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The impact of knowledge capacity on Chinese farmers' green production behavior: a case study in the context of environmental regulation in China

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China's agricultural development has gradually transitioned from traditional to modern agriculture, leading to an increased demand for knowledge and skills among farmers. There are numerous factors influencing farmers' green production behavior, yet research on the impact of knowledge capacity on farmers' green production behavior under environmental regulatory contexts is still lacking. Using microdata from 860 Chinese medicinal herb planting households in Chifeng City, China, this study employs a binary logistic model to investigate the influence of knowledge demand capacity, knowledge absorption capacity, and knowledge transformation capacity on farmers' green production behavior. Simultaneously, by constructing policy scenarios of restrictive environmental regulations, guiding environmental regulations, and incentive environmental regulations, the study analyzes their moderating effects on the relationship between knowledge capacity and green production behavior. The results indicate that knowledge demand capacity does not significantly affect farmers' green production behavior, while knowledge absorption capacity and knowledge transformation capacity have a significant positive impact. Restrictive environmental regulation policies positively moderate the relationship between knowledge demand capacity and farmers' green production behavior. Incentive environmental regulation policies can reverse the negative effect of knowledge demand capacity on farmers' green production behavior, while guiding environmental regulation policies do not have a moderating effect on the relationship between knowledge demand capacity, knowledge absorption capacity, knowledge transformation capacity, and farmers' green production behavior. Therefore improving the mechanism for green production training, enhancing the accessibility of knowledge acquisition for farmers, strengthening the implementation of environmental regulation policies, and forming a virtuous cycle between farmers' internal mechanisms and policy mechanisms.

KEYWORDS
binary logistic model, Chinese medicinal herb planting, environmental regulation, green production behavior, knowledge capacity

1 Introduction

The cultivation of traditional Chinese medicinal herbs is extensively cultivated across China and represents a key segment of the country's specialized agriculture (Li and Gan, 2022). However, as the production and industrial scale of medicinal herbs continues to expand, the overuse of pesticides and fertilizers has become increasingly prominent, posing significant threats to agricultural sustainability and human health (Zhang et al., 2021). In response, the General Office of the State Council of China released the "14th Five-Year Plan for the Development of Traditional Chinese Medicine" in 2022, which promotes the adoption of ecological cultivation practices to enhance the quality of medicinal herbs (Liu et al., 2023). These policy initiatives, together with a suite of laws and regulations supporting the green production of traditional Chinese medicinal herbs, offer robust institutional support for the high-quality development of the industry.

China's agricultural sector has undergone a paradigm shift from traditional to modern agricultural practices (Zhang et al., 2021; Huang et al., 2024), accompanied by continuous advancements in production technologies. This technological evolution has heightened the demand for farmers to enhance their knowledge capability. Knowledge capability herein refers to farmers' ability to acquire and master knowledge pertaining to the scientific application of agricultural inputs such as pesticides and fertilizers. It acts as a pivotal factor shaping farmers' production and management decisions, as well as a key driver in transforming farming practices (Zhang et al., 2022; Hu et al., 2023). The enhancement of knowledge capability renders the adoption of green production practices an inevitable trend. Green production practices encompass agricultural activities that balance production efficiency with ecological and environmental protection, while ensuring the safety of agricultural products (de Andra et al., 2023). Consequently, the relationship between knowledge capability and farmers' green production practices exerts a direct bearing on the advancement of green agriculture.

Green production behavior among traditional Chinese medicinal herb growers entails the reduced application of chemical fertilizers and pesticides during cultivation. This practice is intended to enhance the quality of medicinal herbs, increase farmers' income, foster the sustainability of agriculture and ecosystems, and ensure the long-term healthy development of the industry (Waheed et al., 2020). Extant research on the determinants of farmers' green production behavior has primarily focused on production and operational characteristics (Du et al., 2022; Kamalanon et al., 2022), psychological characteristics (Liu et al., 2020; Sharma et al., 2023), and external contextual factors (He and Qi, 2021; Witek and Kuźniar, 2020). In contrast, insufficient attention has been paid to the impact of knowledge capability on such behavior. Moreover, research on knowledge capability has largely centered on farmers' cognitive perspectives (Ali et al., 2023), its effect on farmers' willingness to adopt green production (Yang and Gong, 2021; Zhang et al., 2025), and related mechanisms (Tang et al., 2021). However, the underlying mechanism by which knowledge capability influences green production behavior remains underexplored.

Environmental problems possess strong externalities (Xu et al., 2023). Relying solely on farmers' voluntary adjustments and market mechanisms may lead to market failure, thus requiring government intervention to mitigate such inefficiencies. Extant research on environmental regulation has primarily focused on how such policies shape farmers' production behaviors (Jin et al., 2022), as well as the mediating and moderating effects of environmental regulation (Ke and Huang, 2024). However, the moderating role of environmental regulation in the relationship between knowledge capability and farmers' green production behavior remains underexplored.

Therefore, this study utilizes field survey data from Chifeng City, Inner Mongolia—a major production base for traditional Chinese medicinal herbs—to unravel the underlying mechanisms through which knowledge capability influences farmers' green production practices within the framework of environmental policies. Drawing on externality theory, this study investigates whether environmental policies exert a moderating role in the relationship between knowledge capability and green production practices among medicinal herb growers. The findings are expected to provide theoretical implications and practical policy recommendations for improving the knowledge capability of cultivators and promoting the transformation and upgrading of the traditional Chinese medicinal herb industry.

2 Methodology

2.1 Theoretical analysis and hypotheses

According to the theory of farmer behavior, farmer behavior is a dynamic process (Biesheuvel et al., 2021), which is influenced by factors such as psychology, society, and culture, based on the assumption of "bounded rationality" proposed by the rational farmer school. With the transition of Chinese agriculture from traditional to modern, there is a significant increase in farmers' demand for knowledge (Sok et al., 2021). In the process of reducing pesticide and fertilizer use, farmers gain long-term economic and ecological benefits, but it also increases production costs. Therefore, farmers make decisions on green production based on the goal of maximizing their own profits and external regulatory conditions.

Farmers' knowledge capacity influences green production behavior through a "cognition–absorption–transformation" process: first, developing awareness of and demand for green technologies (cognition); second, understanding and internalizing relevant knowledge (absorption); and finally, applying such knowledge in actual farming practices (transformation). This process underscores that knowledge capacity is not merely about access to information, but a key internal mechanism driving the adoption of green production behaviors.

Externalities theory refers to the impact of one party's production decision on another party's production decision, and this impact has a dual nature (Harris and Roach, 2021). Since the market cannot effectively solve the problem of externalities, external interventions are necessary. Pesticide and fertilizer reduction behaviors have obvious environmental externalities. For example, if farmers in the cultivation of Chinese medicinal materials only consider maximizing their personal economic interests while neglecting ecological benefits, it will increase the intensity of pesticide and fertilizer application, leading to an increase in environmental costs and a decrease in overall social welfare, deviating from Pareto Optimality. Therefore, the externality theory provides sufficient theoretical basis for the government to introduce environmental regulation policies to address the issue of green production of Chinese medicinal materials. Environmental regulations moderate the relationship between knowledge capacity and green production behavior. Strong regulatory pressure (e.g., restrictive policies or incentives) drives farmers to translate knowledge into practice; by contrast, weak regulation may fail to facilitate behavioral change even among farmers with high knowledge capacity. Thus, the paper constructs a theoretical model of the impact mechanism of knowledge capability on farmers' green production behavior under the context of environmental regulation policies, as shown in Figure 1.

Knowledge demand capability has a positive impact on farmers' green production behavior (Ma et al., 2013). Knowledge demand capability refers to the motivation of farmers to actively learn relevant knowledge about green production. With the increase in income levels, agricultural production has shifted from pursuing quantitative development to pursuing qualitative development, and green organic products are more favored by consumers (Anim et al., 2025). In order to obtain excess profits, farmers actively learn knowledge about green production. Additionally, learning green production knowledge helps reduce dependence on chemicals such as pesticides and fertilizers, thereby enhancing economic and ecological benefits. Given these evidence, the study proposes the following hypothesis:

> *H1*: Knowledge demand capability facilitates farmers' green production behavior.

Knowledge absorption capability significantly influences farmers' adoption of green production practices (Wang et al., 2025). Defined as the ability to obtain and process knowledge and information related to green production through diverse channels, knowledge absorption capacity is critical for implementing sustainable agricultural techniques. In practice, farmers often have relatively limited formal education and possess insufficient foundational knowledge in scientific agricultural production. There are also notable disparities in their ability to acquire and internalize new information (Li et al., 2024). Although governmental training programs have been implemented, many farmers tend to adhere to conventional practices rather than actively seeking science-based solutions, which undermines the advancement of green production in Chinese medicinal materials. Therefore, strengthening farmers' proactive learning initiatives can help transform production patterns, raise awareness of green production, and ultimately enhance the quality and efficiency of medicinal herb cultivation.

> *H2*: Knowledge absorption capability exerts a positive impact on the green production behavior of Chinese medicinal material growers.

Strengthening knowledge transformation capability increases the likelihood that farmers will adopt green production practices (Ding et al., 2022). Knowledge transformation capability refers to farmers' ability to integrate acquired green production knowledge into practical agricultural operations. Although Chinese medicinal herb growers exhibit strong demand for this knowledge, they often face bottlenecks in effectively translating it into practical use (Magesa et al., 2020). Thus, the capacity to transform knowledge into actionable practices serves as a pivotal determinant of successful green production in Chinese medicinal herb cultivation.

> *H3*: Knowledge transformation capability exerts a significantly positive impact on farmers' green production behavior.

Environmental regulation policies are hypothesized to exert a moderating effect on the relationship between knowledge capability and farmers' green production behavior (Hasler et al., 2022). When market self-regulation is ineffective in alleviating the negative externalities arising from individual production activities, government intervention is required to address such market failures (Liu and Wang, 2023). Current environmental regulation policies primarily fall into three categories: restrictive, incentive-based, and guiding (Dhiman, 2020). Restrictive environmental regulations impose mandatory requirements on medicinal herb growers to ensure compliance with green production standards. Incentive-based environmental regulations leverage market mechanisms to incentivize farmers to adopt sustainable production practices (Jiang et al., 2021). In contrast,

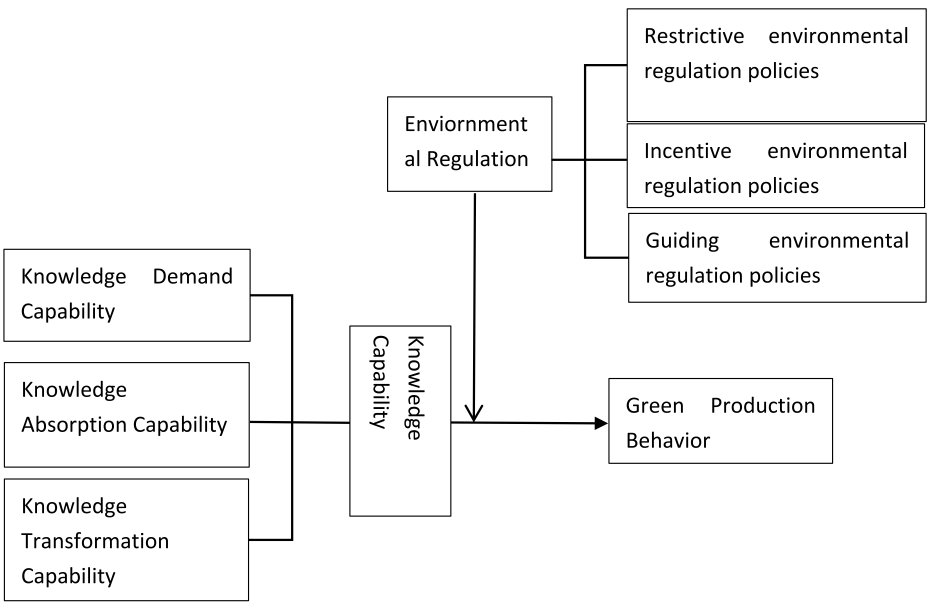

FIGURE 1
Impact mechanism of knowledge capability on farmers' green production behavior under the context of environmental regulation policies.

guiding environmental regulations encompass non-mandatory government interventions—such as green production training, public awareness campaigns, and targeted technical guidance—to encourage green production among medicinal herb growers.

> *H4*: Environmental regulation policies exert a significantly positive moderating effect on the relationship between knowledge capability and farmers' green production behavior.

2.2 Data and statistical description

The data utilized in this study were derived from field surveys conducted in Chifeng City, Inner Mongolia Autonomous Region. The specific study area is illustrated in Figure 2. Chifeng boasts climatic, hydrological, and edaphic conditions highly conducive to the cultivation of traditional Chinese medicinal herbs. Boasting a long-standing tradition of medicinal herb cultivation, the region currently has over 30,000 hectares under cultivation for traditional Chinese medicinal herbs and is renowned as "the Hometown of Sand Ginseng (*Glehnia littoralis*) and *Platycodon grandiflorum* in North China."

Since it did not involve interests and personal privacy, ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the patients/participants OR patients/participants legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

On the basis of the pre-survey of 120 farmers, the formal questionnaire of this study was designed combined with practical problems. The research follows the principle of stratified sampling and random sampling, a total of eight counties, 16 towns, 64 villages, a total of 900 research questionnaires, the recovery of 860 qualified questionnaires, valid response rate is 95.56%, survey questionnaire including individual characteristics, household characteristics, fertilizers, pesticides, farmers input and output and perception scale design five parts. The survey data was authorized by the local government and farmers planting Chinese herbal medicine, and the survey questionnaire did not involve the privacy of Chinese herbal medicine farmers.

Regarding demographic characteristics, males comprised 79.8% of the sample, while respondents aged 40–59 years accounted for 64.19%. The majority of participants (75%) had attained an education level of junior high school or below. In terms of production characteristics, the average cultivation area was 33.6 acres per household, with the majority of farmers (84%) operating between 5 and 30 acres. Additionally, 60% of medicinal herb growers participated in agricultural cooperatives. Concerning cognitive aspects, 64% of respondents expressed the view that reducing pesticide and fertilizer application could increase the market price of medicinal materials, 73% elieved such reduction practices benefit environmental protection, and 69% agreed that decreased chemical usage contributes positively to agricultural and rural development.

2.3 Model specification and variable selection

2.3.1 Model specification

The binary logistic model is employed to model and analyze dichotomous outcome variables, providing insights into both the magnitude and direction of the effects exerted by explanatory variables. In this study, we utilize this model to empirically examine the determinants influencing farmers' adoption of green production practices. The dependent variable (y) represents whether farmers implement green production behavior, coded as "yes = 1" and "no = 0." This categorical classification constitutes a typical binary discrete variable. The specific form of the model is shown in Equation 1.

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \ldots\ldots + \beta_n x_n + \varepsilon \qquad (1)$$

In this study, green production behavior ($y = 1$) encompasses practices including reduced application of pesticides and fertilizers, along with substitution of chemical fertilizers with organic alternatives. Conversely, the absence of all such practices is defined as non-adoption of green production behavior ($y = 0$). The explanatory variables x_1, x_2, x_3,., x_n represent factors influencing farmers' production decisions, while ε denotes the random error term. Given the binary nature of the dependent variable, the The specific form of the model is shown in Equation 2.

$$Logistic\ P_i = \ln\left(\frac{P_i}{1-P_i}\right) = \alpha + \sum_{j=1}^{n} \beta_j x_j + \varepsilon \qquad (2)$$

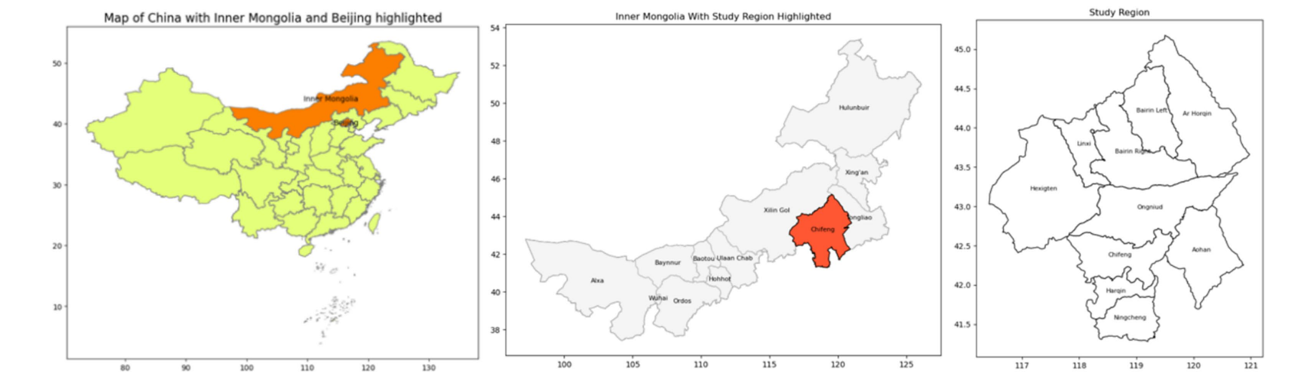

FIGURE 2
Study area.

In the equation, x_j represents the jth factor influencing farmers' green production behavior, α denotes the constant term, β_j represents the regression coefficient, ε is the error term, and $\ln(\frac{P_i}{1-P_i})$ represents the logarithm of the odds ratio for the ith farmer implementing green production behavior compared to not implementing it.

2.3.2 Variable selection and explanation

Dependent variable: The dependent variable refers to whether green production behavior is implemented (Gholamrezai et al., 2021). Farmer behaviors such as reducing pesticide and fertilizer use and substituting organic fertilizer for chemical fertilizer are defined as green production behavior. If a farmer has never implemented any of these production methods, it is defined as not implementing green production behavior.

Core explanatory variables: Referring to the research findings of Yue (2020), three indicators reflecting farmer's knowledge ability are selected: knowledge demand capability, knowledge absorption capability, and knowledge transformation capability. All three dimensions of knowledge capacity (demand, absorption, transformation) were measured on a five-point Likert scale. Reliability was tested via Cronbach's alpha (0.82, 0.79, 0.85 for the three dimensions, all > 0.70). Validity was verified by exploratory factor analysis, which confirmed a three-factor structure consistent with our theoretical framework (all item loadings > 0.70.

Control variables: Based on the research findings of Jin et al. (2022), Li and Wang (2026), and Wang et al. (2021), this study selects three control variables: individual characteristic variables, production characteristic variables, and cognitive characteristic variables.

Moderating variables: Based on the research findings of Jianhua et al. (2023) and Zhu et al. (2021), three types of environmental regulation policies—constraining, incentive, and guiding—are selected. The specific meanings and values of the variables are shown in Table 1.

3 Empirical results and analysis

3.1 Impact of knowledge abilities

3.1.1 Estimation results

Prior to model estimation, a multicollinearity diagnostic test was performed to ensure the reliability of regression estimates. The results revealed that all variance inflation factor (VIF) values for the independent variables were 1.43, well below the threshold of 10, suggesting no substantial multicollinearity concerns. The output of the binary logistic regression analysis is summarized in Table 2.

3.1.2 Estimation results and analysis

As presented in Table 2, knowledge demand capacity did not demonstrate a statistically significant effect on farmers' adoption of green production practices; therefore, Hypothesis 1 is not supported. This lack of significance may be attributed to several factors. Although farmers with heightened awareness of green production recognize its potential economic benefits, successful implementation requires substantial knowledge reserves and technical proficiency. Currently, limited dissemination of relevant policies and technical guidelines for green cultivation of Chinese medicinal herbs has constrained farmers' ability to process and apply such knowledge. Furthermore, the generally advanced age and lower educational attainment among farmers reinforce their reliance on traditional planting methods. The perceived increase in production costs associated with transitioning to green practices further suppresses demand for related knowledge. In contrast, knowledge absorption capacity exhibited a significant positive impact on green production behavior, supporting Hypothesis 2. This suggests that farmers who effectively internalize green production knowledge through training, technical services, and other channels are more likely to integrate such practices into their agricultural operations. Similarly, knowledge transformation capacity significantly and positively influenced green production behavior, confirming Hypothesis 3. Farmers with stronger transformation capabilities typically possess superior resource endowments, face fewer barriers to implementing sustainable practices, and demonstrate greater initiative in adopting green production methods. These advantages enable them to achieve premium returns from eco-friendly cultivation, thereby increasing the likelihood of sustained adoption.

Additional considerations may explain the non-significance of knowledge demand capacity. Potential limitations in the measurement indicators or methodology could compromise the accurate assessment of this variable. Moreover, the transformation of knowledge demand into actual green production behavior is subject to a time lag. The relatively short research observation period may not fully capture this delayed effect, thereby affecting statistical significance.

As shown in Table 2, individual characteristics including age and education level demonstrated statistical significance in influencing green production adoption, with both variables showing positive coefficients. In contrast, gender failed to achieve statistical significance. The results suggest that older farmers possess greater experience in managing pesticide and fertilizer application, while higher educational attainment corresponds to increased adoption of green production practices. This finding corroborates the significant role of knowledge capability in promoting sustainable agricultural practices. Regarding production characteristics, neither annual household income nor planting scale showed significant effects. This may be attributed to the substantial proportion of non-agricultural income in total household earnings, coupled with relatively small land operation scales. Under these circumstances, farmers may prioritize quality of life considerations over potential premium returns from green production methods.

The analysis further reveals that ecological value perception significantly positively influenced farmers' adoption of green production behavior. However, perceptions of economic and social values did not demonstrate significant effects. These results indicate that farmers who recognize the ecological benefits of reducing chemical inputs are more likely to implement sustainable practices. This suggests that immediate environmental concerns, rather than economic incentives or social pressures, primarily drive farmers' decisions regarding green production adoption.

3.2 Regulation effect of environmental regulatory policies on the relationship between knowledge capability and farmers' green production behavior

3.2.1 Estimation results

Adopting the methodology of Wang et al. (2024), we calculated the mean values of the moderating variables and stratified

TABLE 1 Variable assignment and descriptive statistics.

Type of variables		Definition and value	Mean	S.D.
Dependent variable	Green production behavior	Is green production behavior implemented? Yes = 1, No = 0	0.56	0.50
Core explanatory variables	Demand capability	Are you willing to proactively learn about techniques and knowledge related to the use of fertilizers and pesticides? Completely Disagree = 1; Disagree = 2; Neutral = 3; Agree = 4; Strongly agree = 5	4.05	0.92
	Absorption capability	When encountering issues with fertilization or pesticide application, can you inquire about how to solve these problems? Completely Disagree = 1; Disagree = 2; Neutral = 3; Agree = 4; Strongly agree = 5	4.03	0.75
	Transformation capability	Are you able to effectively apply fertilizers and pesticides with the knowledge you have acquired? Completely Disagree = 1; Disagree = 2; Neutral = 3; Agree = 4; Strongly agree = 5	4.57	0.78
Control variables	Age	Respondent's age	55.20	9.12
	Gender	Male = 1, Female = 0	0.80	0.40
	Education level	Primary school or below = 1, Junior high school = 2, High school or vocational school = 3, College or above = 4	2.05	0.67
	Annual family income	Total household income of rural households (10,000 CNY)	17.31	41.21
	Planting scale	Planting area of traditional Chinese medicinal herbs (mu)	27.80	96.74
	Cooperative situation	Joined = 1, not joined = 0	0.59	0.51
	Economic value perception	Do you believe that reducing the use of pesticides and fertilizers can increase the purchase price of traditional Chinese medicinal herbs? Completely Disagree = 1; Disagree = 2; Neutral = 3; Agree = 4; Strongly agree = 5	3.78	3.41
	Ecological value perception	Do you believe that reducing the use of fertilizers and pesticides is beneficial for ecological environmental protection? Completely Disagree = 1; Disagree = 2; Neutral = 3; Agree = 4; Strongly agree = 5	3.56	3.67
	Social value perception	Do you believe that reducing the use of fertilizers and pesticides is beneficial for the development of agriculture and rural areas? Completely Disagree = 1; Disagree = 2; Neutral = 3; Agree = 4; Strongly agree = 5	3.75	3.43
Moderating variables	Restrictive environmental regulation	Does the government impose penalties for violations in the production of traditional Chinese medicinal herbs? Completely Disagree = 1; Disagree = 2; Neutral = 3; Agree = 4; Strongly agree = 5	3.38	0.95
	Incentive environmental regulation	Does the government provide subsidies for the safe production of traditional Chinese medicinal herbs? Completely Disagree = 1; Disagree = 2; Neutral = 3; Agree = 4; Strongly agree = 5	3.26	1.13
	Guiding environmental regulation	Does the government conduct promotional education on the safe production of traditional Chinese medicinal herbs? Completely Disagree = 1; Disagree = 2; Neutral = 3; Agree = 4; Strongly agree = 5	3.34	1.05

TABLE 2 Logistic regression results of factors influencing green production behavior of Chinese medicinal herbs planting households.

Variable	Coefficient	S.D.	p-value
Demand capability	1.405	0.353	0.176
Absorption capability	10.584***	2.716	0.000
Transformation capability	7.859***	2.887	0.000
Age	0.969***	0.011	0.008
Gender	1.074	0.239	0.748
Educational level	0.690**	0.110	0.021
Annual family income	1.002	0.004	0.467
Planting scale	0.998	0.001	0.207
Cooperative situation	0.979	0.166	0.901
Economic value perception	0.865	0.182	0.493
Ecological value perception	1.722**	0.405	0.021
Social value perception	0.921	0.201	0.709
Restrictive environmental regulations	1.017	0.177	0.919
Incentive environmental regulation	7.286***	1.505	0.000
Guiding environmental regulation	1.059	0.197	0.755
−2 log-likelihood	407.77		
Pseudo R^2	0.253		
Sample size	860		

***,**,* represent significant at 1, 5, 10% level, respectively.

the survey data into two subsamples: values below the mean and values above the mean. Using green production behavior as the dependent variable and knowledge capability as the independent variable, we performed binary logistic regression with robust standard errors for each subsample. The regression results are summarized in Table 3. By comparing the regression coefficients and significance levels between the two subsamples, we examine the moderating effects of restrictive, incentive, and guiding environmental regulations on the relationship between knowledge capability and farmers' green production behavior.

3.2.2 Analysis of estimation results

As shown in Table 3, restrictive environmental regulations demonstrate a positive moderating effect on the relationship between knowledge demand capability and green production adoption. However, no significant moderating effect was observed regarding knowledge absorption or transformation capabilities. Under increasingly stringent environmental constraints, farmers with stronger knowledge demand capabilities show greater propensity to implement green production practices.

Incentive-based environmental regulations positively moderate the relationship between knowledge demand capability and farmers' green production behavior. Similar to restrictive policies, they demonstrate no significant moderating effect on knowledge absorption or transformation capabilities. This outcome stems from government initiatives that combine production subsidies with targeted training in green production knowledge. Through technical services and other support measures, these policies effectively address farmers' knowledge needs while amplifying their motivation for sustainable practices. Consequently, incentive-based environmental regulations can transform the previously non-significant impact of knowledge demand capability into a statistically significant driver of green production adoption.

Guiding environmental regulations demonstrate no significant moderating effect on the relationships between knowledge demand, absorption, or transformation capabilities and green production adoption. This limited efficacy arises from farmers' persistent credibility gap—despite recognizing potential economic and ecological benefits from reducing chemical inputs, they remain skeptical about actual implementation. Furthermore, existing government subsidies for green production often prove inadequate, while training programs tend to be superficial rather than substantive. These deficiencies create a mismatch between the knowledge provided and the dynamic challenges farmers face in production. Consequently, guiding policies generate weak implementation outcomes. The design of such regulations frequently overlooks farmers' practical needs, and insufficient policy enforcement further undermines their effectiveness, ultimately preventing these measures from stimulating meaningful behavioral change. The above analysis partially verifies Hypothesis 4, indicating that knowledge capability is an essential factor in farmers' implementation of green production behavior. However, due to the variability in agricultural production, achieving Pareto Optimality based solely on internal factors of farmers is challenging. Environmental regulatory policies are crucial tools for the government to promote green agriculture. Under the background of environmental regulatory policies, the impact of knowledge capability on farmers' green production behavior varies.

TABLE 3 Moderation effects of environmental regulatory policies on farmers' green production behavior.

Index	Constraining environmental regulation		Incentive environmental regulation		Guiding environmental regulation	
	Below the mean	Above the mean	Below the mean	Above the mean	Below the mean	Above the mean
Demand capability	0.378 (0.366)	0.466* (0.389)	−0.011 (0.371)	0.991** (0.415)	0.472 (0.424)	0.402 (0.345)
Absorption capability	2.138** (0.342)	2.389*** (0.389)	2.230*** (0.347)	2.430*** (0.426)	2.786*** (0.407)	1.881*** (0.350)
Transformation capability	2.776*** (0.667)	2.135*** (0.538)	2.291*** (0.493)	2.197*** (0.445)	3.027*** (0.755)	1.925*** (0.496)
Age	−0.028 (0.167)	−0.017 (0.018)	−0.0414* (0.020)	−0.014 (0.016)	−0.011 (0.017)	−0.032* (0.017)
Gender	−0.080 (0.320)	0.159 (0.342)	−0.023 (0.367)	0.165 (0.310)	0.211 (0.334)	0.001 (0.335)
Education level	−0.529** (0.234)	−0.116 (0.252)	−0.402 (0.277)	−0.235 (0.218)	−0.110 (0.243)	−0.501** (0.245)
Annual household income	−0.003 (0.008)	0.006 (0.004)	0.002 (0.003)	0.008 (0.016)	−0.002 (0.008)	0.003 (0.012)
Planting scale	0.003 (0.006)	−0.003* (0.002)	−0.001 (0.001)	−0.005 (0.005)	−0.005 (0.004)	0.002 (0.005)
Cooperative situation	0.237 (0.240)	−0.058** (0.290)	−0.241 (0.310)	0.059 (0.222)	−0.234 (0.236)	0.105 (0.281)
Economic value perception	0.083 (0.291)	−0.617* (0.366)	−0.843* (0.397)	0.122 (0.289)	−0.001 (0.314)	−0.262 (0.333)
Ecological value perception	0.855** (0.349)	0.062* (0.363)	1.456*** (0.366)	−0.084 (0.340)	0.022 (0.341)	1.406*** (0.370)
Social value perception	−0.358 (0.330)	0.269 (0.332)	−0.292 (0.365)	0.357 (0.304)	0.473 (0.316)	−0.438 (0.360)
Constraining environmental regulation	0.565** (0.228)	0.267 (0.346)	0.297 (0.154)	0.133 (0.137)	0.026* (0.145)	0.085 (0.141)
Incentive environmental regulation	0.998*** (0.140)	1.332*** (0.185)	1.036** (0.421)	0.949*** (0.195)	1.165*** (0.173)	1.129*** (0.159)
Guiding environmental regulation	0.228*** (0.137)	−0.181 (0.169)	0.221 (0.181)	0.081 (0.131)	−0.047 (0.242)	−0.130 (0.326)
−2 log-likelihood	179.02	168.94	125.77	101.16	168.88	145.12
Pseudo R^2	0.305	0.336	0.295	0.187	0.296	0.299
Sample size	460	400	433	427	453	407

Coefficients (*B*) from logistic regression models are presented; standard errors are reported in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

4 Discussion

4.1 Differential effects of knowledge capacity dimensions: the moderating role of environmental regulation

Contrary to existing research (Chen et al., 2023), knowledge demand capability demonstrates no significant impact, whereas both knowledge absorption and transformation capabilities exhibit significant positive effects, aligning with previous findings (Xianyu et al., 2024). Although knowledge demand capability alone shows limited direct influence, its importance should not be underestimated. When internal regulatory mechanisms prove insufficient, properly designed environmental policies can effectively activate the potential of knowledge demand capability, thereby transforming its initially non-significant effect into a meaningful driver of green production adoption.

4.2 Heterogeneous impacts of environmental regulation types on the knowledge—green behavior relationship

Environmental regulations significantly moderate the relationship between knowledge capability and green production behavior, though their effects vary across policy types, aligning with existing literature (Nazir et al., 2024). Both restrictive and incentive-based environmental regulations positively moderate the influence of knowledge demand capability, effectively transforming its initially non-significant effect into a statistically meaningful one—a finding consistent with prior research (Wang and Zhang, 2025). In contrast, guiding environmental regulations demonstrate no significant moderating effect, diverging from previous conclusions (Kherazi et al., 2024). Nevertheless, the potential importance of such guiding policies should not be dismissed. As a subtle and cumulative policy instrument, guiding regulations require time to accumulate sufficient momentum and may need to reach a critical threshold before achieving qualitative change in activating knowledge demand capability.

5 Conclusion and implications

5.1 Conclusion

Although knowledge demand capability alone does not significantly influence farmers' adoption of green production practices, when coupled with restrictive environmental regulations, it demonstrates a statistically significant positive effect.

Both knowledge absorption and transformation capabilities significantly promote green production behavior. Furthermore, these relationships are substantially strengthened under incentive-based environmental regulatory frameworks.

In contrast, guiding environmental regulations show no significant moderating effect on the relationships between any dimension of knowledge capability (demand, absorption, or transformation) and the adoption of sustainable agricultural practices.

5.2 Implications

Based on the research findings, the following policy recommendations are proposed:

Although knowledge demand capability alone does not significantly influence green production adoption, it demonstrates positive effects when supported by strengthened environmental regulations. Therefore, in contexts where market mechanisms remain underdeveloped, governments should enhance the dissemination of green production practices through targeted training and technical guidance. Concurrently, improving the precision and persuasiveness of media communication is essential. Regulatory frameworks for the green production of Chinese medicinal materials should be continuously refined, with strengthened supervision and enforcement against non-compliant production practices. These coordinated measures will effectively stimulate farmers' intrinsic motivation while establishing the necessary external conditions for transitioning toward sustainable production models.

Farmers possessing strong knowledge absorption and transformation capabilities demonstrate higher adoption rates of green production practices. When supported by incentive-based environmental regulations, the influence of knowledge demand capability on green production behavior becomes significantly enhanced, further reinforcing sustainable agricultural practices. To capitalize on this synergy, governments should establish comprehensive subsidy mechanisms for green production of Chinese medicinal materials. These policies should aim to increase farmer participation in sustainable practices, improve both awareness and implementation levels of green production methods, and establish multi-channel information support systems to ensure successful adoption.

Although guiding environmental regulations show no significant moderating effect on the knowledge capability-green production relationship, media dissemination can effectively facilitate this process. Government agencies, enterprises, and cooperatives should leverage their organizational strengths to conduct multi-channel publicity campaigns through internet, television, and radio platforms. These efforts should enhance the accessibility of green production knowledge and guide farmers toward sustainable practices. For instance, customized training programs should be developed according to different medicinal herb varieties and farmers' actual needs. Beyond conventional classroom instruction, these programs should incorporate field visits, on-site demonstrations, and case study analysis. Concurrently, multiple stakeholders should collaborate to encourage farmers' voluntary adoption of green production methods. Strengthening partnerships with research institutions and introducing enterprise participation can provide essential materials and technical support for farmers' green transition. Furthermore, improving rural network infrastructure will eliminate barriers to online knowledge acquisition. Providing subsidies for transportation, accommodation, and data expenses incurred during training participation will help alleviate economic constraints and enhance engagement.

This study is subject to several limitations that warrant consideration. First, the research data were confined to Chifeng City, lacking cross-regional comparative analysis of green production behaviors among medicinal herb growers in other production areas. Given that green production adoption exhibits strong positive externality characteristics, farmers' implementation decisions are shaped by multiple factors including economic conditions, policy environments, geographical constraints, and sample characteristics. Future research could incorporate multiple regions and various medicinal herb species to enhance the generalizability of findings and enable comparative analysis of regional differences in farmers' sustainable agricultural practices. Additionally, this study did not exclude elderly participants from the sample, despite potential physical limitations that might affect their agricultural engagement. Future investigations could refine sampling criteria to improve data accuracy regarding farmers' actual capacity to implement green production techniques.

5.3 Research limitations and future prospects

The research limitations of this paper mainly lie in the following aspects. Firstly, the survey area is confined to Chifeng City, which leads to limited sample representativeness. In the future, it can be expanded to major production areas in other regions to conduct regional comparative studies. Secondly, cross-sectional data are adopted, which fails to capture the dynamic changes in knowledge capacity and green production behavior. Future follow-up investigations can be carried out to analyze the long-term effects. Thirdly, due to the scope and structure of the current dataset, we do not conduct extensive robustness checks or heterogeneity analyses (e.g., by farm size, education level, or cooperative membership). Such analyses would help validate the stability of our findings and uncover differential effects across farmer subgroups, and thus are recommended for future research.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/supplementary material.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the patients/participants OR patients/participants legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

WL: Writing – original draft, Validation, Methodology, Writing – review & editing. SW: Data curation, Formal analysis, Writing – review & editing, Writing – original draft. ML: Software, Investigation, Conceptualization, Writing – review & editing, Writing – original draft.

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