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Original Research

Research on Farmers' Low-Carbon Production Behavior: Introducing Green Cognition into the Theory of Planned Behavior

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Abstract

Low-carbon production has great potential to limit greenhouse gas emissions and protect the living environment. This research innovatively introduces green cognition into the theory of planned behavior (TPB) to validate the effect of green cognition on farmers' low-carbon production behavior. In this research, we use structural equation model (SEM) to research the low-carbon production behavior of 265 farmers in Yilan County, Harbin City, China. Our results indicate that farmers' perceived behavioral control (PBC) has a remarkable impact in generating their low-carbon production intention, while attitude (ATT) and subjective norms (SN) have no significant positive impact. Meanwhile, it is verified that the perceived behavioral control and behavioral intention (INT) of farmers have a significant positive impact on their low-carbon production behavior. In addition, the research also verifies that green cognition (GC) has a significant positive impact on farmers' attitudes and subjective norms of low-carbon production behavior, and green cognition may indirectly affect low-carbon production behavior through farmers' subjective norms and intention pathways, reflecting that the extended theoretical framework of planned behavior is applicable to the research of farmers' low-carbon production behavior.

Keywords: green cognition, theory of planned behavior, structural equation model, behavior, low-carbon production

Introduction

With the increasing global greenhouse effect, the development of low-carbon economy has become the focus of attention around the world [1]. Agricultural development, as the foundation of the national economy, has always been at the center of China's attention [2]. However, under the development model of mechanical agriculture and chemical agriculture, agricultural production has become the 2nd biggest contributor to greenhouse gas emissions. The traditional mode of agricultural production with high energy consumption, emissions, and pollution has severely affected our living environment and impeded the sustainable development of agriculture. Not only does it have a negative impact on people's normal lives, but it also poses an undeniable

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threat to the sustainable development of China [3]. Developing low-carbon agriculture characterized by low input, low consumption, low pollution, and superior productivity is particularly important for dealing with these severe challenges. With the increasing attention to environmental protection in China [4], the issue of low-carbon production has allured the attention of the Chinese government [5]. In the report of the 19th CPC National Congress, there is a clear proposal to transform the mode of development of traditional agriculture, to take the road to sustainable agricultural development, and to establish a healthy economic system of green and low-carbon [6]. Meanwhile, the '14th Five-Year Plan' again proposed to further optimize the layout of agricultural production, continue to foster low carbon agricultural production, and actively develop low-carbon agriculture [7]. Nevertheless, as an industry spanning people's livelihood and environmental protection, the steady development of low-carbon production requires the joint efforts of the authorities and farmers [8]. As a major participant in agricultural production activities, farmers' production decisions and behaviors can have a direct effect on the development trend of the agricultural environment. Therefore, it is of profound value to research farmers' low-carbon production behavior [9].

Past studies have made a lot of achievements in accounting for the carbon effect and influencing factors of farmers' low-carbon production behavior. However, the study on the extended TPB to predict individual low-carbon production behavior from a psychological angle is even closer to empty. So, it is important to introduce green cognition into TPB to study it. Green cognition refers to farmers' cognition of agricultural production environment of low-carbon production behavior [10]. Green cognition is a significant factor influencing individual intention and behavior to protect the environment, which determines whether an individual will take the lead in carrying out environmental protection activities. ATT, SN and PBC contained within the original TPB model are all internal psychological factors of the individuals, and the absence of investigation of pivotal external factors such as green cognition in the original model [11]. However, low-carbon production behavior is strongly affected by external factors, so introducing green cognition into the TPB model as the critical influencing factor of farmers' low-carbon production is of great importance.

The innovations of this paper: (1) The first time that green cognition is introduced into TPB, and the TPB is extended from external and internal angles that makes up for the shortcomings of the original study of TPB solely from the angle of internal and psychological. (2) This study breaks the restriction that most research on low-carbon production behavior concentrates on technology improvement and investigates the intention of low-carbon production from the psychological angle of farmers, which compensates for the absence of individual psychological factors on low-carbon production behavior.

Literature Review

Research on Low-Carbon Production

Farmers' low-carbon production behavior refers to the responses or decisions made by farmers in agricultural production activities regarding the amount of fertilizer and pesticide applied, the way of disposing of discarded agricultural films, and the way of straw disposal in order to maximize their own interests. As a result, it has produced positive externality for the ecological environment, giving consideration to the economic benefits and ecological effects of agricultural production. The specific ways include changing the traditional intensive cultivation mode, changing the land use mode and applying new low-carbon agricultural technologies [12].

The theory of low-carbon production emphasizes the basic principle of sustainable development, minimizing the consumption of high carbon energy such as coal and oil, reducing greenhouse gas emissions such as carbon dioxide, and adopting technological innovation to achieve a win-win situation in economic and social development and ecological environment protection. The new form of agricultural development that has emerged in the context of a low-carbon economy is known as low-carbon agriculture, and in the process of building an ecological civilization, it is necessary to pay attention to the economic, social and ecological functions of agriculture, and it requires the use of low-carbon technologies and other means to improve the ecological effect on the basis of ensuring the economic benefits of farmers [13].

Most previous studies focused on accounting for the carbon effect and influencing factors. The research results are as follows: The growing emphasis on environmental protection in China has led to an increasing focus on low-carbon production. Some researchers believe that by replacing farmers' production input with energy and analyzing various coefficients of carbon emissions from farmers' production input, it is possible to calculate the carbon emission effect of farmers' agricultural production [14]. Founded on the measurement of the carbon effect of agriculture, scholars have also discussed agriculture's strategies for dealing with carbon compensation policies and found that the cost advantage of agricultural greenhouse gas emission reduction is more obvious than that of other industries [15]. A growing number of researchers have concentrated on the influencing factors. By analyzing the research findings, massive researchers have designated that it is primarily affected by the following factors: age, occupation, education level, family economic status, scale of agricultural land, land ownership and regional environmental characteristics [16]. Some researchers use the econometric model to study and believe that it is primarily affected by the following factors: cost of irrigation equipment, income status of farmers, quality of cultivated land,

credit conditions, planting scale, and relevant policies promulgated by the government [17].

The research of the literature shows that while researchers have made many achievements in low-carbon production research, there are still deficiencies. (1) The econometric model is used by massive researchers to analysis the influencing factors of individual' low-carbon production behavior. Using TPB, the research on it from the perspective of farmers' psychology is inadequate. TPB plays a momentous role in forecasting the influencing factors of human consciousness [18]. Therefore, it is important to use TPB to explain the behavior from the perspective of psychological mechanism. (2) Massive researchers merely extend the TPB from an internal point of view, and few bring in external factors like green cognition. External factors can directly or indirectly affect individual behavioral intentions. Thus, there is a need to introduce external factors such as green cognition into TPB to conduct extended TPB research.

Research on Green Cognition

Green cognition refers to farmers' cognition of agricultural production environment of low carbon production behavior. Farmers' cognitive theory, as a theory extended from the field of psychology, mainly refers to the process of information acquisition or processing by individual farmers through a series of mental activities. That is, it serves as a subjective concept that is the expression of the farmer's view of external things and is the basis for taking decisions and taking actions. In fact, if farmers take adopting green production behavior as a productive investment, they will only adopt green production behavior if the post-investment benefit is greater than the pre-investment benefit. Therefore, whether farmers will develop the intention to produce green and whether they are willing to engage in green production behavior depends on farmers' understanding of green cognition, if farmers believe that green cognition will bring them benefits, they will engage in green production behavior. Farmers' behavior theory believes that farmers' behavioral decisions are limitedly rational, and their production and management behaviors are affected by their own capital endowment, external environmental instability and information asymmetry, resulting in farmers' pursuit of profit maximization goals may not be achieved, but as far as possible to achieve a "satisfactory solution". In this paper, farmers are regarded as rational economic agents, and when they engage in agricultural production, they are more interested in maximizing their own interests and satisfying their desired utility. Therefore, when farmers make decisions about the adoption of green production methods, they evaluate their own green cognition according to their peculiar conditions and make decisions that are beneficial to them.

Ritter et al. studied the motivation of consumers to consume green in emerging countries, using Brazil as an example. The study found that green consumers tend to blame companies that pollute the environment, that the higher the level of education, the greater the awareness of green cognition, and that companies providing more information about green products to consumers would increase consumer green consumption behavior [19]. Kanchanapibul et al. concluded that environmental emotion is a key factor influencing the degree of participation in pro-environmental behavior, and that stronger green cognition can compensate for the lack of environmental knowledge, leading to green production [20]. Wang et al. built on farmers' knowledge of the concept and impact of pesticide residues and the safety interval, the study concluded that stronger green cognition can promote safe application behavior [21]. Raza et al. argued that farmers can promote their active implementation of straw return behavior by perceiving the environmental and human health hazards caused by straw burning [22]. Cao et al. built on the survey data of grain farmers in Ningxia concluded that the higher the farmers' awareness of the arable land protection policy, the more favorable their implementation of straw returning behavior [23]. Ren et al. believed that ecological cognition has a positive regulating effect on farmers' green production decisions, and farmers with a high degree of green cognition have a higher tendency of green production behavior [24]. Therefore, it is a great innovation to include green cognition as a critical factor in the study when forecasting farmers' low-carbon production behavior.

Extended TPB

TPB is originated from the rational behavior theory proposed by Ajzen, which is the most classical theory to explore individual's behavior from the angle of psychology [25]. TPB has been widely used in numerous research fields, such as consumer behavior and pro-environmental behavior [26, 27]. It has also been proven in large number of studies to be successful in forecasting individual behavior and is an important theoretical model widely used in academic research on behavior. So we use the theory of planned behavior as the basis to study the low-carbon production behavior of farmers. Specifically, TPB holds that the individual's behavior intention is affected by three aspects: ATT, SN and PBC. ATT means the individual's positive or negative appraisal of the behavior itself. That is, it is farmers' cognition of preference for low-carbon production behavior [28, 29]. SN means the individual's cognition of social stress to determine whether to carry out actions. That is, whether farmers' implementation of low-carbon production behavior is affected by the views or behaviors of those linked to them [30]. PBC means the controllable cognition of individual behavior implementation, that is, whether farmers have the energy and knowledge to implement low-carbon production behavior.

Despite the good explanatory and predictive capacity of TPB, studies show that certain behavioral intentions are affected by concrete factors, which are not involved in the TPB [31]. TPB primarily concentrates on the research of endogenous factors and does not have the effect of exogenous conditioned perceptual factors, which is driven by green cognition. As a result, there are flaws in the utilize of the TPB model to interpret farmers' behavior intention of low-carbon production. Researchers have provided evidence that external factors indirectly influence individual behavioral intention through their influence on individual' ATT and other psychological elements. For this reason, this paper holds that incorporate external factors into the TPB model can better interpret individual behaviors.

Green cognition has an important influence on individual attitudes towards low-carbon activities and the generation of low-carbon production intention. The higher the farmers' green cognition is, thus the easier it is to implement low-carbon production behavior. Green cognition has been proven to be a factor worthy of investigation in forecasting individual intention on actual environmental protection behavior. Therefore, in this study, green cognition is involved into the TPB model as a pre-variable, which can preferably investigate farmers' low-carbon production behavior (Fig. 1).

Hypotheses

ATT means an individual's estimate of whether the behavior is favorable or unfavorable. The individual with positive attitude towards a certain behavior, namely the person has a positive evaluation of a specific behavior, the stronger the person's behavior will be. Therefore, ATT has a positive effect on individual behavior intention. Attitudes have been highlighted in previous studies as predictors of individual behavior domains, and these studies have led to the conclusion that a positive attitude has an essential role in facilitating the adoption of a certain behavior [32]. Therefore, this paper holds that farmers who hold a positive attitude towards low-carbon production are expected to gain utility from low-carbon production, and they will have a positive intention to execute low-carbon production (Fig. 2).

H1: Farmers' attitude has a positive effect on their low-carbon production intention.

SN is concerned with how individuals ponder expectations of "significant others" for specific behaviors. When a person's subjective norm is strong, the individual cares more about the opinions of those around him or her, then it will be easy for the person to follow the advice and pressure of the people around them to choose their own behavior. Subjective norm is the influencing factor of whether the individual can perform a specific behavior under social and external pressure. Numerous papers have demonstrated the predominance of SN in forecasting individual behaviors in all manner of fields such as protecting environment and green tourism and draw the conclusion that SN has a positive effect on individual behavior intentions [33]. In summary, the present study holds that individuals who are more sensitive to pressure from others are more susceptible to the influence of others' suggestions and views and are more likely to modify their initial decisions under the guidance and pressure of others. (Fig. 2).

H2: Farmers' SN have a positive effect on their low-carbon production intention.

PBC is considered as the perceived ease or difficulty of presenting a behavior, and a reflection of one's experience and expected barriers. When a person with high PBC, namely the person holds that he or she can simply perform a certain behavior, then more likely to engage in that behavior or it is not easy to act. Ajzen pointed out that PBC has a direct positive effect on individual behavior intention, the individual with higher PBC, the greater the willingness to conduct a certain behavior. Currently, numerous studies have verified the predominance of PBC in forecasting individual behaviors in all manner of fields such as protecting environment and have reached the conclusion that PBC has a positive effect on people's behavior intention and behavior [34]. Therefore, this paper concludes that farmers who know about low-carbon production

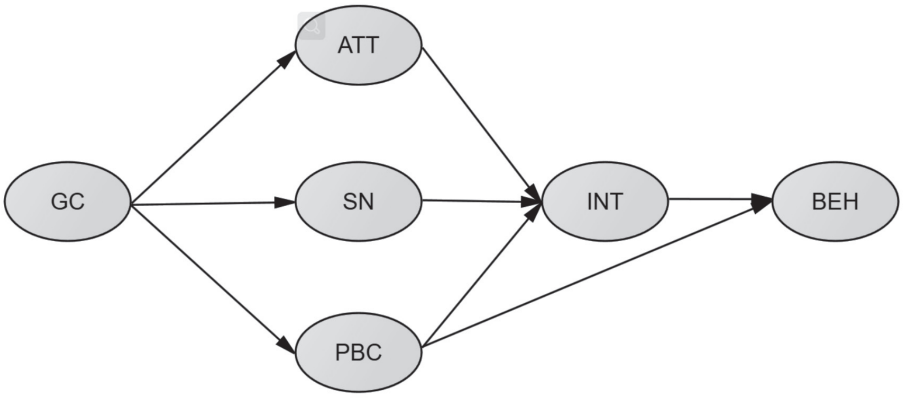

Fig. 1. Extended TPB.

and have enough time to learn more about low-carbon production are more likely to be willing to produce low-carbon production and thus more likely to do it (Fig. 2).

H3: Farmers' PBC has a positive effect on their low-carbon production intention.

H4: Farmers' PBC has a positive effect on their low-carbon production behavior.

Behavior intention lie between human cognition and outward behavior. It means the tendency of people to respond to or handle objective things, namely the status of preparation for behavior [35]. It performs an essential part in behavior, an individual with higher INT, the higher their faith in executing the behavior and the greater the opportunity to carry out the behavior. Currently, numerous research have shown the predominance of INT in forecasting individual behaviors in all manner of fields such as protecting environment and have drawn the conclusion that INT has a direct effect on human behavior [36], and the higher the individual's behavioral intention for a particular behavior, the easier to implement the behavior. This study concludes that farmers with a strong desire for low carbon production are more committed to do it. In contrast, a farmer who vacillates over low-carbon production is less likely to end up engaging in low-carbon production (Fig. 2).

H5: Farmers' INT has a positive effect on their low-carbon production behavior.

Green cognition belongs to the external influencing factors of individuals, refers to farmers' cognition of the agricultural production environment that adopts low-carbon production behavior in the process of agricultural production. Few researchers have included relevant factors such as green cognition in TPB studies, and therefore the effect of green cognition on the three pre-variables of TPB has not been studied. However, some researchers have extended the TPB model by introducing external factors into TPB, concluding that external factors have a positive effect on individuals' ATT, SN, and PBC [37]. So, this study suggests that green cognition is an external factor that has a significant effect on individual behavior, with positive effects on farmers' ATT, SN and PBC towards low-carbon production (Fig. 2).

H6: Green cognition has a positive effect on farmers' ATT towards low-carbon production.

H7: Green cognition has a positive effect on farmers' SN towards low-carbon production.

H8: Green cognition has a positive effect on farmers' PBC towards low-carbon production.

Methods

Empirical Model

SEM derived from path analysis developed by Sewall Wright, which is a multivariate statistical analysis approach to analyze the relationship between variables and verify the consistency between theoretical model and sample data [38], has been widely used in economics, sociology, tourism and other fields [39-40]. It incorporates methods from factor analysis, correlation analysis, and regression analysis. On the one hand, it can handle latent variables that are not observed, in addition, it can also analyze the direct and indirect effect and the size and direction of the effect between variables, which is a very important tool in the analysis of multivariate data. The SEM deals with complex statistical data by specific statistical means, which evaluates empirical results based on the degree of matching between model and real data, so as to realize the goal of quantitative research on the actual problems.

The concrete content of this paper is the relationship between farmers' ATT, SN, PBC, GC, low-carbon production intention and actual low-carbon production behavior. Meanwhile, it also concentrates on the indirect effect of green cognition on low-carbon production behavior by affecting farmers' ATT, SN and PBC. Given that ATT, SN, GC, and INT are all latent variables, which can't be directly measured, the SEM model is adopted for research.

SEM is divided into structural model and measurement model. The measurement model:

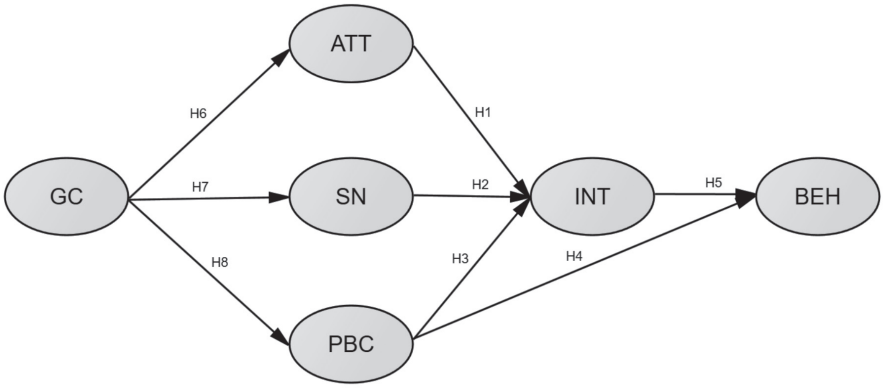

Fig. 2. Hypothetical path diagram.

$$x = \Lambda_x \xi + \delta$$

$$y = \Lambda_y \eta + \varepsilon$$

X is an exogenous identifier, Λx is the factor load matrix connecting x variables to ξ, ξ is an exogenous latent variable, δ is the measurement error of x, y is the endogenous identifier, Λy is the factor load matrix connecting y variables to η variables, η is the endogenous latent variable, ε is the measurement error of y.

The structural model:

$$\eta = B\eta + \Gamma\xi + \zeta$$

η is the endogenous latent variable, β is the relationship between endogenous latent variables, Γ is the influence of exogenous latent variables on endogenous latent variables, ξ is an exogenous latent variable, ζ is the interference term in the equation.

Research Area

The study area of this paper is Yilan County, Harbin City, Heilongjiang Province, the total area is 4672 square kilometers and the total population is 390000. Locating in the Lesser Khingan mountains, Wanda mountains, Zhangguangcai mountains extension zone. The region has unique advantages in the development of agricultural production and is also a major base for grain production in China. However, massive greenhouse gases are produced in agricultural production, which leads to severe pollution of the environment. Yilan County has placed ecological environmental protection and pollution control in a prominent position in recent years, among which low-carbon production is a key step, actively implemented the 'Detailed Rules for the Implementation of Special Work on Air Pollution Prevention and Control in Heilongjiang Province' and introduced relevant regulations and punishment measures on low-carbon agricultural production, meanwhile, farmers who do well in low-carbon agricultural production will be given agricultural subsidies. The above measures have resulted in significant improvements to the ecological environment. For this reason, Yilan County in Harbin, Heilongjiang Province is selected as the study area for this paper.

Sample Selection

The research samples of this paper are farmers in Yilan County, three townships in Yilan County with large numbers of farmers and a comprehensive low carbon production system are selected for research based on the basic research focus, Yilan Town, Sandaogang Town, and Dalianhe Town are selected as the study area based on field visits and access to pertinent information (Fig. 3). Because Yilan County is a small county in China's county division, so we take the county as the unit for investigation. This allows us to determine the size of the total sample founded on the population of each town. Simultaneously, in the actual process of distributing the questionnaires, we also distributed questionnaires founded on the actual observation of

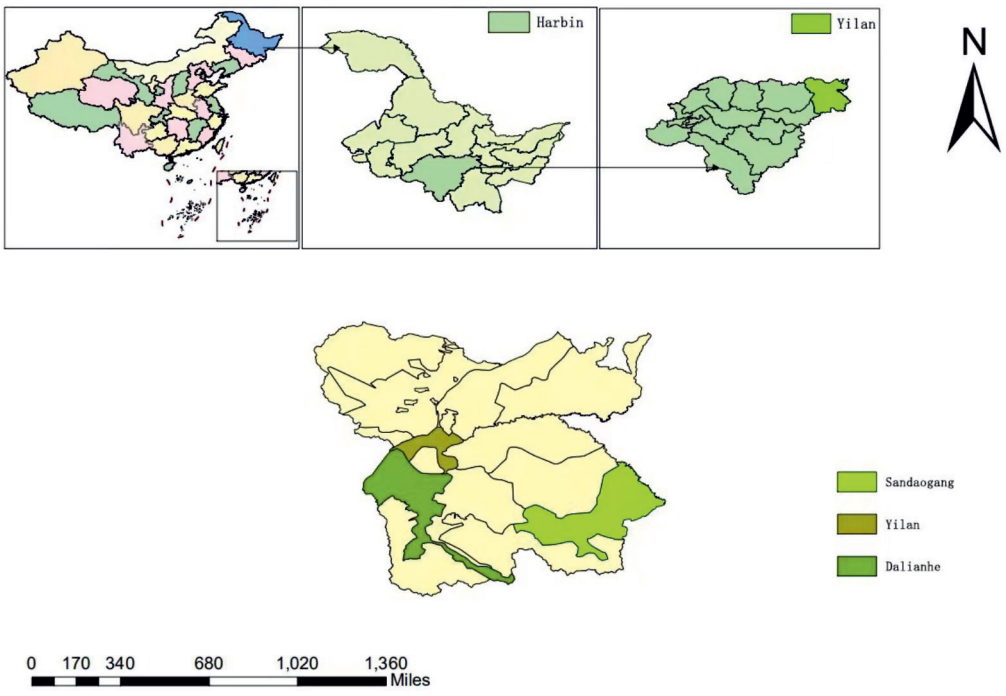

Fig. 3. Research area.

the low-carbon production behavior of each town in the study area.

This survey was conducted on May 15, 2022, and ended on June 30, 2022. Questionnaires were distributed in the pattern of face-to-face interviews. At the end of the interview, we collected the questionnaires and classified them according to the standard, and then the data were imported into the SPSS.26 software through manual entry. Finally, 268 questionnaires were sent out, 220 of which were valid, with an effective rate of 82.09%.

Questionnaire Design

Building on the mature scale of previous studies using TPB and associated research on low-carbon production behavior. The paper is founded on the actual situation of low-carbon production in Yilan County, Harbin City, Heilongjiang Province, and aims to revise and improve the scale locally, and to avoid the use of vague language in the questionnaire to ensure that the problem is concise and easily understood.

The questionnaire consists of seven parts with 25 questions in total. The first part is the demographic characteristics of farmers, involving gender, household size, annual household income, source of household income, education, total household expenditure, low-carbon production attention degree, time of agricultural planting, age, area of agricultural planting, whether to use chemical fertilizer according to the instructions, and whether low-carbon production has been implemented. Second, the scale of farmers' attitude towards low-carbon production, containing 4 measurement Question. Question 1: Attitude that low-carbon production has a more dynamic [41]. Question 2: Attitude that low-carbon production helps to improve the efficiency of resource utilization [41]. Question 3: Attitude that low carbon production helps prevent environmental deterioration [42]. Question 4: Attitude that low-carbon production can bring some benefits [41]. Third, the scale of farmers' subjective norms towards low-carbon production, containing 4 measurement Question. Question 1: Government requirements impact [43]. Question 2: Social impact [41]. Question 3: Family impact [43]. Question 4: Relatives and friends influence [44]. Fourth, the scale of farmers' s perceived behavioral control towards low-carbon production, containing 4 measurement items. Item 1: Educational level [44]. Item 2: Idle time condition [43]. Item 3: Economic strength [43]. Item 4: Vision [42]. Fifth, the scale of farmers' s intention towards low-carbon production, containing 3 measurement Question. Question 1: Intention to implement low-carbon production [43]. Question 2: Intention to advice others to implement low-carbon production [44]. Question 3: Intention to keep up with information related to low-carbon production [43]. Sixth, the scale of farmers s green cognition, containing 6 measurement items. Item 1: I am very familiar with the government's support policies for green production technology [45]. Item 2: I am very familiar with the government's policies on environmental protection [45]. Item 3: I am very familiar with the government's subsidy policy on green production [45]. Item 4: I am very familiar with the government's campaign to promote organic manure [45]. Item 5: The waste of agricultural resources in the production process makes me angry [45]. Item 6: Environmental pollution caused by agricultural production makes me very angry [45]. Seventh, the scale of farmers' s behavior towards low-carbon production, containing 4 measurement items. Question 1: Farmers own low-carbon production situation [44]. Question 2: Advice others to adopt low-carbon production [41]. Question 3: Focus on relevant information on low-carbon production [42]. Question 4: Assist relatives and friends grasp the low-carbon production [42].

Results and Discussion

Descriptive Statistics

Table 1 is the basic characteristics of farmers in Yilan County studied in the study. The information in the table shows that male and female farmers make up 58.2% and 41.8% of the sample, indicating a balanced proportion of male and female farmers. The majority of farmers are greater the age of 50, representing

Table 1. Demographic characteristics.

Variable	Classification	Frequency	Percentage
Gender	Man	128	58.2
	Woman	92	41.8
Age	Lowest than 25	27	12.3
	25-35	31	14.1
	36-45	59	26.9
	More than 45	103	46.8
Education	Elementary school	66	30
	Middle school	79	36
	High school	24	10.9
	College degree or above	10	5
	16 and above	6	2.7
Low-carbon production attention degree	Never	36	16.4
	Occasionally	102	46.4
	Regular	82	37.2
Whether low-carbon production has been implemented	Yes	118	53.6
	No	102	46.4

46.8% of the population, and the majority of farmers have received middle school education or higher. 37.2% of the farmers said that they were concerned about the issue of low-carbon production, and 16.4% of the respondents said that they never paid attention to it, showing that Yilan County had promoted the issue of low-carbon production, but the publicity still needed to be reinforced. Meanwhile, 53.6% of farmers said they have started low-carbon production.

Reliability and Validity Analysis

Reliability means the degree of consistency or stability of the scale data. Cronbach's alpha should be used to test the reliability of the data. The overall reliability of the data is acceptable if $\alpha \geq 0.7$, the α values of each measurement item are 0.926, 0.944, 0.916, 0.915, 0.955 and 0.899, respectively, which are all higher than 0.7. Meanwhile, the overall α value is 0.940 (Table 2), means the reliability of the scale is acceptable.

Validity analysis means the analysis of the accuracy of the scale. In this paper, the validity test involves structural validity test and convergence validity test. We use KMO and Bartlett sphere to test the structural validity. The KMO statistics of all the measurement items in this study are higher than 0.7, the P values are all lower than 0.05 (Table 2), showing that the model has good structural validity. In the convergence validity test, we use the values of CR and AVE to measure the convergence validity. The CR values in all measurements of the model are 0.93, 0.95, 0.83, 0.92, 0.95 and 0.9, respectively, all of which are greater than 0.7, and the AVE values are 0.76, 0.81, 0.59, 0.78, 0.78 and 0.70 (Table 2), respectively, all of which all greater than 0.5, showing that the model has good convergent validity.

Fitness Analysis

Model fitness refers to the evaluation of the fitting effect among the hypothetical model and the real data, and the commonly used evaluation indexes are absolute fitting index and relative fitting index. The absolute fitting index involves chi-square test and RMSEA. When the chi-square/df value is less than 3 and the RMSEA value is less than 0.08, the overall fitting degree of the model is good. Researchers pointed out that the relative fitting index indicators involve NFI, RFI, CFI, IFI, TLI, the above values are higher than 0.9, showing that the model fits well. AMOS.23 software is used for computation, the chi square/df is 1.699, which is less than 3. RMSEA has a value of 0.051, which is lower than 0.8. The values of NFI, RFI, CFI, IFI, and TLI are 0.927, 0.911, 0.968, 0.969, and 0.961, respectively, all of which are greater than 0.9 (Table 3). All indicators are up to standard, showing that the model fit in this paper is good.

Hypothesis Test

Research findings from the low-carbon production hypothesis model show that among the eight hypotheses in the paper, other than the rejection of hypotheses H1, H2, and H8, the rest of the hypotheses are valid (Table 4 and Fig. 4). P values<0.001 is described as ***, and 0.001≤P values<0.05 is described as **. According to the standardized regression coefficient, perceived behavioral control has the biggest positive effect on farmers' low-carbon production intention, while ATT and SN have no significant effect. For every one standard deviation increase in perceived behavioral control, farmers' low-carbon production intention will increase by 0.869 standard deviation. Green cognition has the greatest impact on farmers' attitude towards low-carbon production. For every one standard deviation increase in green cognition, farmers' attitude towards low-carbon production will increase by 0.98 standard deviation. Among all the factors influencing farmers' low-carbon production behavior, behavior intention has the biggest effect ability, followed by farmers' perceived behavior control. For every one standard deviation increase in behavior intention, farmers' low-carbon production behavior will increase by 0.699 standard deviation.

Table 2. Reliability and validity test results.

Constructs	Alpha value	KMO value	P value	CR	AVE
ATT	0.926	0.860	0.000	0.93	0.76
SN	0.944	0.868	0.000	0.95	0.81
PBC	0.916	0.783	0.000	0.83	0.59
INT	0.915	0.751	0.000	0.92	0.78
GC	0.955	0.922	0.000	0.95	0.78
BEH	0.899	0.838	0.000	0.90	0.70

Table 3. Fitness test results.

Fit index	value	Acceptable value
Chi-square/df	1.699	<3
RMSEA	0.051	<0.08
NFI	0.927	>0.9
RFI	0.911	>0.9
CFI	0.968	>0.9
IFI	0.969	>0.9
TLI	0.961	>0.9

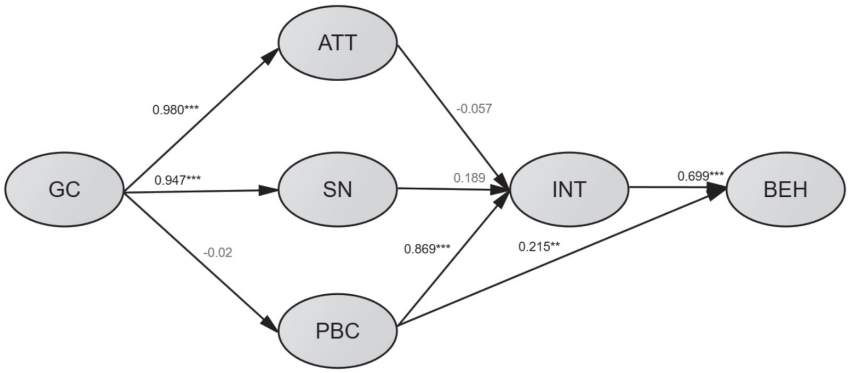

Fig. 4. Standardized output of constructs.

Table 4. Confirmatory factor analysis results.

Hypothetical path	Estimate (Non-standardized)	Estimate (Standardized)	P Values	C.R.	Significance
ATT→INT	-0.057	-0.057	0.733	-0.342	Unsupported
SN→INT	0.191	0.189	0.261	1.125	Unsupported
PBC→INT	1.051	0.869	***	14.642	Supported
PBC→BEH	0.238	0.215	**	2.026	Supported
INT→BEH	0.639	0.699	***	6.237	Supported
GC→ATT	0.898	0.980	***	15.981	Supported
GC→SN	0.845	0.947	***	16.168	Supported
GC→PBC	0.015	0.020	0.780	0.279	Unsupported

Discussion

Results Analysis

1) The effect of ATT and SN on farmers' low-carbon production intention.

An unexpected finding is that farmers' ATT and SN have no significant positive effect on their intention to low-carbon production (Estimate = -0.057, P Value = 0.733, C.R. = -0.342; Estimate = 0.189, P Value = 0.261, C.R. = 1.125), so we assume that H1 and H2 are rejected. The results are contrary to past research which suggested that farmers' ATT and SN play an essential role in whether they choose to recycle. However, this finding is also the same as other studies, in which Tarkiainen argued that individuals' ATT and SN had little impact on their behavioral intention to buy organic food. Thus, the results of this paper are acceptable, it shows that there is no significant positive effect between ATT and SN on farmers' low-carbon production intention, and there are several possible reasons for this. First, farmers themselves do not realize the benefits of low-carbon production, so it is difficult to generate low-carbon production intention. Second, the government's insufficient publicity, the low recognition in society and the low participation of relatives and friends in low-carbon production may limit the impact of SN on farmers' intention.

2) The effect of PBC on farmers' low-carbon production intention.

The results support the hypothesis that farmers' PBC has a significant positive impact on their low-carbon production intention (Estimate=0.869, P Value=***, C.R.=14.642), so we assume that H3 is valid. The result is the same as previous research on the effects of PBC on individual behavior intention in various fields, such as teachers using new technology and college students texting while driving, and these studies all conclude that PBC has a significant positive effect on individual behavior intention. The study provides some support for the positive effect of PBC on farmers' low-carbon production intention, it confirms the important effect of farmers' knowledge and the government's help about low-carbon production. It also shows that farmers will change their low-carbon production intention depending on the external and their own objective conditions.

3) The effect of PBC and INT on farmers' low-carbon production behavior.

The results show that farmers' PBC and behavioral intention can have a significant positive effect on low-carbon production behavior (Estimate = 0.215, P Value = ***, C.R. = 2.026; Estimate = 0.699, P Value = **, C.R. = 6.237), so we assume that H4 and H5 are valid. It is different from past studies that have shown the predominance of PBC and behavior intention in forecasting individual behaviors such as

recycling and protecting the environment. The research highlights the direct effect of farmers' time and energy on their own low-carbon production behavior, and that farmers who lack necessary conditions for low-carbon production will not adopt low-carbon production. In addition, this paper argues that farmers with greater willingness to produce low carbon are more likely to adopt low carbon production.

4) The effect of GC on farmers' ATT, SN and PBC towards low-carbon production

The results support the hypothesis that green cognition has a significant positive impact on farmers' ATT and SN of low-carbon production (Estimate = 0.980, P Value = ***, C.R. = 15.981; Estimate = 0.947, P Value = ***, C.R. = 16.168), so we assume that H6 and H7 are valid. The finding is the same as previous research demonstrating the predominance of green cognition in forecasting individual environmental behavior. For example, Despotović et al. measured environmental knowledge in terms of the number of environmental issues that farmers can correctly describe and studied that green cognition can significantly contribute to farmers' awareness of environmental responsibility and environmental protection behavior [46]. Langenbach et al. found that individuals regulate the relationship between environmental attitudes and behaviors in the core aspect of cognitive control, and individuals with high cognitive level are more likely to carry out pro-environment behaviors [47]. The study shows that green cognition, as an external factor, has a significant positive effect on farmers' ATT and SN towards low-carbon production. The conclusion verifies that farmers with high degree of green cognition are easier to produce low-carbon production intention if they recognize the benefits and are easier to adopt the advice of the government and take the right way to implement low-carbon production.

The results do not support that green cognition has a positive effect on farmers' PBC in low-carbon production (Estimate = 0.020, P Value = 0.780, C.R. = 0.279), so we assume that H8 is rejected. In this paper, we do not believe that green cognition, as an external factor, has a positive effect on farmers' ATT and SN towards low-carbon production. It may be due to the fact that farmers with a high degree of green cognition may not carry out low-carbon production owing to their lack of sufficient time and necessary low-carbon production conditions.

Theoretical Contributions and Practical Significance

The theoretical contributions: (1) Focusing on green cognition, the low-carbon production behavior of farmers is investigated. The original TPB mainly emphasizes the study on individual's own emotions and lacks the influence of exogenous condition cognition factors like green cognition. The paper introduces green cognition into TPB, which bridges the gap of TPB in predicting farmers' low-carbon production behavior. It provides a more comprehensive understanding of the influencing factors of farmers' low-carbon production behavior, which is a reference for future TPB research. (2) The existing research on farmers' low-carbon production behavior mainly focus on technology improvement, and there is a lack of research on it from a psychological perspective. The psychological factors of farmers perform a crucial role and need to be the focus of research. Therefore, this study takes farmers as research objects, which helps to abundant the research content related to farmers' low-carbon production, thus attracting more researchers' attention to it.

The practical significance: (1) Firstly, farmers' PBC has a significant positive effect on their low-carbon production intention. Thus, policy makers should publicize the profits in several methods to make individuals aware of the significance of low-carbon production in the sustainable development of environment. Meanwhile, policy makers should take the lead in low-carbon production activities, so that farmers can feel that it is easy for them to take part in low-carbon production, so as to encourage others to actively take part in low-carbon production. (2) Finally, green cognition has a significant positive effect on farmers' ATT and SN of low-carbon production, and green cognition can indirectly affect low-carbon production behavior through farmers' subjective norms and intention paths. Therefore, policy makers should strengthen policy incentives, provide various forms of agricultural green subsidies, and improve farmers' awareness of the importance of green production, for the benefit of settling the obstacles of external factors in the process of low-carbon production.

Conclusions

This study is the first attempt to use green cognition as an external factor to predict the influences on farmers' low-carbon production behavior. Empirical analysis provides evidence that the extended TPB model with green cognition has good predictive capacity in studying farmers' low-carbon production behavior. The hypotheses are verified by SEM, through empirical test, we can come to the conclusion: (1) After introducing green cognition into TPB, green cognition has a significant positive effect on farmers' ATT and SN of low-carbon production behavior. (2) Farmers' PBC has a prominent role in accelerating their low-carbon production intention. (3) Farmers' PBC and behavior intention have a positive direct effect on their low-carbon production behavior.

Finally, although our study makes important theoretical contributions, it is subject to several limitations. (1) In the investigation stage, the older generation farmers have some deviation in understanding the questionnaire, which leads to the elimination of more invalid questionnaires. Future research should provide

more patient explanations to the older generation of farmers. (2) Furthermore, this study is investigated in part regions of China, research carried out in other parts of China, depending on regional differences may have different results. Thus, it is essential to conduct research in other regions of China.

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Conflicts of Interest

The authors declare no conflict of interest.

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