: * and **, respectively indicate significance at the level of 10% and 5%.

5.4. Analysis of Heterogeneity

Given the inherent heterogeneity of the farmer population, variations in the adoption of technology might be observed among different types of farmers with varying resources when utilizing the agricultural socialized services.

1. Analysis of Heterogeneity among Different Types of Farmers: Table 8 presents the heterogeneous estimation results concerning the impact of the utilization degree of

transactional social services (X1) and productive social services (X2) on farmers' technology adoption. The results from Model (1) suggest that transactional social services tend to foster technology adoption more effectively among part-time farmers compared to non-part-time farmers, although the impact is significantly positive for both groups. This may be attributable to the fact that part-time farmers, given their limited time and resources for tea garden investment, are more inclined to embrace the market transaction information and capabilities offered by the transactional social services. Non-part-time farmers, who potentially reap more benefits from the productive socialization services—both in terms of tea yield and sustainable land production for tea plantations—may possess greater ability (in terms of time and resources) to learn about, invest in, and implement new technologies.

Table 8. Results of heterogeneity estimation.

Variable	Model (1) Sideline Business	Model (2) Non-Side-Business	Model (3) Sideline Business	Model (4) Non-Side-Business	Model (5) High Income	Model (6) Low Income	Model (7) High Income	Model (8) Low Income	Model (9) Large-Scale	Model (10) Small-Scale	Model (11) Large-Scale	Model (12) Small-Scale
X1	0.8476 **	0.3635 *			0.7025 **	0.4523 *			0.5311 *	0.2758		
	(2.0460)	(1.6652)			(1.9736)	(1.9478)			(1.9289)	(0.9844)		
X2			0.5272	1.7744 ***			2.3948 ***	1.1386 **			1.4493 **	1.4031 **
			(0.5479)	(3.4302)			(2.9278)	(2.0864)			(2.2337)	(2.1648)
Head of a household	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
family	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant term	−0.3890	−0.8742	−0.1222	−1.2208 **	0.2582	−1.1179 *	−0.4157	−1.1956 **	−0.3220	−1.5551 **	−0.4589	−1.7770 **
	(−0.3753)	(−1.5740)	(−0.1189)	(−2.1391)	(0.2795)	(−1.9086)	(−0.4284)	(−2.0214)	(−0.4719)	(−2.1697)	(−0.6607)	(−2.4387)
N	239	690	239	690	313	616	313	616	456	473	456	473
Pseudo R^2	0.0773	0.0494	0.0592	0.0613	0.0826	0.0538	0.0966	0.0547	0.0564	0.0743	0.0589	0.0820

Note: *, **, and *** respectively indicate significance at the level of 10%, 5%, and 1%.

2. Heterogeneity Analysis of Farmers with Varying Endowments.

(1) Disparate Income Scales: This study identifies high agricultural income farmers as those with a per capita proportion of tea income in the total household income exceeding the mean value (assigned a value of 1), whereas those below the average are considered as having a low agricultural income (assigned a value of 0). As discernible from Models (5) through (8), transactional and productive social services exert a more pronounced effect in fostering technology adoption among farmers with a higher tea income proportion. The reason lies in their heavier reliance on tea as their primary capital, which stimulates a stronger interest in embracing technologies that can enhance productivity, efficiency, and sustainability. They are also more likely to directly benefit from services like investment in novel technologies, training in their application, and updates on the latest advancements.

(2) Varied Tea Field Sizes: The size of tea land is quantified in this study as the ratio of the tea garden's area to the number of plots. As revealed by Models (9) and (10) in Table 8, for every unit increase in the degree of transactional social services use, the likelihood of technology adoption among farmers with larger tea plantations rises by 0.53 units. In contrast, the promotional effect is not quite prominent among farmers with smaller-scale tea plantations. The explanation for this might be that larger tea plantation scales translate into higher tea yields, making these farmers more susceptible to external fluctuations such as market risks. Transactional social services can mitigate farmers' market uncertainty, deliver relevant information and transaction services, and augment farmers' income. Meanwhile, productive social services can positively influence technology adoption among farmers with different tea land scales. For every unit increment in the degree of productive social services use, the probability of technology adoption for farmers with larger scale tea land

amplifies by 1.45 units, and for those with smaller scale tea land, it increases by 1.4 units. Irrespective of the tea garden plot size, productive social services can offer direct assistance to its production practice, thereby bolstering technology adoption.

5.5. Robustness Check

The previous regressions, controlled by the various classifications of household heads and families, have demonstrated consistent results, attesting to their robustness. Table 9 below shows this. To further assess the strength of these results, the primary model is substituted. Regardless of whether we employ fundamental linear regression or Logit regression, the degree of usage of both transactional and productive socialized services significantly and positively influences the adoption of soil testing and formula fertilization technology at a 5% or 1% level. These findings provide additional validation for the robustness of the earlier estimation results.

Table 9. Robustness test results of the replacement master model.

Variable	Model (1) OLS	Model (2) OLS	Model (3) Logit	Model (4) Logit
Transactional social services	0.1346 **		0.8174 **	
	(2.4533)		(2.4390)	
Productive socialized service		0.4392 ***		2.7347 ***
		(3.4125)		(3.5200)
Householder control variable	Yes	Yes	Yes	Yes
Household control variable	Yes	Yes	Yes	Yes
Constant term	0.2982 **	0.2407 *	−1.4831 *	−1.9073 **
	(2.1225)	(1.6953)	(−1.8026)	(−2.2709)
R^2/Pseudo R^2	0.0390	0.0450	0.0503	0.0569

Note: *, **, and *** respectively indicate significance at the level of 10%, 5%, and 1%.

6. Mechanism Analysis

The aforementioned regression analysis extensively elucidates the impact of the usage degree of transactional and productive social services on farmers' adoption of soil testing and formula fertilization technology. Nevertheless, it does not respond to the question of how these two service categories facilitate the technology adoption process. Therefore, this section endeavors to substantiate the mechanism hypothesis presented in the second part.

6.1. Farmers' Price Expectations

Table 10 illustrates that the core explanatory variables in Models (1) and (4) yield significant positive coefficients at the 5% and 1% levels, respectively. This signifies a direct promotional effect of the intensity of use of both transactional and productive socialized services on the farmers' adoption of soil testing and formula fertilization technology. Models (2) and (5) present the regression results relating the usage intensity of transactional and productive socialized services to farmers' price expectations. The significant regression coefficients of 0.4926 and 1.2843 respectively suggest that the utilization of these services can equip farmers with the necessary knowledge and technology, thereby promoting the production of high-quality products and escalating the price expectations of the corresponding agricultural commodities. The regression results of Models (3) and (6) denote the joint significance test results of the adoption of soil testing and formula fertilization technology influenced by transactional and productive social service usage intensity and farmers' agricultural product price expectations. After the addition of mediating variables, the coefficients for both remain significantly positive. These findings establish the path of "transactional and productive social service usage intensity—agricultural product price expectation—soil testing and formulation fertilization technology adoption", revealing a partial mediating effect. The mediating effect of agricultural product price expectation constitutes 13.69% and 21.98% of the total effect, respectively. This outcome corroborates research Hypothesis H2.

Table 10. Test results of the intermediary mechanism of farmers' price expectations.

Variable	Model (1) Technology Selection	Model (2) Price Expectation	Model (3) Technology Selection	Model (4) Technology Selection	Model (5) Price Expectation	Model (6) Technology Selection
Transactional social services	0.1346 **	0.4926 ***	0.1161 **			
	(2.4533)	(4.8905)	(2.0913)			
Productive socialized service				0.4392 ***	1.2843 ***	0.3954 ***
				(3.4125)	(5.4368)	(3.0280)
Price expectation			0.0378 **			0.0341 *
			(2.1020)			(1.8994)
Householder control variable	Yes	Yes	Yes	Yes	Yes	Yes
Household control variable	Yes	Yes	Yes	Yes	Yes	Yes
Constant term	0.2982 **	3.6519 ***	0.1603	0.2407 *	3.5116 ***	0.1209
	(2.1225)	(14.1655)	(1.0355)	(1.6953)	(13.4769)	(0.7788)
adj. R^2	0.039	0.037	0.042	0.045	0.043	0.047
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mediating effect			0.0060			0.0096
Intermediate effect/total effect			0.1369			0.2198

Note: The sampling times of Bootstrap is 1000 times, the same as below. *, **, and *** respectively indicate significance at the level of 10%, 5%, and 1%.

6.2. Farmers' Industry Cognition

As per Models (1) to (3) in Table 11, the intensity of transactional social service usage significantly enhances farmers' industry cognition at the 1% level. Concurrently, farmers' industry cognition exerts a significant positive influence on the adoption of soil testing and formula fertilization technology at the 5% level. Even without considering farmers' industry cognition, the total effect of the use intensity of transactional social services on the adoption of soil-testing and formula fertilization technology is 0.1346, significant at the 5% level. After factoring in farmers' industry cognition, the direct effect of the usage intensity of transactional social services on the adoption of such technology is 0.1159, also significant at the 5% level. These results validate that farmers' industry cognition exerts a significant partial mediating effect on the relationship between transactional social service usage and the adoption of soil testing and formula fertilization technology. The rise in intensity of farmers' use of transactional social services would enhance their understanding of market trends and industry development direction. Given the increasing consumer demand for green products and the advocacy for green agricultural development, farmers are more likely to employ soil testing and formula fertilization technology. As per Models (4) to (6), the use of productive social services can also promote the adoption of such technology by improving farmers' industry cognition. The industry cognition of farmers accounts for 14.64% and 13.28% of the total effect, respectively. These research results also confirm Hypothesis H3.

Table 11. Test results of the intermediary mechanism of farmers' industry cognition.

Variable	Model (1) Technology Selection	Model (2) Industry Cognition	Model (3) Technology Selection	Model (4) Technology Selection	Model (5) Industry Cognition	Model (6) Technology Selection
Transactional social services	0.1346 **	0.5541 ***	0.1159 **			
	(2.4533)	(5.1220)	(2.0850)			
Productive socialized service				0.4392 ***	0.7810 ***	0.4123 ***
				(3.4125)	(3.0414)	(3.1933)
Industry cognition			0.0339 **			0.0344 **
			(2.0269)			(2.0848)

Table 11. *Cont.*

Variable	Model (1) Technology Selection	Model (2) Industry Cognition	Model (3) Technology Selection	Model (4) Technology Selection	Model (5) Industry Cognition	Model (6) Technology Selection
Householder control variable	Yes	Yes	Yes	Yes	Yes	Yes
Household control variable	Yes	Yes	Yes	Yes	Yes	Yes
Constant term	0.2982 **	3.9084 ***	0.1656	0.2407 *	3.8946 ***	0.1065
	(2.1225)	(14.1164)	(1.0706)	(1.6953)	(13.7502)	(0.6845)
adj. R^2	0.039	0.034	0.042	0.045	0.016	0.048
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mediating effect		0.00580				0.0053
Intermediate effect/total effect		0.14640				0.1328

Note: *, **, and *** respectively indicate significance at the level of 10%, 5%, and 1%.

6.3. Trust

Table 12 shows the test results of the mediation effects for the transmission mechanism "transactional and productive social service use intensity—farmer trust—soil testing and formula fertilization technology adoption". The regression coefficients of Models (1) and (4) were found to be significantly positive, thus indicating a direct promotional impact of transactional and productive social service use intensity on the adoption of soil testing and formula fertilization technology, thereby reinforcing hypothesis H1's validity. The regression outcomes of Models (2) and (5) are significantly positive at the 1% level, suggesting that transactional and productive social service use intensity can significantly enhance farmers' trust in social organizations and technologies that provide pertinent services, thus substantiating Hypothesis H4. In Models (3) and (6), the regression coefficients of the mediation variables and core explanatory variables are significantly positive. After incorporating the mediation variable of farmers' trust, the regression coefficients of Models (1) and (3) decrease. This confirms that farmers' trust in government, cooperatives, and socially provided technology plays a partial mediating role in the transmission path. The mediating effect of trust accounts for 13.51% and 13.91% of the total effect, respectively. An increase in farmers' trust facilitates the adoption of soil testing and formula fertilization technology. In sum, the mediation effect test results validate Hypothesis H4 and its transmission mechanism.

Table 12. Test results of farmers' trust intermediary mechanism.

Variable	Model (1) Technology Selection	Model (2) Trust	Model (3) Technology Selection	Model (4) Technology Selection	Model (5) Trust	Model (6) Technology Selection
Transactional social services	0.1346 **	0.6153 ***	0.1159 **			
	(2.4533)	(4.8785)	(2.0885)			
Productive socialized service				0.4392 ***	1.3021 ***	0.4015 ***
				(3.4125)	(4.3784)	(3.0928)
Trust			0.0305 **			0.0290 **
			(2.1265)			(2.0292)
Householder control variable	Yes	Yes	Yes	Yes	Yes	Yes
Household control variable	Yes	Yes	Yes	Yes	Yes	Yes
Constant term	0.2982 **	3.7046 ***	0.1852	0.2407 *	3.5949 ***	0.1366
	(2.1225)	(11.4768)	(1.2349)	(1.6953)	(10.9589)	(0.9064)
adj. R^2	0.039	0.059	0.042	0.045	0.055	0.048
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mediating effect			0.0048			0.0063
Intermediate effect/total effect			0.1351			0.1791

Note: *, **, and *** respectively indicate significance at the level of 10%, 5%, and 1%.

6.4. Pursuit of Positive Social Evaluation

Table 13, based on the regression results of Models (1) and (4), reveals that both transactional and productive social service use intensity have a significant positive influence on farmers' adoption of soil testing and formula fertilization technology. The regression results of Model (2) indicate that the adoption of transactional social services has a significantly positive impact on farmers' use of soil testing and formula fertilization technology at the 1% level. In Model (3), the direct effect of positive social evaluation is 0.1170 and is significant at the 5% level. This further suggests that farmers' proactive pursuit of positive social evaluation can significantly enhance the level of technology adoption. Even after incorporating positive social evaluation, the coefficient of technology adoption of soil testing and formula fertilization by farmers remains significantly positive. The results demonstrate a direct promotional impact of transactional social service use intensity on the adoption of soil testing and formula fertilization technology by farmers. The coefficients corresponding to Models (1) to (3) in Table 13 are significant, and the size of this effect is 0.0049, constituting 12.4% of the total effect of transactional social service use intensity on farmers' adoption of such technology. The results reveal a significant partial mediating effect of farmers' pursuit of positive social evaluation on the relationship between transactional social services and farmers' adoption of soil testing and formula fertilization technology. Similarly, as per Models (4) to (6), productive social service is concluded to promote the adoption of soil testing and formula fertilization technology by farmers by encouraging their pursuit of positive social evaluation, and this mechanism accounts for 17.3% of the total effect. In conclusion, transactional and productive social services can provide farmers with essential technologies and resources to meet social demands better, thereby increasing their market recognition, encouraging farmers to maintain their image and status, pursue positive social evaluation, and promote a more active adoption of soil testing and formula fertilization technology. This is also consistent with the conclusions of relevant studies [42]. These findings validate research Hypothesis H5.

Table 13. Test results of the intermediary mechanism of farmers' pursuit of positive social evaluation.

Variable	Model (1) Technology Selection	Model (2) Positive Social Evaluation	Model (3) Technology Selection	Model (4) Technology Selection	Model (5) Positive Social Evaluation	Model (6) Technology Selection
Transactional social services	0.1346 **	0.5127 ***	0.1170 **			
	(2.4533)	(4.4782)	(2.1130)			
Productive socialized service				0.4392 ***	1.1505 ***	0.4018 ***
				(3.4125)	(4.2674)	(3.0969)
Positive social evaluation			0.0344 **			0.0325 **
			(2.1794)			(2.0658)
Householder control variable	Yes	Yes	Yes	Yes	Yes	Yes
Household control variable	Yes	Yes	Yes	Yes	Yes	Yes
Constant term	0.2982 **	3.4007 ***	0.1811	0.2407 *	3.2951 ***	0.1336
	(2.1225)	(11.6045)	(1.2061)	(1.6953)	(11.0808)	(0.8851)
adj. R^2	0.039	0.050	0.043	0.045	0.048	0.048
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mediating effect			0.0049			0.0068
Intermediate effect/total effect			0.1242			0.1730

Note: *, **, and *** respectively indicate significance at the level of 10%, 5%, and 1%.

6.5. Speculative Behavior of Rural Households

Table 14 presents the regression outcomes of Models (1) and (2), where the interaction coefficient between the intensity of use of transactional and productive social services and speculative behavior is −0.7506 and −1.7203, respectively. Both coefficients pass the significance test at the 1% level, suggesting that farmers' speculative behavior exerts a negative regulatory effect on the relationship between the intensity of use of transactional and productive social services and the adoption of soil testing and formula fertilization technology. This result implies that under the conditions of speculation, the farmers' short-term perspective might lead them to make decisions without comprehensive consideration, potentially overlooking significant aspects such as the suitability of adopted technologies, possible risks, and transaction costs. Such a mindset could undermine not only the positive impact of transactional and productive social services but also weaken the influence of transactional and productive social service use intensity on the adoption of soil-testing formula fertilization technology, thereby hampering the effective implementation of soil-testing formula technology. These findings substantiate the research hypothesis H6.

Table 14. Test results of the moderating effect of farmers' speculative behavior.

Variable	Model (1)	Model (2)
	Technology Adoption	
Transactional social services	3.1389 ***	
	(3.1172)	
Speculative behavior	0.2353 **	0.4408 **
	(2.0038)	(2.5179)
intera1	−0.7506 ***	
	(−2.6975)	
Productive socialized service		7.5917 ***
		(3.5190)
intera2		−1.7203 ***
		(−2.8678)
Householder control variable	Yes	Yes
Household control variable	Yes	Yes
Constant term	−1.7252 ***	−2.6768 ***
	(−2.6573)	(−3.3142)
Pseudo R^2	0.0582	0.0647
Prob > chi2	0.0000	0.0000

Note: **, and *** respectively indicate significance at the level of 5%, and 1%.

7. Conclusions and Policy Recommendations

7.1. Conclusions

Agricultural socialization services act as a principal driver to advance the agricultural economy and its large-scale management. In this paper, we have explored the role of social services in promoting the green production behavior of tea farmers, offering insights for accelerating agricultural transformation towards sustainable development. Utilizing the micro-survey data from tea farmers across 929 geographical indication regions in Shaanxi, Sichuan, and Anhui, we quantified the use of transactional social services and productive social services via the coefficient of variation method, investigating their impact on farmers' adoption of soil testing and formula fertilization technology. The study found:

(1) Correlation coefficient analysis showed that both productive social services and transactional social services were strongly correlated with the adoption of soil testing and formula fertilization technology by tea farmers.

(2) Transactional and productive social services significantly encourage the uptake of soil testing and formula fertilization technology by tea farmers. Specifically, productive social services have a 3% greater promotional effect on adoption decisions than transactional social services. In terms of adoption enthusiasm and scale, the influence of productive social services is approximately twice that of transactional services. Nevertheless, both types of services have a significant positive impact on technology adoption.

(3) By choosing the ratio of social service users to family farmers as the instrumental variable, we largely mitigated potential endogenous problems caused by reverse causality or omitted variables. The core conclusions remain robust even after the application of the instrumental variable method.

(4) The mechanism of how transactional and productive social services promote the adoption of soil testing and formula fertilization technology is multifaceted, primarily achieved via six pathways: enhancing farmers' price expectations, trust-building, industry cognition improvement, pursuing positive social evaluation, and speculative behavior management. The first four factors significantly enhance the positive impact of social services on technology adoption, while speculation may hinder it.

(5) Heterogeneity analysis revealed the promotional effect of transactional and productive social services on technology adoption varies across different types of farmers and their varying endowments. Transactional social services proved more impactful for part-time farmers, while productive social services were more beneficial for non-part-time farmers.

7.2. Policy Recommendations

Based on these findings, we propose several policy recommendations:

(1) Policymakers should acknowledge the varying impacts of social services on different groups of farmers. Service provision should be tailored to the farmer's type, endowment, and income level, ensuring all farmers receive necessary support for green production. Policies should incentivize and reward farmers for earning positive social evaluations, which could include financial rewards, public acknowledgment, or preferential access to resources or services.

(2) The government should foster trust amongst farmers, providing up-to-date market information, such as anticipated tea prices, to facilitate informed decisions and enhance their market competitiveness. Regular training programs to improve farmers' technical skills and information access, such as green production technology like soil testing and formula fertilization, should be considered.

(3) Enhancement of crop insurance programs, price support mechanisms, or direct subsidies for adopting green technologies could motivate farmers to compete in the market, adopt green production technologies, and mitigate market risks. Consequently, farmers will be more inclined and better equipped to employ soil testing and formula fertilization technologies, thus promoting the green transformation of agriculture and rural areas.

8. Discussion

From the perspective of farmers, this study revealed the complex relationship between productive and transactional social services and the adoption of soil testing and formula fertilization technology by tea farmers. The study found that there was a strong correlation between these services and technology adoption, and productive services had a greater impact on technology adoption. The two services had different promoting effects on soil testing and formula fertilization technology adoption among tea farmers with different types, endowments, and incomes. The price expectation, trust, industry awareness, positive social evaluation and speculative behavior of tea farmers all influence the above effect.

Previous studies on agricultural socialized services are scarce and pay more attention to productive services while ignoring the role of transactional socialized services. With the progress of technology and economic development, the technology of soil testing and formula fertilization that is conducive to promoting sustainable agricultural development is gradually promoted. The research gap on the influence of agricultural socialization service on the adoption of soil testing and formula fertilization technology and its mechanism needs to be supplemented.

In this study, the coefficient of variation method is innovatively used to measure the transactional and productive services, which can measure the degree of variation in each observation index and assign appropriate weights. From the three aspects of transactional, productive, agricultural social services on the technology adoption decision, technology adoption enthusiasm, and technology adoption scale, the impact of social services on farmers' adoption of soil testing and formula fertilization technology was comprehensively considered, and this impact would show differences depending on whether farmers have part-time jobs, the size of tea land, and the proportion of agricultural income. We also use the instrumental variable method to improve the accuracy of the estimated results. In addition, we also explore the symbiotic relationship between transactional and productive social services, with a total of five pathways affecting the impact of the two services on technology adoption, namely, the four intermediary mechanisms of price expectation, trust, industry awareness, and positive social evaluation of tea farmers, and the regulatory mechanism of speculation. It has greatly enriched the literature on agricultural socialization service and green production technology adoption.

Of course, our study also has certain limitations, and this paper may be limited in its generalization to other types of farmers or agricultural techniques, as the focus is primarily on tea farmers. Building on this basic research, future surveys could be expanded by including a more diverse group of farmers. Moreover, a deeper look at the interwoven dynamics between transactional and productive services may reveal how best to balance them for maximum effectiveness. Bespoke policy approaches may be more effective than one-size-fits-all solutions. It will be interesting to explore how the complex balance between trust building, market creation, and skill provision has evolved over time, and what this means for the future of agricultural practices and technology adoption.

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