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Determinants of Green Production Adoption among Chinese Medicinal Herb Farmers: Evidence from a Binary Logistic Analysis

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ABSTRACT

Encouraging farmers to engage in environmentally responsible production is essential for raising rural incomes, improving sectoral performance, and maintaining ecological stability. This research examines what shapes farmers' green production behavior in Cheifeng, China, using a binary logistic model applied to 860 household-level observations. The analysis shows that only 54.5% of surveyed families practiced green production, indicating a clear gap that requires targeted support. The findings reveal that age, party membership, total earnings, cultivated area, irrigation conditions, market-related aspects, policy guidance, social influences, and the ability to transfer knowledge all play significant roles. Among these, age, party membership, total land area, irrigation conditions, and knowledge-diffusion ability reduce the likelihood of green behavior, while the remaining factors enhance it. To raise adoption levels, the study suggests expanding information channels, establishing training frameworks, improving transparency in quality and safety, creating traceability systems, and offering policy-based incentives. The research further emphasizes the importance of publicity efforts, technical assistance, and media outreach in promoting greener cultivation of Chinese medicinal materials.

Keywords: Chinese medicinal materials, Green production behavior, Influencing factors, Binary logistic model

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Introduction

The transition toward green agriculture is a necessary foundation for protecting rural ecosystems and ensuring high-standard agricultural output [1]. Environmentally aligned production practices contribute to sustainable farming systems, consumer food safety, and ecological preservation [2, 3]. These practices aim to pursue "high yield, high quality, and high efficiency" while reducing reliance on chemical fertilizers and pesticides—an approach especially important for the long-term development of the Chinese medicinal materials sector. For decades, agricultural growth in China has depended on expanding inputs of natural resources. Although this model supported rapid economic gains, it also accelerated ecosystem degradation and contamination of agricultural water sources [4, 5].

China is the world's largest producer of traditional Chinese medicinal materials, with the broadest variety and a mature production system, a status it has held for nearly 20 years. However, as cultivation areas and production volumes increase, concerns about excessive agrochemical use and product safety have intensified. These issues threaten environmental quality and pose risks to public health, creating additional pressure on sustainable agriculture [6]. Strengthening ecologically friendly production in this sector is therefore essential not only for rural revitalization but also for advancing the national "Healthy China" initiative.

To support the preservation and modernization of traditional Chinese medicine and to stabilize the medicinal materials industry, the government has issued multiple policy directives. In 2019, the General Office of the State Council released guidance under the "Thirteenth Five-Year Plan," calling for more rigorous quality control and the creation of a full-process traceability framework for medicinal materials [7]. In 2021, new measures aimed at promoting the characteristic development of traditional Chinese medicine proposed technical norms for harvesting, on-site processing, ecological cultivation, wild nurturing, and simulated wild production. Then, in 2022, the "Fourteenth Five-Year Plan'' for the sector emphasized developing standardized breeding and production bases, encouraging ecological cultivation in mountainous and forest regions, refining production layouts, improving rapid testing technologies, and using innovation and demonstration to disseminate green production technologies and models [8]. Collectively, these policies form a strong regulatory foundation for the sustainable and high-quality growth of the traditional Chinese medicinal materials industry.

Traditional Chinese medicine (TCM) serves as an umbrella term that encompasses both traditional Chinese medical practice and traditional Chinese pharmacology. TCM is a broad discipline grounded in classical theories and accumulated practical experience, examining how health and illness change throughout human life and offering methods for prevention, diagnosis, therapy, rehabilitation, and health maintenance [9, 10]. It relies on approaches such as herbal materials, acupuncture, and therapeutic massage to help restore physical well-being. Traditional Chinese pharmacology, in contrast, focuses on the theoretical foundations and clinical uses of Chinese medicinal substances, including how medicinal plants are cultivated, harvested, processed, and prepared. Among these components, Chinese medicinal materials form the essential physical base that supports the healthy progression of TCM. Promoting ecologically sound cultivation practices for high-quality medicinal materials is therefore a key condition for ensuring the long-term sustainability of the TCM field [6–12].

In recent years, population expansion has sharply reduced the availability of wild medicinal resources, making the imbalance between supply and demand much more severe. As a result, cultivated medicinal materials have become the dominant source of products traded on the market [13, 14]. However, the growing reliance on cultivated materials has altered production origins and, in many cases, caused a notable decline in quality, increasing uncertainty in quality assessment [15]. Farmers play a central role in this process—they are not only the main actors in production decisions but also the immediate beneficiaries, meaning their choices directly influence both the safety and the quality of medicinal materials [16, 17].

Although China's medicinal-material cultivation industry is experiencing a rare period of expansion, problems such as the overuse of pesticides and fertilizers have become widespread [18]. Despite differences in farming objectives, many growers prioritize quantity rather than quality, which undermines the overall standard of medicinal materials and limits the healthy progression of the TCM industry [19, 20].

Research shows that the economic burden from fertilizer-related non-point source pollution exceeds the financial losses caused by rising fertilizer prices [21]. Data from the Ministry of Agriculture and Rural Affairs indicate that, in 2021, fewer than 5 million mu of medicinal materials were grown using ecological practices—only about one-sixteenth of the total cultivation area. This demonstrates that environmentally friendly production still has a long way to go. Because information among market participants is highly asymmetric, farmers growing Chinese herbal materials often increase their use of fertilizers and pesticides in pursuit of profit, leading to decisions that seem rational individually but are irrational collectively [22, 23]. As China's economy enters a new phase, achieving harmony between people and nature and integrating ecological goals into industrialization, urbanization, agricultural modernization, and digitalization has become an overarching direction for development [24].

However, as rural areas undergo rapid transformation, with younger and middle-aged workers moving to non-agricultural employment, production costs rising, and agricultural risks growing, farmers' profit margins continue to shrink [25]. Although the government has introduced subsidy programs for TCM cultivation and promoted ecological production models, farmers' willingness to adopt green practices remains low because of limitations in policy execution and shortcomings in market mechanisms. Therefore, understanding the factors and pathways that shape farmers' green production behavior has become an urgent research priority.

Green production behavior describes how farmers adjust their agricultural practices to account for production efficiency, product safety, and the protection of ecological systems, with the broader aim of moving agriculture toward long-term sustainability [26]. As the traditional Chinese medicinal materials industry has expanded quickly, attention—both in China and abroad—has increasingly turned to how growers of these materials engage in environmentally conscious production. Because these medicinal materials form the starting point of the entire TCM supply chain, understanding green behavior within this group is particularly important. For these growers, green production behavior refers to the set of practices used to produce high-quality, or authentic, medicinal materials. Such authenticity is typically associated with minimal chemical inputs, especially fertilizers and pesticides, and is expected to raise product quality, improve growers' earnings, enhance the agricultural ecological environment, and foster a stable and healthy medicinal-materials industry. From this, a development pattern emerges in which economic, ecological, and social benefits reinforce one another [27, 28].

Most existing work treats medicinal-material cultivation like general agricultural production when examining farmers' adoption of green practices. After reviewing the literature, the key influences on green production behavior can be grouped into several categories.

(1) Production and management attributes. Prior research shows that farm operational characteristics have important impacts. For instance, Chen Xuetong *et al.* (2021) identified a U-shaped association between farm size and the uptake of low-input ecological methods, a pattern likewise reported by Hua Lu *et al.* (2019). Dusen *et al*. (2022) observed that planting scale and specialization encourage green production, while Ceddia Michele Graziano *et al*. (2022) found that both operation size and labor investment matter significantly.

(2) Psychological dimensions. Studies have demonstrated that awareness of green production, decision-making tendencies, and environmental cognition all increase the likelihood that farmers will adopt environmentally responsible behaviors [29–32]. Li Hao (2020), drawing on concepts of fairness and trust, showed that farmers' sense of fairness in agricultural environmental protection directly—and also indirectly—affects their environmentally oriented behavior. Lucy Emerton *et al*. (2018) likewise argued that farmers' willingness strongly shapes their behavioral choices.

(3) External conditions. Policy frameworks, market environments, and social influences all play notable roles. Chen Zhuanqing (2021) reported that policy guidance and market orientation can positively steer farmers toward greener practices. He Yue (2021) further verified that market mechanisms, incentive programs, and constraint systems strengthen green production behavior. Research also indicates that regulatory intensity [33], subsidy programs [34], and formal governmental regulations significantly shape farmers' decisions.

Overall, researchers in China and abroad have investigated the determinants of green production behavior extensively. However, despite the large body of work, scholars vary widely in how they conceptualize the factors involved. Much of the literature isolates either internal factors—such as psychological or production characteristics—or external ones like policy and market influences. Only a small number of studies explore how internal and external elements interact. Because green production behavior is multifaceted and evolving, understanding these combined influences remains an open question. On this basis, and drawing from theories of farmer behavior, externalities, and principal-agent relationships, this paper analyzes how internal and external factors jointly shape farmers' green production behavior at the micro level. The goal is to offer theoretical support for improving and refining policy tools aimed at promoting environmentally friendly cultivation of traditional Chinese medicinal materials—a topic with important implications for the sustainable development of this industry.

Theoretical analysis and framework

This study draws upon farmer behavior theory [35] and—premised on the assumptions of "rational agents" and externalities theory [36]—employs the agency-theory-based "hidden action moral risk model" to interpret the determinants of farmers' green production choices. The model, proposed by Becker *et al.* (1974), has become a standard tool for examining moral hazard and related ethical concerns [37].

The "hidden action moral risk model" describes circumstances in which individuals deliberately obscure conduct or information, thereby generating ethical vulnerabilities. It highlights four essential elements: concealed behavior, uneven distribution of information, divergence of interests, and credibility issues. Concealed behavior arises when actors hide or alter information to secure higher private returns, particularly under information disparities. Information asymmetry refers to unequal knowledge among participants, giving rise to unfair use of information and ethical complications. Conflicts of interest surface when the objectives of involved parties are misaligned, making ethical decision-making more complex. Integrity issues relate to the reliability and honesty of actors' behavior [38].

Within this model, information gaps and misaligned interests can prompt individuals to mask actions or withhold information, producing risks such as deception, misleading claims, and market distortions. These risks can impose broad social and economic costs [39]. The cultivation of traditional Chinese medicinal materials fits the structure of an agency relationship: principals (government agencies, cooperatives, and leading firms) rely on farmers as agents. For this reason, the "hidden action moral risk model" offers a suitable analytical framework for interpreting farmers' decisions regarding green production.

First, the model's notion of "hidden actions" is directly relevant. Farmers engaged in traditional Chinese medicinal material cultivation make decisions with the intention of maximizing personal benefit. Their options generally involve either applying green production standards or neglecting to do so. Opting out of green practices may lead farmers to apply excessive chemical fertilizers or pesticides to boost short-term gains, even when such routines contradict ethical expectations [13, 40]. When principals cannot observe these behaviors, agents may exploit this lack of oversight to pursue self-interested hidden actions.

Second, the feature of "information asymmetry" is likewise evident. Principals, such as government bodies, expect farmers to carry out cultivation in ways that align with the broader objectives of the agency relationship. Yet, principals cannot directly monitor the full range of farmers' production behaviors, resulting in an informational imbalance. This can incentivize farmers to choose non-green methods that raise yields and profits, while the ecological degradation and quality risks generated during the production process are not directly borne by the farmers themselves [41].

Third, the characteristic of "conflicts of interest" is also present, as green production of traditional Chinese medicinal materials exhibits clear externalities. Farmers' adherence or non-adherence to green standards affects how principals respond. If farmers fail to implement green practices, they may lose subsidies, face market compliance issues, or suffer reputational damage. These outcomes impose losses on both agents and principals [42]. Thus, the agency arrangement operates within a structure where both incentives and risks coexist.

Lastly, the situation also reflects the "integrity issues" component within the "hidden action moral risk model." When striving to maximize their own advantages, principals—such as governmental authorities—may engage in agency-related behaviors that tilt toward their own interests. Yet, because information is unevenly distributed, the cost of overseeing agents becomes substantial, creating room for integrity-related problems on the part of principals. Taken together, this discussion shows how the "hidden action moral risk model" helps explain farmers' decision-making patterns regarding green production of traditional Chinese medicine. The model reveals the simultaneous presence of concealed behaviors, unequal information, diverging interests, and credibility concerns, underscoring the intricate balance of incentives and risks embedded in agency relationships.

Building on this logic, the article adopts the agency-theory-derived "hidden action moral risk model" to assess the suitability of farmers' green production decisions. Within this framework, stakeholders fall into two roles: principals and agents. Principals assign production tasks to agents and expect their actions to reflect the principals' goals. However, because principals only observe the final results rather than the full process, they lack direct control over agents' real behavior. Under these conditions, agents may take actions that prioritize their own benefit, while principals often struggle to monitor these behaviors due to high supervisory expenses. Such gaps easily generate moral hazard [43].

Research within the agency framework indicates that farmers' green production costs are shaped by market environments, their own endowments, and their level of knowledge. Revenue from traditional Chinese medicinal material production is influenced by market checks and pricing systems. Penalties for failing to follow green standards and subsidies for compliance depend on organizations and government support systems. Considering farmers' real production situations, the likelihood that they choose green practices is shaped by individual characteristics, market influences, and governmental involvement. Additionally, prior studies show that social factors play an important role in whether farmers adopt green production.

In conclusion, this study applies the "hidden action moral risk model" to examine how farmers make decisions about green production. The agency relationship involves principals who desire actions that align with their interests, yet face significant monitoring challenges. The model demonstrates that choices regarding green production depend on farmers' personal traits, market mechanisms, governmental policies, and broader social elements.

Research hypotheses

Knowledge capability exerts a significant impact on whether farmers adopt green production practices [26]. This capability includes the need for knowledge, the ability to obtain it, and the capacity to apply or convert that knowledge. As income growth accelerates, consumer demand for personal health rises accordingly, shifting increasingly toward eco-friendly and safe agricultural goods [34, 44]. Because farmers are the primary actors in the cultivation of traditional Chinese medicinal materials, their decisions directly affect product quality and safety. Whether they willingly seek out green production knowledge and integrate it into cultivation practices remains a point of inquiry. According to rational smallholder theory, farmers—as economic decision-makers—tend to select actions that optimize their financial returns. Although mastering and implementing green production knowledge may increase production costs, green agricultural products often secure price premiums, thereby expanding farmers' income streams [21, 45].

Based on this reasoning, the study proposes the following hypothesis:

H1. Knowledge capability positively affects farmers' green production behavior.

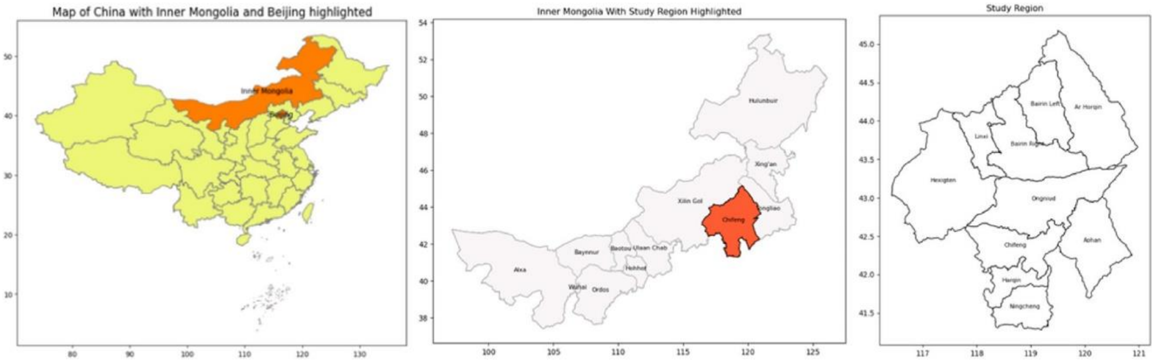
Market forces, governmental measures, and a wide range of outside influences play a decisive role in shaping farmers' environmentally responsible production choices [14, 23]. As China continues to urbanize and more rural residents shift into non-farming occupations, farmers have become increasingly diverse. Differences in production goals have given rise to several groups: survival-oriented, lifestyle-oriented, production-oriented, and function-oriented farmers [46]. Earlier studies show that these farmer categories, shaped by their distinct resource bases and objectives, respond very differently to external influences when engaging in green production [32]. Based on this reasoning, the study puts forward the following hypothesis:

H2. External factors influence farmers' green production behavior in uneven ways.

Materials and methods

Research area

Chifeng, located in eastern Inner Mongolia, borders Tongliao to the east, Chaoyang to the southeast, Chengde to the southwest, and Xilingol League to the northwest. Its coordinates span from 41◦17′10″N to 45◦24′15″N and from 116◦21′07″E to 120◦58′52″E. The region serves as an important setting for research on ecological cultivation, ecological resource protection, and the development of industries based on Chinese medicinal plants.



In 2021, Chifeng had 550,000 mu of cultivated land for medicinal crops (with 1 mu equal to 666.666 m²). It has long been known as a major base for northern and Mongolian herbal medicine in China, consistently ranking first in cultivation scale within the region and among all prefecture-level cities in the country. Drawing on favorable natural conditions and deep cultivation traditions, the city has expanded its medicinal-plant industry and gradually built a complete industrial chain.

Herbal-medicine cultivation has grown into a leading sector in Chifeng, beginning in Harqin Banner and spreading to neighboring areas. In the northern part of the region, Hexigten Banner, Linxi County, Baarin Left Banner, and AR Horqin Banner form the main production belt. In the central zone, the dominant areas include Harqin Banner, Ongniud Banner, Ningcheng County, Yuanbaoshan District, Hongshan District, Chifeng City, and Aohan Banner. The planting area has steadily expanded. By July 2020, key Mongolian and Chinese herbal crops included Platycodon grandiflorum (73,200 mu), Radix isatidis (31,000 mu), Radix saposhnikoviae (25,000 mu), Radix Astragali (116,000 mu), Radix scutellariae (27,000 mu), and an additional 15,000 mu of Radix isatidis. By late July 2021, the total cultivated area of Chinese and Mongolian medicinal materials in Chifeng had reached 550,000 mu, with an output of 464,000 tons and a projected value of 7.01 billion yuan, placing it first in Inner Mongolia and fifth nationwide among league cities in both production and scale.

Variable selection and assignment

Using insights from prior literature and the specific conditions of the study area, this work groups the determinants of farmers' green production decisions into seven broad domains: personal attributes, household-related features, production conditions, market-related influences, policy-related influences, social influences, and knowledge/skill capacity. These categories form the basis of the indicator framework, and all variables are summarized in **Table 1.**

The dependent variable is "whether green production behavior is carried out" [32].

The independent variables include:

- Market influence: measured through the question, "Do you think adopting green production will increase the purchase price of traditional Chinese medicinal materials?" [47].
- Policy influence: captured by "Have you obtained any government subsidy related to green production?" [48].
- Social influence: assessed via "Does media information and advocacy for green production noticeably shape your planting choices?" [44].
- Knowledge capability: evaluated with three items — "Are you willing to learn technical information about fertilizers and pesticides?", "When encountering problems with their use, can you figure out how to address them?", and "Can you practically apply the information you have learned?" [33].

Control variables consist of gender, age, education level, party membership, health condition, total household size, annual income, farming scale, and irrigation status [34, 46, 49].

Table 1. Description of the basic characteristics of the sample farmers.

Variable Settings	Variable Definition and Assignment	Standard Deviation	Mean
Dependent Variable	Whether green production behavior is implemented. YES = 1, NO = 0	0.50	0.56
Independent Variables			
Market-Driven	Do you believe implementing green production will increase the price of Chinese medicinal herbs? YES = 1, NO = 0	0.48	0.65
Policy-Driven	Do you receive government subsidies for green production? YES = 1, NO = 0	0.50	0.47
Social Drive	Have media campaigns promoting green production impacted your farming practices significantly? YES = 1, NO = 0	0.57	0.50
Ability to Demand Knowledge	Would you be willing to proactively learn about fertilizer and pesticide application techniques? YES = 1, NO = 0	0.92	4.05
Gain the Ability	Are you open to acquiring knowledge about fertilizer and pesticide application? YES = 1, NO = 0	0.75	4.03
Absorptive Capacity	If you encounter problems with fertilization and pesticide application, can you find a solution? YES = 1, NO = 0	0.78	4.57
	Can you effectively apply the knowledge gained to fertilization and pesticide use? YES = 1, NO = 0		
Control Variables			
Age	Age of the respondents in years	9.12	55.20
Gender	Male = 1, Female = 0	0.40	0.80
Party Membership	Yes = 1, No = 0	0.66	0.06
Education (Edu)	Primary school or below = 1, Junior High = 2, High School/Technical School = 3, Junior College or higher = 4	0.67	2.05
Health Status (Hea)	Poor = 1, Average = 2, Healthy = 3	0.47	1.99
Total Family Size	Number of family members involved in farming (persons)	0.94	0.88
Annual Family Income	Total household income of rural households (in 10,000 yuan)	41.21	17.31
Total Cultivated Land	Area of land used for Chinese medicinal herb farming (in mu)	96.74	27.80
Irrigation Conditions	Extreme scarcity = 1, Supply tension = 2, Drought tension = 3, Relatively adequate = 4	0.72	3.47

Data source and questionnaire structure

A questionnaire was used to collect data, and all participants signed written consent forms. Ethical approval was issued by the Institutional Ethics Committee of the School of Economics and Management, Beijing Forestry University (approval number 2170188). Fieldwork took place in December 2022 across eight counties (banners/districts) in Chifeng City, Inner Mongolia Autonomous Region.

The rationale for choosing Chifeng City is threefold.

First, Chifeng sits at the meeting point of warm-temperate and cold-temperate zones, features hilly landforms, and experiences four distinct seasons. Its yearly average temperature ranges from 0 to 7 °C, while annual precipitation is roughly 381 mm. These conditions are highly suitable for the cultivation of Chinese medicinal plants. The city is a major origin of high-quality northern Chinese and Mongolian herbal products and is often referred to as the "hometown of Chinese North American ginseng and platycodon." Its cultivation area for medicinal plants has remained stable at around 700,000 mu (approximately 46,667 ha) per year, placing it among the top prefecture-level cities nationwide. Its products are widely recognized and exported to South Korea, Japan, and other Southeast Asian markets. Although most growers operate on a small or medium scale, large-scale planting continues to expand, a pattern similar to other major medicinal-plant regions in China.

Second, the rapid growth of the medicinal-plant sector in Chifeng is accompanied by an absence of unified technical rules for wild-simulated cultivation. Standards for pesticides, fertilizers, and related inputs are lacking, resulting in frequent over-application.

Third, Chifeng is a priority area for ecological cultivation and ecological resource protection. Recent initiatives include drafting a comprehensive plan for fertilizer and pesticide use, promoting "zero-growth" goals for chemical inputs, expanding the use of organic fertilizers and biopesticides, and encouraging soil testing with formula fertilization. These measures have steadily reduced chemical-input intensity, supported sustainable agriculture, improved production efficiency, and helped preserve ecological quality and medicinal-material quality.

Considering output levels, chemical-input use, and the implementation of green-production practices across counties, the research team selected eight representative sites: Kalaxi Banner, Ningcheng County, Aohan Banner, Songshan District, Yuanbaoshan District, Wengniute Banner, Bairin Left Banner, and Bairin Right Banner.

A draft questionnaire was created after reviewing existing work and assessing local realities. A pilot study was conducted in November 2022 in Niujiayingzi Town, Kalaxi Banner, where 120 growers of medicinal plants were interviewed. Discussions were held with local authorities, cooperatives, and key enterprises. Feedback from this preliminary stage, along with expert suggestions, guided the development of the final survey instrument.

The research team consisted of young faculty members, doctoral candidates, and several master's students. Prior to data collection, all team members received thorough training. The investigators were organized into groups headed by senior instructors, with each unit made up of 3–4 individuals—a team leader, a questionnaire recorder, and a reviewer. To further guarantee sample reliability, the team proactively contacted classmates, relatives, friends, and acquaintances working in rural economic management offices and agricultural technology departments. With their assistance, initial communication was carried out with village (gacha) leaders in the selected areas before formal fieldwork began.

A stratified sampling strategy guided the selection process, and specific respondents were chosen randomly. The procedure unfolded as follows. First, eight counties (banners/districts) were designated as primary sampling units. Within each county, Chinese medicinal-material planting areas were divided into five levels: very low, low, medium, high, and very high. From each level, two towns (or townships) were randomly chosen. Next, based on the number of growers in each selected town or township, villages (gachas) were ranked. From those with the highest 50 **%** concentration of growers, four villages (gachas) were randomly selected. Finally, within every sample village (gacha), 15–20 planting households were randomly surveyed. In total, 900 questionnaires were issued, 861 valid responses were obtained, yielding an effectiveness ratio of 97.6 %.

During data processing, missing values were capped at 5 %. Any questionnaire exceeding this threshold was discarded. For cases in which missing items were below 5 %, the Bayesian interpolation method was applied due to the small proportion of missing entries. This approach can notably influence the accuracy of the dataset.

Descriptive statistics

Table 2 summarizes the main features of the sampled farmers. In terms of gender, 79.8 % of respondents were men and 20.2 % were women, showing that decisions regarding medicinal-plant cultivation are largely made by males. Concerning age, 6.63 % were under 40, 25.47 % were aged 41–50, 38.72 % fell within 51–60, and 29.19

% were above 61. Educationally, 20.2 % had a primary-school education or less, 54.8 % had junior-secondary schooling, 24.5 % held senior-secondary or technical-secondary qualifications, and 0.4 % had tertiary education or higher.

Regarding political affiliation, 7 % were party members, while 93 % were not. Household size data show that families with three or fewer members represented 45.58 %, those with four to six members accounted for 51.86 %, and those with more than seven members constituted 2.56 %. For annual household income, 5.93 % earned below 30,000 yuan, 31.51 % earned between 30,000 and 100,000 yuan, 49.19 % between 100,000 and 200,000 yuan, 10.47 % between 200,000 and 500,000 yuan, and 2.91 % exceeded 500,000 yuan.

With regard to operational scale, 9.42 % farmed fewer than five mu, 23.84 % farmed 6–10 mu, 42.21 % operated 11–20 mu, 18.14 % farmed 21–50 mu, and 6.4 % exceeded 51 mu. Considering production choices, 54.5 % of farmers adopted green production practices, while 45.5 % did not, meaning that more than half engaged in such practices.

Table 2. Description of basic characteristics of sample farmers.

Variable Settings	Variable Assignment	Rate	Frequency	Variable Settings	Variable Assignment	Rate	Frequency
Sex	Male	79.8%	687	**Total Family Size**	Less than three people	45.58%	392
	Female	20.2%	173	4-6 people	446		51.86%
Age	Under 40 years	6.63%	57	More than seven people	22		2.56%
	41-50 years	25.47%	219				
	51-60 years	38.72%	333	**Annual Family Income**	Less than ¥30,000	5.93%	51
	Over 61 years	29.19%	251	¥30,001-¥100,000	271		31.51%
Education (Edu)	Primary and below = 1	20.2%	174	¥100,001-¥200,000	423		49.19%
	Junior High = 2	54.8%	472	¥200,001-¥500,000	90		10.47%
	High School or Technical Secondary = 3	24.5%	211	Over ¥500,000	25		2.91%
	Junior College or above = 4	0.3%	3				
Party Member	No	93%	800	**Total Area of Cultivated Land**	Below 5 mu	9.42%	81
	Yes	7%	60	6-10 mu	205		23.84%
Irrigation Conditions	Extreme scarcity	2.6%	23	11-20 mu	363		42.21%
	Supply is tight	4.8%	42	21-50 mu	156		18.14%
	Tension in a drought	35.8%	308	Over 51 mu	55		6.40%
	Relatively well off	56.6%	487				

Model construction

This research utilizes a Binary Logistic Model to explore what drives farmers to engage in green production. The dependent variable contains two outcomes—1 for “Yes” and 0 for “No”—reflecting a binary decision framework. A farmer’s choice is shaped by both internal motivations and outside conditions. Because farmers differ in resource availability and in the objectives guiding their household operations, the elements influencing their decisions are not uniform across individuals.

To capture these differences, the study identifies 15 variables, grouped into two categories, each designed around the characteristics of farmers in the selected region. The arrangement of these factors and their assumed relationships are presented in **Figure 1**, which outlines the model structure for determinants of green production behavior.

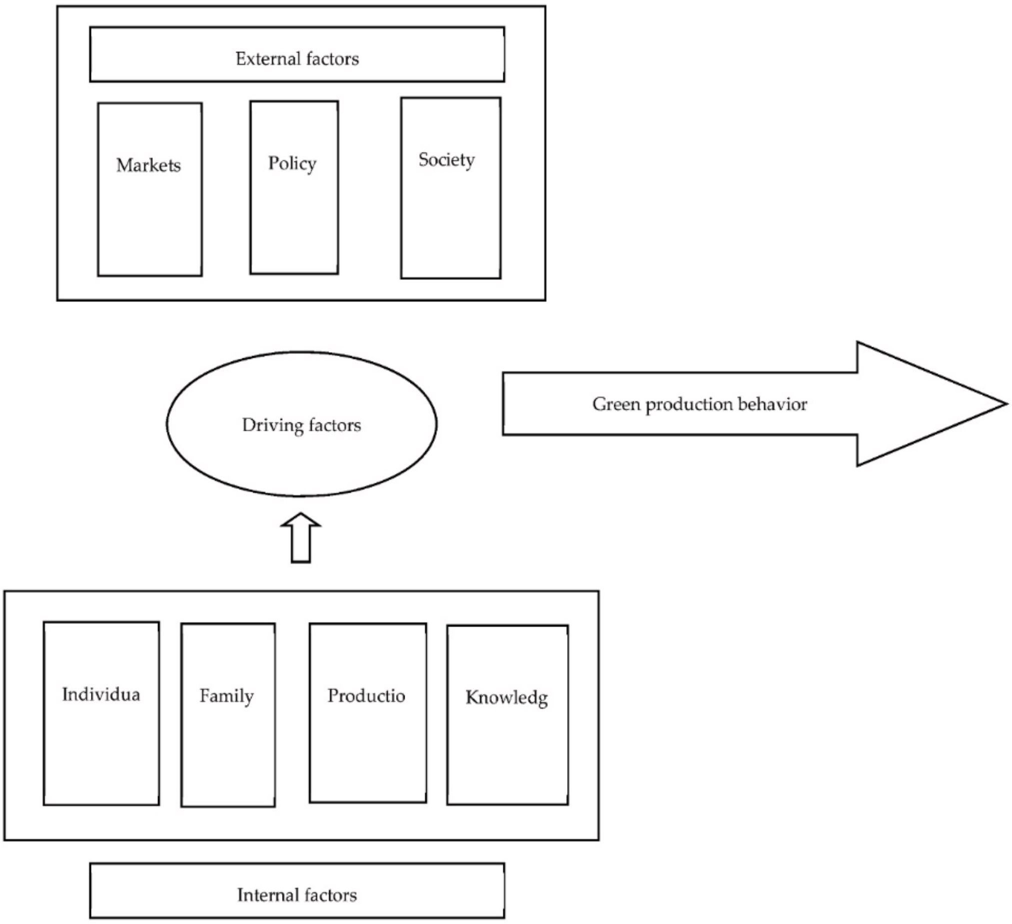


Figure 1. Structure of the model for factors influencing farmers' green production behavior.

In this setup, P represents the likelihood that a farmer adopts green production. The corresponding binary model is written as follows:

$$P = \exp(\beta_0 + \beta_1 Mar + \beta_2 Gov + \beta_3 Soc + \beta_4 kno - regu + \beta_5 kno - acqu + \beta_6 kno - abso + \beta_7 sex + \beta_8 age + \beta_9 edu + \beta_{10} Hea + \beta_{11} cadr + \beta_{12} far - num + \beta_{13} inco + \beta_{14} land + \beta_{15}\ irra/[1+\exp(\beta_0 + \beta_1 Mar + \beta_2 Gov + \beta_3 Soc + \beta_4 kno - regu + \beta_5\ kno - acqu + \beta_6 kno - abso + \beta_7 sex + \beta_8 age + \beta_9 edu + \beta_{10} Hea + \beta_{11} cadr + \beta_{12} far - num + \beta_{13} inco + \beta_{14} land + \beta_{15} irra)] \quad (1)$$

$$\text{Logistic } P_i = \ln\left(\frac{P_i}{1 - P_i}\right) \quad (2)$$

$$\text{Logistic } (P|y = 1) = \text{Ln } (p|1 - p) = \beta_0 + \beta_1 Mar + \beta_2 Gov + \beta_3 Soc + \beta_4 kno - regu + \beta_5 kno - acqu + \beta_6 kno - abso + \beta_7 sex + \beta_8 age + \beta_9 edu + \beta_{10} Hea + \beta_{11} cadr + \beta_{12} far - num + \beta_{13} inco + \beta_{14} land + \beta_{15}\ irra \quad (3)$$

Among these variables, P_i denotes the likelihood that a farmer adopts green production, whereas $1 - P_i$ corresponds to the likelihood of choosing non-green production. Mar stands for market-related conditions; Gov captures governmental influences; Soc reflects social-environmental pressures. The variables kno-regu, kno-acqu, and kno-abso refer respectively to the need for knowledge, the process of obtaining information, and the ability to internalize that information. Sex, Age, Edu, and Hea indicate gender, age level, educational background, and health status. Card identifies party membership, Far-num represents household size, Inco refers to total income, Land specifies total land area, and Irra characterizes irrigation conditions. The coefficients β1–β15 are the parameters associated with each explanatory variable, while β0 is the model's intercept.

Software validation

Drawing on existing studies, the Hosmer–Lemeshow (HL) goodness-of-fit test is recognized as the most suitable method for evaluating binary logistic models. The test compares predicted outcomes with observed data; when the ρ-value exceeds 0.05, the HL test is considered successful, indicating no statistically meaningful gap between predictions and actual observations. If the ρ-value falls below 0.05, the test fails [50], which suggests a noticeable discrepancy between predicted and real values and therefore weak model fit [51, 52]. The HL statistic is calculated using the following formula:

$$HL = \sum_{j=1}^{J} \frac{(Y_j - N_j P_j)}{N_j P_j (1 - P_j)} \quad (4)$$

where **J** indicates the number of groups in the sample, $\mathbf{Y_j}$ is the count of observations within group **J**, $\mathbf{N_j}$ represents the total observed cases in that group, $\mathbf{P_j}$ is the predicted probability of the event occurring in group **J**, and $\mathbf{N_j P_j}$ corresponds to the expected number of events based on the model.

Results and Discussion

Determinants of farmers' green production behavior

The study employed a binary logistic regression to explore the factors driving green production, with the outcomes presented in **Table 3**. The Hosmer–Lemeshow (HL) test was conducted to assess the model fit, resulting in a P-value greater than 0.05, which indicates that predicted and observed outcomes do not differ significantly and that the model fits the data adequately.

Among the independent variables, nine factors reached statistical significance: age, party membership, total household income, cultivated land area, irrigation status, market influence, policy influence, social influence, and knowledge transformation ability. These variables are considered the main determinants affecting farmers' adoption of green production practices.

To examine multicollinearity, the Variance Inflation Factor (VIF) was calculated, with values ranging between 1.2 and 4, confirming no severe multicollinearity issues. The odds ratio (OR) was used to assess the magnitude of influence, representing the expected change in the probability of green production when other factors remain constant. The ranking of the nine factors according to OR values is as follows: Market factors > Social factors > Family income > Policy factors > Age > Total cultivated area > Irrigation conditions > Knowledge transformation ability > Party membership.

Table 3. Regression results of the selected variables.

Variable Name	Coefficient	OR Value	Standard Error	p Value	Wald χ2	Z Value
Age	-0.003	0.997	0.009	0.047	0.096	-0.309
Sex	-0.167	0.846	0.176	0.344	0.896	-0.946
Education (Edu)	0.003	1.003	0.128	0.981	0.001	0.024
Party Member	-0.735	0.479	0.301	0.015	5.947	-2.439
Total Family Size	0.069	1.071	0.047	0.146	2.117	1.455
Annual Family Income	0.360	1.433	0.168	0.032	4.606	2.146
Total Area of Cultivated Land	-0.014	0.988	0.004	0.000	12.385	-3.519
Market Factors	0.573	1.773	0.151	0.000	14.469	3.804
Policy Factors	0.227	1.255	0.166	0.002	1.869	1.367
Social Factors	0.411	1.508	0.156	0.008	6.968	2.640
Ability to Demand Knowledge	-0.009	0.991	0.170	0.960	0.003	-0.050
Gain the Ability	0.138	1.148	0.181	0.447	0.577	0.760
Absorptive Capacity	-0.612	0.542	0.271	0.024	5.100	-2.258
Irrigation Conditions	-0.014	0.987	0.004	0.000	12.385	-3.519
Intercept	2.031	7.622	0.786	0.010	6.679	2.584

Impact of farmers' resource endowments on green production

For individual-level characteristics, both age and party membership were statistically significant. The coefficient for age (−0.003) suggests that older farmers are less inclined to implement green production, likely due to entrenched cultivation habits and limited access to new information. Conversely, younger and middle-aged farmers, being more open to innovation and willing to take risks, are more likely to adopt green production techniques.

The coefficient for party membership (−0.735) indicates a negative relationship with green production. Although village cadres tend to have higher awareness of relevant regulations and ecological practices, small-scale planting and opportunistic behaviors among some party-member households reduce their engagement in green production. Education level did not show a significant effect, which may be explained by the predominance of older, experienced growers with relatively low formal education who are less attentive to green production and reluctant to adopt new methods. Likewise, gender was not significant, likely because decisions regarding medicinal crop cultivation are mostly made by male household heads, so gender itself does not directly determine green production behavior.

In terms of family characteristics, the total family income has a significant effect on farmers' green production practices, with a regression coefficient of 0.360. This suggests a positive relationship between farmers' total family income and their adoption of green production methods. In regions where Chinese medicinal plants are cultivated, farmers generally have higher agricultural and labor incomes, which makes them more likely to focus on improving the quality of these crops during green production, leading to better returns. Conversely, the total cultivated land area shows a significant negative association with green production behavior (regression coefficient of -0.014). This implies that farmers with larger plots of land prioritize increasing output to achieve higher profits. Larger areas of land often mean higher land contracts, rents, labor, and machinery costs, as well as increased pesticide and fertilizer usage, all of which reduce the likelihood of adopting green production methods. Household size, however, does not significantly affect the decision to adopt green production behavior, likely because many rural households have long-term migrant workers with stable incomes. The average number of farmers in a household is typically 2-3.

Regarding irrigation, a negative correlation of 0.014 was found with green production behavior. This suggests that farmers with better irrigation systems expect higher land returns, and thus are less likely to engage in green production practices since their productivity is already sufficient. On the other hand, areas with poor irrigation, typically in mountainous regions where fertilizers are less effective, tend to encourage the use of more organic manure, thus promoting green production methods.

Influence of external factors on green production behavior

Market factors have a positive regression coefficient of 0.573, indicating a strong connection between market conditions and green production behavior. This means that as farmers expect higher market prices for Chinese medicinal materials due to green production, they are more likely to adopt such practices. This aligns with expectations, as a strong market price mechanism motivates farmers to engage in green production. However, in cases where the market price mechanism is weak, farmers are less inclined to pursue green production, and economic considerations play a key role in their decisions.

The policy factor shows a positive relationship with a regression coefficient of 0.227, suggesting that government subsidies for green production in the Chinese medicinal plant sector encourage farmers to adopt environmentally friendly practices by offsetting the additional costs of these methods.

Social factors also have a positive impact, with a regression coefficient of 0.411. This reflects the increasing willingness of farmers to engage in green production, driven by growing government investments in environmental protection, which have led to improvements in air quality, water resources, and rural living conditions over time.

Influence of knowledge on adoption of green production practices

The ability to seek and acquire knowledge did not pass the significance test, with regression coefficients of -0.009 and 0.138, respectively, showing that these factors do not significantly impact the green production behavior of farmers. In contrast, the ability to apply knowledge showed a significant negative effect, with a regression coefficient of -0.612, meaning that it does influence the implementation of green practices. This may be due to the fact that older farmers with lower education levels often find it difficult to integrate new ideas or information related to green production. However, those with a higher capacity to convert knowledge into practice were more inclined to adopt sustainable farming practices. On the other hand, some farmers were hesitant to make the shift due to the increased costs and lower yields typically associated with traditional Chinese medicine cultivation. Consequently, the ability to transfer knowledge had a generally negative influence on adopting green production behavior.

Promoting green production and enhancing agricultural output through improved quality is key to the broader goal of agricultural revitalization. By examining the factors that influence farmers' decisions, this research offers insights that can inform policies around green production in agriculture. Compared to earlier studies, this article adds new depth in the following ways:

1. Application of Binary Logistic Regression: This method analyzes the core factors affecting green production behavior, linking both internal and external influences, and addressing prior research gaps by focusing on how farmers' mindset and social contexts influence their decisions. The findings reveal that both internal and external factors, including resource endowments, strongly impact the green production behavior of Chinese medicinal herb farmers. External elements like market conditions, government policies, and societal factors all have a positive influence on adopting green practices, which aligns with Research Hypothesis 1. Among these, market influences are the most significant, showing that farmers are particularly sensitive to market price fluctuations. Meanwhile, the role of policy subsidies is less prominent, suggesting that current policies do not adequately address the diverse needs of farmers. Therefore, more tailored strategies are required to address this diversity within the Chinese medicinal herb farming community.
2. Exploring the Mechanisms behind Green Production Choices: This research fills a gap in previous studies by exploring how both internal and external factors shape the decision to adopt green production. It suggests that there is significant potential to enhance the subsidy structures and policy frameworks that support green production in the Chinese medicinal herb sector, thus confirming the validity of Research Hypothesis 2. Contrary to earlier studies, this study finds that the ability to acquire and demand knowledge had no significant influence, while the ability to apply knowledge showed a negative relationship. This difference may stem from the specialized knowledge required for medicinal herbs, which sets this industry apart from other agricultural sectors. The small-scale nature of Chinese agriculture, with its largely less-educated farming population, makes farmers less receptive to new practices.

This study underscores the strong relationship between various factors, such as internal resources, market dynamics, policy interventions, and social influences, and the adoption of green production practices among Chinese medicinal herb farmers. The findings resonate with earlier research, though market factors emerged as a more dominant influence, highlighting farmers' strong sensitivity to market prices. In contrast, policy support appeared less effective, revealing a need for a more targeted approach to green production subsidies and more comprehensive policy backing for the industry.

Contrary to previous research, this study found that the ability to acquire knowledge did not significantly influence green production behavior. Instead, only the ability to apply knowledge showed a negative effect, which may be due to the distinct nature of the Chinese medicinal herb industry. Unlike other crops, Chinese herbs require specialized knowledge. Additionally, Chinese agriculture is marked by a mix of more and less educated farmers, with many still preferring traditional practices and being resistant to new methods.

The study also found that while reducing the use of pesticides and fertilizers has positive external benefits, the policy subsidy mechanism needs to be a stronger motivator. However, the empirical results suggest that policy subsidies impact all farmers dealing with pesticides to varying degrees. This points to a gap in policy design, where the diverse needs of farmers are not adequately addressed, highlighting the lack of precision and differentiation in current implementation strategies. To achieve better results with fewer efforts, further segmentation of the Chinese medicinal herb sector is essential.

Moreover, the research revealed a shift toward agricultural transformation among Chinese medicinal herb farmers. This transformation, driven by industrialization and urbanization, aims to absorb surplus labor from rural areas. As a result, traditional small-scale farmers are transitioning from subsistence farming to more commercially oriented practices, reflecting broader trends of urbanization and the growth of non-agricultural employment.

Conclusion

This study takes a micro-level approach, conducting household surveys among Chinese medicinal herb growers in Chifeng City, a major production area for Chinese herbs. By drawing on theories related to farmer behavior, externalities, and principal-agent relationships, the study investigates the internal and external factors influencing farmers' decisions regarding green production. The main findings are as follows:

First, the adoption rate of green production practices among Chinese medicinal herb farmers is relatively low, standing at 54.5%. Farmers exhibit limited enthusiasm for green production, and their behavior is shaped by both internal and external influences. Without a strong market mechanism, positive reinforcement from social and policy factors helps counterbalance the limitations of market-driven incentives.

Second, nine key factors were identified as significantly impacting farmers' decisions to implement green production practices. These factors include age, party affiliation, family income, cultivated land area, irrigation conditions, market influences, policy support, social factors, and knowledge transformation ability. These factors vary in their impact, with market factors having the strongest positive influence, followed by social factors, family income, policy support, age, cultivated land area, irrigation conditions, knowledge transformation ability, and party affiliation.

Third, the direction of influence varies among these factors. Factors such as age, party affiliation, cultivated land area, irrigation conditions, and knowledge transformation ability were found to negatively affect the adoption of green production practices, while market influences, policy support, and social factors play a significant role in promoting it. The implementation of green production behavior is thus the result of a combined effect of both internal and external factors.

Based on these findings, several policy recommendations are made to encourage green production behavior among farmers and support the transformation and upgrading of the Chinese medicinal herb industry. Given the relatively low adoption rate of green production (54.5%), the government should focus on increasing awareness and motivation among farmers. This can be achieved by enhancing incentive mechanisms and providing a variety of pathways to encourage farmers to adopt green production practices.

Despite the wide range of factors influencing farmers' green production practices, only nine were deemed significant in this study. It is crucial for the government to design specific policies that address these key determinants, along with implementing differentiated strategies that target the unique needs of various farmer groups. Additionally, boosting family income through various channels, improving the pricing structure for Chinese medicinal herbs, and establishing essential mechanisms—such as pricing strategies for premium herbs, quality standards, traceability systems, and brand development—are necessary steps. These initiatives will provide essential guidance for policy-making, aiding in the consistent enhancement of Chinese medicinal herb quality and ensuring a stable supply.

In light of the current shortcomings of the market system, it is necessary to focus on raising awareness and providing support for green production methods in the Chinese medicinal herb industry. This could involve improving the precision and effectiveness of media outreach, while also implementing a subsidy system to motivate farmers to adopt green production practices.

For factors like age, political affiliation, land size, irrigation conditions, and knowledge transfer ability—which negatively impact green production behavior—the government should encourage younger and middle-aged individuals to start businesses in rural areas, enhance the leadership role of party members, improve rural infrastructure, and increase access to green production knowledge. Establishing comprehensive training programs would further empower farmers with the skills needed for green production.

One limitation of this study is its geographic focus on Chifeng City, without comparing farmers' behaviors in other major regions of Chinese medicinal herb production. Farmers' green production behaviors are influenced by a variety of factors, including economic conditions, policy frameworks, geographical contexts, and sample size. Future research could include a broader range of regions and herb varieties to enhance the findings' applicability. Expanding the study to the provincial or national level would provide deeper insights into the factors affecting green production behavior across different regions, facilitating the creation of tailored ecological and management systems for medicinal materials. It would also be beneficial to compare Chinese medicinal herbs with other crops to highlight their unique characteristics and contribute valuable knowledge for the sustainable growth of the industry.

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