A Study on the Impact of Effective Use of Geographical Indications on Carbon Reduction Technology in the Production Layer of Traditional Chinese Medicine Industry in China

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Abstract. The double carbon target is a solemn commitment made by the Chinese government to the world, and emission reduction and sink increase in the agricultural production process is an important way to achieve the double carbon target. However, the current status of green production in Chinese medicine is not optimistic, which is not conducive to agricultural emission reduction on the one hand, and will inevitably restrict the long-term well-being of the traditional Chinese medicine industry in driving economic growth on the other. Based on a microdata survey of Eucommia farmers in Lueyang County, Shaanxi Province, this study empirically analyzed the effect of effective use of GI on farmers' adoption of carbon emission reduction technologies using the Propensity Score Matching method and explored the degree of adoption of each carbon emission reduction technology by farmers using the entropy weighting TOPSIS. The results show that the effective use of GI has a positive impact on farmers in terms of fertilizer and medicine savings, and no impact in terms of water and energy saving. And the ease of implementation of the emission reduction measures had a positive effect on the adoption by farmers.

Keywords: geographical indication, traditional Chinese medicine industry, Propensity Score Matching, the entropy weighting TOPSIS, carbon emission reduction.

1. Introduction

Warming, greenhouse effect and other ecological and environmental problems gradually push the issue of carbon emission reduction to the world people's conference table. The Central Economic Work Conference in December 2020 proposed that China's carbon emissions strive to peak by 2030 and be neutralized by 2060[1]. The conference also clarified the status of green development in agriculture in this long-range plan, indicating that carbon sequestration and efficiency enhancement in agriculture is the cornerstone to achieving green emission reduction in the country[2].

In recent years, green production has been gradually carried out in all walks of life, and carbon emission reduction technologies are being improved and promoted, but China's traditional Chinese medicine industry is still dominated by high consumption, high pollution, and low-quality of crude production methods, and the natural environment of some production sites has touched the ecological red line, greatly limiting the sustainable development of Chinese pharmaceutical industry[3]. At present, there are no binding regulations related to energy measurement apparatus and other relevant regulations for TCM production in China, and it is impossible to propose specific initiatives for energy saving and consumption reduction based on them[4]. It can be seen that the policy dimension is not binding enough for the green production of TCM, which leaves a wide research opening for studying landmark policies[5].

In Lueyang Eucommia industry, for example, the concept of carbon emission reduction has not yet been established and the technology of carbon emission reduction has not yet been popularized in most production entities[6]. This is not conducive to the development of carbon sequestration and emission reduction in the production process of Eucommia and the modernization of agriculture.

Lueyang Eucommia has been successfully registered as a national geographical indication in 2008 and has been identified as a key forestry seed base by the State Forestry Administration. The effective use of GI aims to improve the market competitiveness of products from the product's own quality and industry chain optimization, and also puts forward higher requirements for all aspects of TCM

production and consumption reduction[7], it also improves the visibility of agricultural products, expands consumer markets and promotes sustainable agricultural development, and the economic and cultural benefits it brings are conducive to strengthening the protection and development of TCM industry.

Therefore, this study takes the production of Eucommia in Lueyang County, Shaanxi Province, as an example, to further improve the green production of Chinese medicine production by exploring the influence process of the effective use of GI in promoting carbon reduction technology and improving resource utilization in the production layer of Chinese medicine, and to propose practical measures to help Lueyang Eucommia industry flourish, increase farmers' economic income, improve government financial revenue, consolidate the results of poverty eradication and help rural revitalization. In the post-epidemic era, promote the green production of TCM in large quantities and contribute to the public health of human beings.

2. Assumptions and model construction

2.1. Assumptions

1. Farmers who use GI effectively are more willing to adopt carbon reduction measures than those who do not use it effectively. It has been shown in the literature that the use of GI will prompt farmers to adopt environmentally friendly technologies in planting [8], and GI agricultural products pay much attention to soft and hard power [9], so farmers will continuously improve their own production behavior and production technology in order to enhance the competitiveness of crops, adopt carbon saving and emission reduction technologies in production to protect the environment and fulfill their social responsibility.

2. Ease of implementation of emission reduction measures has a positive effect on adoption by farmers. Carbon reduction measures vary in difficulty, and the degree of adoption of each carbon reduction technology by farmers in the production process also varies. Mi Songhua et al. pointed out that when farmers have higher knowledge and understanding of abatement technology, they are more likely to adopt that carbon reduction technology [10].

2.2. Variable selection and descriptive statistics

1. Dependent variable

The dependent variable of this study is the use of carbon abatement technologies, characterized by four aspects: water saving, fertilizer saving, medicine saving, and energy saving, respectively, and the use of technologies in each aspect is characterized by a five-level Likert scale.

2. Core independent variables

In the questionnaire, "Do you use the GI brand of Eucommia?" This question was used as a prerequisite for the effective use of GI by farmers, and when respondents selected "Yes", the next two sub-questions, "How do you think it is useful for the marketing of Eucommia? and "By how much has the income of growing Eucommia increased?" If the respondents selected "general effect" and "0-10% increase" and above respectively, the farmers were considered to have effectively used the GI and were recorded as 1, while the rest were considered not to have effectively used the GI and were recorded as 0.

3. Control variables

In this study, the age and education level of farmers were selected to characterize the basic information of farmers. If the respondents are younger and have higher education levels, they are more likely to accept new knowledge and learn new skills and are more likely to use GI effectively.

The number of laborers, the presence of party members and village officials, the number of mechanized farming tools, and the number of means of transportation were selected to characterize the household information of farmers. Respondents with a larger number of laborers in their

households have frequent information exchanges with each other and are more willing to seek more effective marketing channels, and are more likely to use GI effectively. In addition, if there are party members and village cadres in the household, farmers have a more comprehensive understanding of the corresponding national policy information and respond more actively to the policy, and the probability of effective use of GI by farmers is greater. At the same time, the number of mechanized farming tools and the number of transportation means that the farmers are more active in production, and the more the number of mechanized farming tools, the more active the farmers are in planting, and therefore the greater the possibility of effective use of GI.

The presence or absence of green production subsidies and the holding of corresponding presentation sessions were selected as indicators of external production welfare. When respondents received green production subsidies and learned about the use of GI at the presentation, their motivation for green production increased accordingly, their understanding of the benefits of GI use became more comprehensive, and their willingness to respond to the national policy became stronger, and the tendency to use GI increased.

Whether neighbors use GI effectively or not is selected to characterize social endowment. The influence of the surrounding environment on people is huge, and the likelihood of farmers using GI increases significantly when their neighbors are using it[11].

The definitions and descriptive statistics of each of the above variables are shown in **Table 1**.

Table 1. Variable assignment descriptions and descriptive statistics

Variable Type	Variable Name	Variable Definition	Full sample	Participation group	Non-participating group	Difference
Self-endowment	Age	30 years old and below=0, 31-40 years old=2, 41-50 years old=3, 51-60 years old=4, 61 years old and above=5	3.47	3.319	3.597	-0.277***
	Education level	Uneducated = 1, elementary school = 2, junior high school = 3, high school/junior high school = 4, college/bachelor's degree and above = 5	4.31	4.549	4.101	0.448***
	Number of labor force	Actual number of family workers	2.12	2.221	2.025	0.195**
	Whether there are party members and village cadres in the household	Yes=1, No=0	0.54	0.77	0.336	0.434***
	Number of mechanized farming tools	Actual number of mechanized farming tools	1.33	1.676	1.025	0.651***
	Number of transportation tools	Actual number of transportation	1.07	1.197	0.958	0.239***
External environment	Whether there is green production subsidy	Yes=1, No=0	0.35	0.582	0.134	0.448***
	Whether the corresponding report meeting has been held	Yes=1, No=0	0.57	0.84	0.328	0.513***
	Whether neighbors are effectively using geographical indications	Yes=1, No=0	0.54	0.883	0.202	0.681***

Note: ***, **, and * indicate that the estimation results are significant at the 1%, 5%, and 10% levels, respectively.

2.3. Data analysis ideas

This paper first performs the policy combing and research work and analyzes and organizes the data and questionnaire reliability and validity analysis on the basis of the preliminary work, so as to prepare for the construction of the relevant model. Then, we use PSM to find out the match between the use of effective GI and non-effective GI farmers' production level carbon reduction measures, and further prove the scientificity and rationality of the matching results through the common support domain test, balance test, and robustness test[12]. Next, the weight indicators of the four aspects of carbon emission reduction are calculated by using entropy weighting TOPSIS, and the above two models are integrated to provide data support for specific measurements. Finally, after relevant analysis and integration, a more scientific conclusion is drawn, and based on the actual situation, relevant policy recommendations are put forward to specifically grasp the implementation of the main task and measure the comprehensive benefits of the policy, with the target public demand as the guide.

2.4. Logit model matching variables

For the treatment of the propensity score of the treatment group (effective use of GI) and the control group (ineffective use of GI), a logit model is proposed to calculate the propensity score by selecting nine matching variables in terms of farmers' own endowment and external environment[13].

2.5. Propensity score matching

For this study, the purpose of using propensity score matching was to match farmers who used GI effectively with those who did not, to eliminate the effects of covariates (control variables), and to compare the extent to which the two scenarios had contributed to the implementation of carbon reduction technologies by farmers growing GI agricultural products[14].

First, logit regression was used to estimate the matching scores for the treatment group (effective use of GI) and the control group (ineffective use of GI). The formula is as follows:

$$P\left(x_i\right)=P\left(k_i=1|\,x_i\right)=\frac{e^{\beta x}}{1-e^{\beta x}} \tag{1}$$

To ensure the reliability of the matching results, a common support and balance test was conducted on the matching results, and then the average treatment effect of the farmers in the sample was calculated[15]. For the farmers themselves, their adoption level is A. Then we have:

$$A_i=\begin{cases} A_{1i}, k_i=1 \\ A_{0i}, k_i=0 \end{cases} \tag{2}$$

Calculating the average treatment effect ATT, we have:

$$\begin{aligned} ATT &= E\{A_{1i}-A_{0i}|k_i=1\} \\ &= E\{E[A_{1i}-A_{0i}|k_i=1, P(x_i)]\} \\ &= E\{E[A_{1i}|k_i=1, P(x_i)]-E[A_{0i}|k_i=1, P(x_i)|k_i=1]\} \end{aligned} \tag{3}$$

PSM highlights the steps as shown in **Figure 1**.

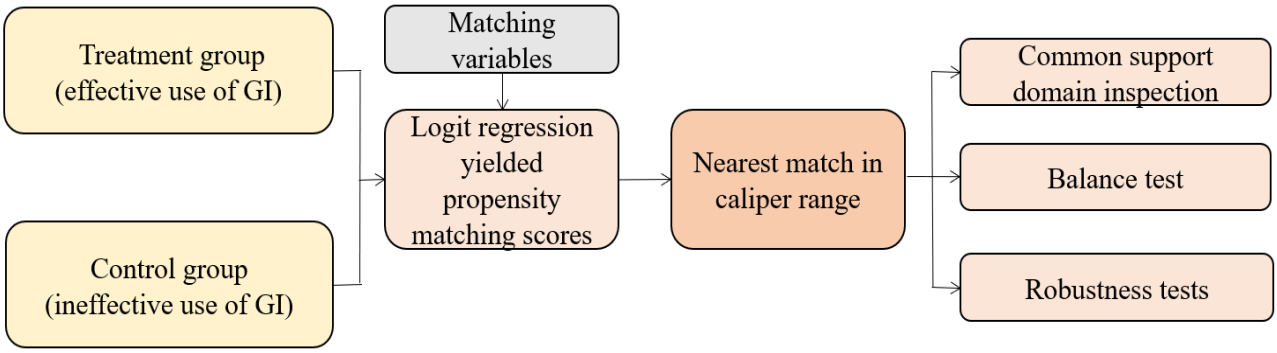


Figure 1. PSM focus steps

2.6. Entropy weighting TOPSIS construction weights

In this paper, the indicators are standardized using entropy weighing TOPSIS. Assuming that there is a prevention and control measure for the implementation of the carbon reduction technology and the degree of adoption is $k(k=1,2,3,4)$. Assuming that a total of p farmer samples are selected, of which $y_1, y_2, \cdots, y_p$, and assuming that the standardized value of each indicator data is $z_1, z_2, \cdots, z_p$, then for the i th farmer sample.

The positive indicators are:

$$z_{ji} = \frac{y_{ji} - \min(y_j)}{\max(y_j) - \min(y_j)} \tag{4}$$

The negative indicators are:

$$z_{ji} = \frac{\max(y_j) - y_{ji}}{\max(y_j) - \min(y_j)} \tag{5}$$

Then we find the information entropy of each index. From the definition of information entropy in information theory, it is known that the information entropy of a set of data is $E_j = lin(n)^{-1} \sum_{i=1}^{n} p_{ji} \ln(p_{ji})$, Among them $p_{ji} = \frac{z_{ji}}{\sum_{i=1}^{n} z_{ji}}$.

Finally, the weights of each index are determined. According to the formula of information entropy, the information entropy of each index is obtained, and then the weight of each index is calculated by information entropy.

$$W_j = \frac{1 - E_j}{p - \sum E_j} (j = 1, 2, \cdots, p) \tag{6}$$

2.7. To obtain the score of a particular aspect of the sample farmers' carbon reduction measures

For the ith farmer, the adoption score of an aspect is $S_{ki} = \sum_{j=1}^{p} w_j y_{li}$. Similarly, the scores of other farmers in that aspect can be derived, as well as the scores of other aspects of farmers. Using the above method again, the weights of each aspect are obtained, and the final adoption score is obtained. Then the final adoption degree of the ith farmer is $C_i = \sum_{k=1}^{4} a_k S_{li}$.

3. Model solving

3.1. Propensity score matching

Team members calculated the fitted value of effective GI use by farmers, i.e., the propensity score of farmers, based on the logit regression estimation results. To ensure the matching quality of the sample data, the pre-match and post-match density function plots were further plotted after obtaining the propensity scores, as shown in **Figure 2**. The post-match propensity scores of farmers using GI and farmers not using GI have a large range of overlap, and most of the observations are within the common range of values. In addition, the results of sample loss under the nearest neighbor matching method within the given caliper range show that the sample loss between the treatment and control groups is 6, which is a good matching effect.

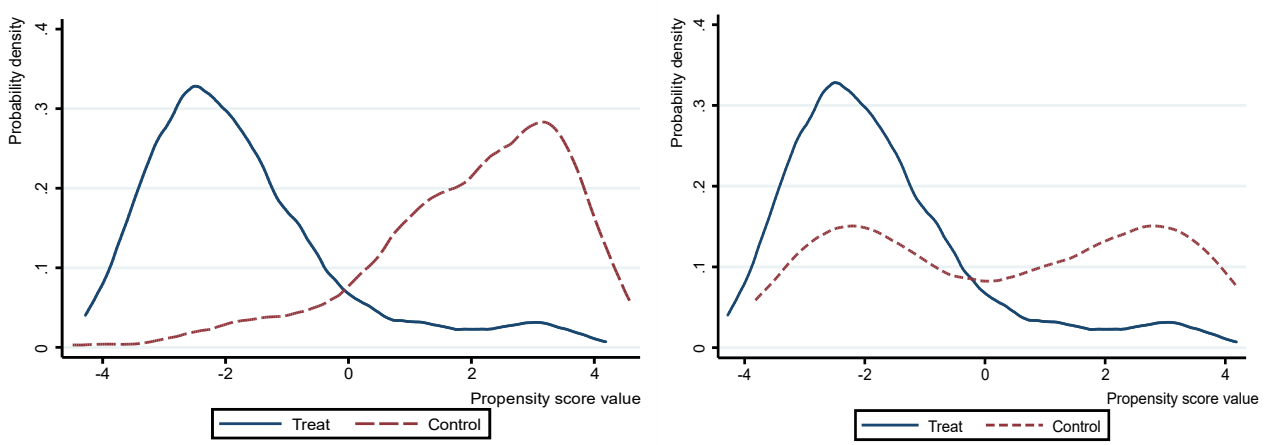


Figure 2. Common support domain before and after matching

In order to ensure the reliability of the matching results, a balance test should be conducted between the farmers who effectively use GI and those who do not effectively use GI before matching. In other words, after matching, there should be no significant systematic differences in the characteristics of the two groups of farmers, except for the differences in the use of carbon reduction technologies. The results of the equilibrium test between farmers who effectively use GI and those who do not effectively use GI are shown in **Table 2**.

Table 2. Nearest match balance test results within the caliper range

Matching Variables	U	Mean value		Standard deviation (%)		T-test $P>\|t\|$
	M	Experimental group	Control group	Deviation	Reduction	
Age	U	3.3192	3.5966	-39.4	92.5	0.000
	M	3.3254	3.3047	2.9		0.759
Education level	U	4.5493	4.1008	56.8	82	0.000
	M	4.5407	4.6214	-10.2		0.221
Number of labor force	U	2.2207	2.0252	22.1	28	0.020
	M	2.2057	2.0650	15.9		0.061
Whether there are party members and cadres in the family	U	0.7700	0.3361	96.8	92.2	0.000
	M	0.7656	0.7316	7.6		0.424
Number of mechanized farming tools	U	1.6761	1.0252	48.7	67.5	0.000
	M	1.6364	1.4246	15.8		0.087
Number of transportation tools	U	1.1972	0.9580	31.5	85	0.001
	M	1.1722	1.2082	-4.7		0.628
Green production subsidy	U	0.5822	0.1345	105.3	94.9	0.000
	M	0.5742	0.5515	5.3		0.642
Holding report training sessions	U	0.8404	0.3277	121.5	95.3	0.000
	M	0.8373	0.8130	5.8		0.514
Whether neighbors are effectively using GI	U	3.8357	3.4496	39.2	92.2	0.000
	M	3.8182	3.8482	-3.1		0.734

The average treatment effects of effective use of GI on four aspects of water saving, fertilizer saving, pesticide saving, and energy saving of farmers were measured, and the estimated results are shown in **Table 3**.

Table 3. Treatment effects of propensity score matching

		Processing group	Control group	ATT	T-test
Water Conservation	Before Matching	9.1408	9.0504	0.0904	0.43
	After Match	9.1435	9.3257	-0.1822	-0.39
Fertilizer saving	Before Match	10.1878	8.6134	1.5743***	6.78
	After Match	10.1818	8.0880	2.0938***	3.95
Pesticide saving	Before Match	10.2253	9.0042	1.221***	5.52
	After Match	10.2344	9.5694	0.665*	1.69
Energy conservation	Before Match	10.1362	8.7605	1.3756***	6.32
	After Match	10.1388	9.2515	0.8872	1.59

After the counterfactual estimation of propensity matching, it can be seen from **Table 3** that there is no significant difference in water savings before and after matching. The total table value of fertilizer savings before matching was 10.1878 for farmers who used GI effectively and 8.6134 for those who did not use GI effectively, with a difference of 1.5743, which was significant at the 1% level; after matching, the total table value of GI use was 10.1818 for those who used GI effectively and 8.088 for those who did not use it effectively, with a difference of 2.0939, which was significant at the 1% level. The total table value of pesticide savings for farmers who used GI effectively before matching was 10.2253 and 9.0042 for those who did not use GI effectively, with a difference of 1.221 and significant at the 1% level; after matching, the total table value of GI used effectively was 10.2344 and 9.5694 for those who did not use GI effectively, with a narrowing difference of 0.665 at the 10% level of significance. The total table value of energy saving for farmers who used GI effectively before matching was 10.1362 and 8.7605 for those who did not use GI effectively, and the difference between them was 1.3756, which was significant at 1% level; after matching, the total table value of GI used effectively was 10.1388 and 9.2515 for those who did not use it effectively, and the difference between them was narrowed to 0.8872, which was not significant.

In order to verify the accuracy of the effect of effective use of GI on the use of carbon emission reduction technology by farmers, this study also used the matching between the effective use of GI and the non-effective use of GI by using the Mahalanobis matching and the kernel matching again, and the matching results are shown in **Table 4**. It can be seen that the results of the effect of effective use of GI on the use of carbon emission reduction technology at the production level of farmers obtained by using Mahalanobis matching and kernel matching are basically consistent, which indicates that the results are robust.

Table 4. Matching results

	Mahalanobi matching				Kernel matching			
	Effective Use	**Not effectively used**	**ATT**	**T-test value**	**Effective Use**	**Not effectively used**	**ATT**	**T-test value**
Water Conservation	9.1408	9.408	-0.2676	-0.61	9.1408	9.3027	-0.1618	-0.28
Fertilizer saving	10.1878	8.3098	1.8779***	3.10	10.1878	8.0129	2.1749***	3.46
Pesticide saving	10.2254	9.4883	0.7371**	2.05	10.2254	9.6572	0.5681	0.95
Energy conservation	10.1362	8.9484	1.1878	1.07	10.1362	9.3987	0.7375	1.30

3.2. Entropy Weighing TOPSIS

The results obtained using MATLAB R2020a software are shown in **Table 5**.

Table 5. Adoption of emission reduction measures

Emission reduction measures	Coefficient of variation	Weights	Average Adoption Level
Use of ground cover	0.4472	0.0655	2.3836
Use of piped water distribution	0.4485	0.0657	2.4035
Use of sprinkler and drip irrigation	0.3875	0.0568	2.2040
Use of drought-resistant water retention agents	0.3666	0.0537	2.1020
Use of crop rotation system	0.4281	0.0627	2.3503
Use of slow and controlled release fertilizer technology	0.4445	0.0651	2.4501
Use of urease nitrification inhibitors	0.3989	0.0585	2.2860
Use of integrated water and fertilizer irrigation	0.3964	0.0581	2.2705
Use of biological control	0.3961	0.0581	2.2373
Regular cleaning of fields for weeds	0.5733	0.084	2.8581
Use of drip irrigation for application	0.3923	0.0575	2.2084
Mulching with mulch, shade nets, etc.	0.4033	0.0591	2.2772
No-till or less-till land	0.4472	0.0655	2.3969
Biological tillage	0.4485	0.0657	2.4412
Use of integrated machinery	0.3563	0.0522	2.0067
Use of circular ecological ideas	0.4887	0.0716	2.5654

The coefficient of variation of using mulch, pipeline water transfer, crop rotation system, slow-release fertilizer technology, regular cleaning of field weeds, mulch cultivation, no-till or less tillage, biological tillage, and circular ecological ideas were larger, at 0.4 or more, but the average adoption of regular cleaning of field weeds and using circular ecological ideas were higher, at 2.5 or more; meanwhile, the average adoption of using drought and water conservation agents and integrated mechanical operation were lower, at 2.2 or less. meanwhile, the average adoption level of using drought and water conservation agents and integrated mechanical operation was lower, both being below 2.2.

4. Conclusion

4.1. Summary

The effective use of GI has no impact on water and energy conservation. After the counterfactual estimation of propensity score matching, the t-test value of -0.39 for water conservation is not significant for the mean treatment effect, which cannot indicate that the effective use of GI has an effect on water conservation, probably due to the fact that the Party and the State have traditionally attached importance to water conservation and promoted the construction of water-saving society comprehensively as a strategic and fundamental initiative to solve China's water resources problems. The t-test value of 1.59 for energy saving, with the same insignificant mean treatment effect, cannot indicate that the effective use of GI has an effect on energy saving. During our research, we found that Eucommia is easy to survive and does not require much effort from farmers, so farmers generally do not consider themselves responsible for saving energy.

The effective use of GI has a significant positive impact on fertilizer and medicine savings. After propensity score-matched counterfactual estimation, the net effect of fertilizer saving was 2.0938, which was significant at the 1% level, i.e., farmers who effectively used GI were 209% more likely

to adopt fertilizer saving than those who did not effectively use it; the average treatment effect in terms of fertilizer saving was 0.665, which was significant at the 10% level, i.e., farmers who effectively used GI had 66.5% higher adoption in terms of medicine saving than those who did not. Since two of the four abatement aspects could not be verified effective use of landmarks tends to use carbon abatement technologies more than ineffective use, hypothesis one could not be proven.

The adoption of more costly and difficult carbon reduction measures is low, while the adoption of simpler carbon reduction measures by farmers is high. From the results of the average degree of adoption, it can be concluded that the higher cost and more difficult to use emission reduction measures, such as the use of sprinkler irrigation and drip irrigation, drought-proof water retention agents and integrated mechanical operations, etc., are adopted by farmers to a lesser extent and are less willing to accept, and its coefficient of variation is also small, indicating a certain uniformity in the will of farmers not to adopt it. In contrast, measures such as regular cleaning of field weeds and the use of circular ecological ideas are simpler and easier to implement and have a higher degree of adoption by farmers. This fully also verifies hypothesis two.

4.2. Recommendations

Based on Smith's policy implementation process model, with policy feasibility and implementation as the first consideration criteria, the policy recommendations are supported by "target public requirements" and "perform the main task " in both directions, and a number of policy recommendations are made:

Implementing the "target public requirement" driven policy: the government has increased its efforts to give production subsidies to farmers growing GI products, and to purchase the products of farmers applying carbon emission reduction technology at a price slightly higher than the market price to enhance farmers' willingness to use GI and carbon emission reduction technology. And the government needs to strengthen the cultivation of farmers' green agricultural production skills, and promote the concept of technological dividends so that the new Chinese medicine production and emission reduction technology can be landed.

Implement the " perform the main task " driven policy: the relevant government departments increase the management of geographic indication of Eucommia production, popularize the knowledge of emission reduction in TCM production internally, broaden the breadth of application of carbon emission reduction in TCM, and collaborate with farmers to help promote the top-level research and development of carbon emission reduction technology and standby teaching. To break through existing bottlenecks and to continue and develop the accumulated experience in a variety of production.

Based on the above policies and the hot spots of the times, the GI brand can also play a combination with “the one-village, one-product strategy” to enhance the recognition of the township through iconic products, which can make the village and township among the ranks of one-village, one-product model townships, but also make the GI branding, large-scale production, brand benefits to pull the scale effect and promote the sustainable development of the green economy of Chinese medicine.

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