Study on Agricultural Product-coupled Subsidy Policy Considering Output Uncertainty and the Development of Tobacco Agriculture

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Objectives: The health and well-ordered development of tobacco agriculture is very important. The incentive effects of plant-coupled subsidies and output-coupled subsidies on farming decisions with the consideration of uncertainty are investigated. The study shows that if the same unit subsidy is adopted, the incentive effect of the two policies will be determined by the expected output. When the expected output is higher, the incentive effect of the output-coupled subsidy is better than that of the plant-coupled subsidy. And when the expected output is lower, the incentive effect of the plant-coupled subsidy is better. If the implementation scheme limits the total amount of subsidies, it is better to determine subsidy policy by optimal output. The higher the optimal output is, the better the plant-coupled subsidy is. And when the optimal output is relatively low, the output-coupled subsidy shows a better incentive effect. Meanwhile, the study results also show that the incentive effects of the two coupled subsidy policies for increasing production and income are consistent, and the advantages of the policy with better incentive effects increase as the amount of subsidies increases.

Key words: output uncertainty; agricultural product; tobacco agriculture; coupled subsidy

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As the primary industry in a lot of countries around the world, agriculture is an important part of social and economic development. In addition, a considerable part of the tertiary industry relies on agricultural inputs to create added value to the economy. At the same time, the production uncertainty is particularly prominent in agriculture. Because there is a certain cycle in the production of agricultural products, which is affected by weather, natural disasters and pests, the quantity and quality of products produced by using given inputs can not be predicted with certainty[1]. For example, a study on farmers' income of corn and soybean shows that the important factor leading to the fluctuation of farmers' income is the output uncertainty[2]. In fact, the reduction of output not only directly affects the income of farmers, but also has a great adverse impact on the development of agriculture such as textile and food industries.

Therefore, to protect the interests of farmers and the healthy development of agriculture and related industries, agricultural subsidies are the basic policies that have been implemented in almost all countries. Typically, agricultural subsidy policy tools can be divided into two main categories: support measures for agricultural producers and agricultural products and general service support measures for agriculture. The former can be divided into coupled subsidy and decoupled subsidy according to whether it is coupled with agricultural product price, output and planting area. Among them, agricultural products coupled subsidy is one of the most widely used subsidies [3].

At the same time, while tobacco industry somehow contributes to the regional economy, the regulations are more and more strict.[4] Tobacco agriculture is required to be more health and environment friendly. Under the existing restrictions, how to optimize the subsidy policy to encourage the well-ordered development of tobacco agriculture is one of the important topics at present.

Liu[5] believes that tobacco control policy need to be developed based on environment protection law. Zhou[6] further pointed out that the subsidy policy should not only meet the relevant requirements of WTO, but also protect the interests of producers. Han and Zhang[7] found that the direct subsidies for grain are not conducive to the expansion of planting scale by studying the microscopic survey data of 13,889 farmers from 2013 to 2017. Liu Zhenbin et al.[8] pointed out that under the background of grain price fluctuation, the current grain price subsidy policy has some drawbacks and it is necessary to carry out reform, and made suggestions on the target orientation of grain subsidy policy reform from three angles: realizing pricing by market mechanism, "separating price from subsidy" and linking subsidies with grain output.

In the specific formulation of subsidy methods, Feng et al.[9] studied the wholesale price and surplus product subsidy contract considering the influence of supplier logistics level on the end market demand of agricultural products. Berenger et al.[10] discussed different subsidy methods by considering the uncertainty of demand, but all the studies focused on the demand side, not on the supply side, and farmers faced the decision-making and behavior of subsidy methods. Ruffe et al.[11] analyzed the influence of different agricultural subsidies on the technical efficiency of dairy industry in western European countries by means of empirical research. In the study, the subsidies coupled with plant area, animal husbandry quantity and farm nature were discussed. It was found that the subsidy effects of different subsidies in different countries and regions were not completely the same, but also completely opposite. Czewski et al.[12] made an empirical analysis on the subsidy mode coupled with capital, land and labor through the data of the European Union. The results showed that the structure of subsidy mode is more important than the total amount of subsidy. Alizamir et al.[13] compared the effects of price difference-coupled subsidy and income-coupled subsidy provided by the US government on consumers, farmers and the government, and found that under the price difference subsidy, farmers always choose to increase the planting area, while under the income subsidy, it will decrease. The above research shows that the coupled subsidy can produce certain incentive effect, but the influencing factors of its effect need to be further explored.

The existing literature has made a profound theoretical explanation and rich empirical test on the theoretical basis, main measures and characteristics, effect analysis and changes of agricultural products coupled subsidies. However, the research on the specific formulation and optimization of coupled subsidies is limited. Based on this, this paper adopts the game theory and the operational optimization theory to explore the intrinsic incentive mechanism of the coupled subsidy, which is one of the most important types of subsidies currently used, and systematically studies the optimization of the coupled subsidy in the direction of increasing production and increasing income. This study will supplement the current theoretical system of agricultural subsidies based on empirical research, and provide powerful theoretical support and reference for the further improvement of agricultural subsidies policy.

MODEL AND HYPOTHESIS

Before the planting cycle, the sponsor will announce the corresponding subsidy strategy. In this cycle, the budget of total subsidy is $\bar{S}$, and planting-coupled subsidy and output-coupled subsidy are considered. If planting-coupled subsidies are selected, s_P is subsided per unit according to the number of farmers' planting areas; if output-coupled subsidies are selected, s_H is subsided per unit according to the final output of farmers. Regardless of the subsidy strategy, the total subsidy cannot exceed the budget $\bar{S}$.

According to the subsidy policy, farmers can decide that their planting quantity is y. Assuming that their unit planting cost is c, due to the uncertainty of climate and other factors, under the probability of α, there will be optimum output conditions. At this time, a higher unit output r_H will be obtained, and the total output will be q_H. The probability of not having optimum output conditions is $\bar{\alpha}$ （$\bar{\alpha}=1-\alpha$）. In this case, the output is lower, which is r_L per unit and the total output is q_L.

Assuming that the market price p $p\in\{p_H, p_L\}$ is determined by the final output and satisfies $p=a-bq$ and $q\in\{q_H,q_L\}$, where $q\in\{q_H,q_L\}$ is the upper limit of acceptable price in the market, which reflects the overall market situation, and b is the sensitivity coefficient of price to output, which reflects the sensitivity of the market to output without losing generality. $b>0$ is assumed in this paper. The information is known by both the sponsor and the farmers, based on which their own optimal strategies can be made accordingly. For farmers, the expected income is their optimal goal. For the sponsor, it is necessary to consider both increasing production and income at the same time.

The decision-making sequence is that the sponsor first decides the subsidy mode and announces it. Then, the farmers make the decision on the planting quantity under the given subsidy mode, and finally sell the products in the market according to the actual output and get the corresponding sponsor subsidies.

THEORETICAL ANALYSIS AND DISCUSSION

In the process of analysis and solution, the backward analysis is adopted. That is, the possible decisions of farmers under a given subsidy mode is considered first, and then the optimal subsidy mode of the sponsor is solved.

The optimal decision of farmers without subsidies.

To better compare and discuss the two different ways of coupled subsidies, firstly, consider how farmers will make decisions without subsidies. Their optimal planting strategies and optimal expected returns are shown in Theorem 1.

Theorem 1. When the sponsor does not provide subsidies, the farmers' optimal planting strategy is $y_{No}^*=\dfrac{a(\alpha r_H+\bar{\alpha} r_L)-c}{2b(\alpha r_H^2+\bar{\alpha} r_L^2)}$, and the optimal expected income is $\mathrm{E}[\pi_{No}]^*=\dfrac{(a(\alpha r_H+\bar{\alpha} r_L)-c)^2}{4b(\alpha r_H^2+\bar{\alpha} r_L^2)}$.

Proof: the income of farmers is $\pi_P=p\cdot q-c\cdot y$, that is, the sales income minus the planting cost. According to the probability and output of high and low output, the expected income is

$$\mathrm{E}[\pi_{No}]=-b(\alpha r_H^2+\bar{\alpha} r_L^2)y^2+(a(\alpha r_H+\bar{\alpha} r_L)-c)y.$$

Because the expected return is a quadratic function of the decision variable y, the optimal solution can be obtained by FOC. Make the first derivative zero.

$$\frac{d\mathrm{E}[\pi_{No}]}{dy}=-2b(\alpha r_H^2+\bar{\alpha} r_L^2)y+a(\alpha r_H+\bar{\alpha} r_L)-c=0.$$

The optimal planting quantity and the corresponding optimal expected income can be obtained as follows.

$$y_{No}^*=\frac{a(\alpha r_H+\bar{\alpha} r_L)-c}{2b(\alpha r_H^2+\bar{\alpha} r_L^2)};$$

$$\begin{aligned}&\mathrm{E}[\pi_{No}]^*\\&=-b(\alpha r_H^2+\bar{\alpha} r_L^2)\cdot\frac{(a(\alpha r_H+\bar{\alpha} r_L)-c)^2}{4b^2(\alpha r_H^2+\bar{\alpha} r_L^2)^2}\\&+(a(\alpha r_H+\bar{\alpha} r_L)-c)\frac{a(\alpha r_H+\bar{\alpha} r_L)-c}{2b(\alpha r_H^2+\bar{\alpha} r_L^2)}\\&=-\frac{(a(\alpha r_H+\bar{\alpha} r_L)-c)^2}{4b(\alpha r_H^2+\bar{\alpha} r_L^2)}+\frac{(a(\alpha r_H+\bar{\alpha} r_L)-c)^2}{2b(\alpha r_H^2+\bar{\alpha} r_L^2)}\end{aligned}$$

$$=\frac{(a(\alpha r_H+\bar{\alpha} r_L)-c)^2}{4b(\alpha r_H^2+\bar{\alpha} r_L^2)}.$$

The proof is completed.

It can be seen that farmers' decisions are mainly determined by the overall market situation a, the sensitivity of the market to output b, the unit cost c and the output uncertainty. When the overall market demand is greater and the possibility of optimum output is higher, farmers tend to increase the planting area. While when the market is more sensitive to output and the unit cost keeps rising, farmers tend to reduce planting.

The farmers' optimal decision and subsidy effect when the unit subsidy is the same

Firstly, considering the given subsidy policy, the choice and decision of farmers is shown in the following theorem.

Theorem 2. (1) When the unit planting subsidy provided by the sponsor is s_P, the optimal decision of farmers is

$$y_P^*(s_P)=\frac{a(\alpha r_H+\bar{\alpha} r_L)-c+s_P}{2b(\alpha r_H^2+\bar{\alpha} r_L^2)},$$ and the optimal expected return is

$$\mathrm{E}[\pi_P]^*(s_P)=\frac{(a(\alpha r_H+\bar{\alpha} r_L)-c+s_P)^2}{4b(\alpha r_H^2+\bar{\alpha} r_L^2)};$$

(2) When the subsidy per unit output provided by the sponsor is s_H, the optimal decision of farmers is

$$y_H^*(s_H)=\frac{(a+s_H)(\alpha r_H+\bar{\alpha} r_L)-c}{2b(\alpha r_H^2+\bar{\alpha} r_L^2)},$$ and the optimal expected return is

$$\mathrm{E}[\pi_H]^*(s_H)=\frac{((a+s_H)(\alpha r_H+\bar{\alpha} r_L)-c)^2}{4b(\alpha r_H^2+\bar{\alpha} r_L^2)}.$$

Proof: (1) Under the planting-coupled subsidy, farmers' income is $\pi_P=p\cdot q-c\cdot y+s_P\cdot y$, and their expected income is

$$\mathrm{E}[\pi_P]=-b(\alpha r_H^2+\bar{\alpha} r_L^2)y^2+(a(\alpha r_H+\bar{\alpha} r_L)-c+s_P)y.$$

It can be obtained after making the first derivative equal to zero

$$\frac{\partial \mathrm{E}[\pi_P]}{\partial y}=-2b(\alpha r_H^2+\bar{\alpha} r_L^2)y+a(\alpha r_H+\bar{\alpha} r_L)-c+s_P=0.$$

Therefore, the optimal planting strategy and the optimal expected income are

$$y_P^*(s_P)=\frac{a(\alpha r_H+\bar{\alpha} r_L)-c+s_P}{2b(\alpha r_H^2+\bar{\alpha} r_L^2)}$$ and

$$\mathrm{E}[\pi_P]^*(s_P)=\frac{(a(\alpha r_H+\bar{\alpha} r_L)-c+s_P)^2}{4b(\alpha r_H^2+\bar{\alpha} r_L^2)},$$ respectively.

(2) Under the output-coupled subsidy, the farmers' income is $\pi_H=p\cdot q-c\cdot y+s_H\cdot q$, and their expected income is

$$\mathrm{E}[\pi_H]=-b(\alpha r_H^2+\bar{\alpha} r_L^2)y^2+((a+s_H)(\alpha r_H+\bar{\alpha} r_L)-c)y.$$

After making first derivative equal to zero, it can be obtained that

$$\frac{\partial \mathrm{E}[\pi_H]}{\partial y}=-2b(\alpha r_H^2+\bar{\alpha} r_L^2)y+(a+s_H)(\alpha r_H+\bar{\alpha} r_L)-c=0.$$

Therefore, the farmers' optimal strategy and optimal expected return are

$$y_H^*(s_H)=\frac{(a+s_H)(\alpha r_H+\bar{\alpha} r_L)-c}{2b(\alpha r_H^2+\bar{\alpha} r_L^2)}$$ and

$$\mathrm{E}[\pi_H]^*(s_H)=\frac{((a+s_H)(\alpha r_H+\bar{\alpha} r_L)-c)^2}{4b(\alpha r_H^2+\bar{\alpha} r_L^2)}$$

respectively.

The proof is completed.

It can be observed that the overall situation of the market, the sensitivity of the market to output, the uncertainty of unit cost and output have the same influence on farmers' decision-making as when there is no subsidy, and the influence of unit subsidy is mainly determined by the output uncertainty. Theorem 3 compares the decision-making of farmers under the two coupled subsidy policies.

Theorem 3. When $\alpha r_H+\bar{\alpha} r_L>1$, the effect of unit output subsidy is better than that of unit planting subsidy.

Proof: By

$$y_P^*(s_P{=}s)-y_H^*(s_H=s)$$
$$=\frac{a(\alpha r_H+\bar{\alpha} r_L)-c+s_P}{2b(\alpha r_H^2+\bar{\alpha} r_L^2)}-\frac{(a+s_H)(\alpha r_H+\bar{\alpha} r_L)-c}{2b(\alpha r_H^2+\bar{\alpha} r_L^2)}$$
$$=\frac{1-(\alpha r_H+\bar{\alpha} r_L)}{2b(\alpha r_H^2+\bar{\alpha} r_L^2)}s$$,it can be seen that when $\alpha r_H+\bar{\alpha} r_L>1$, $y_P^*(s_P=s)-y_H^*(s_H=s)<0$. The proof is completed.

It can be seen that $(\alpha r_H+\bar{\alpha} r_L)$ represents the expected output, and the comparison between it and 1 is in fact the comparison between P1 and the planting quantity. When the unit subsidy is the same, the higher the expected output is, the more total subsidies the farmers will receive, which will encourage the farmers to increase the planting area. However, when the expected output is low, the total subsidy amount obtained under the planting subsidy mode will be relatively large, so the incentive effect under the coupled subsidy mode is better. It is worth noting that no matter what kind of subsidy is adopted, the incentive effect on output and income is the same.

The farmers' optimal decision and subsidy effect when the total amount of subsidies is the same

However, when the budget of the total subsidy is limited, the two subsidy methods cannot always keep the same unit subsidy, and the optimal subsidy strategy and subsidy effect will change accordingly.

Theorem 4. When the total subsidy is $\bar{S}$, the optimal decisions of different subsidy modes, the optimal decisions of farmers and the optimal expected returns are shown in the following table.

Table 1
Optimal decision when the total subsidy is $\bar{S}$

	Planting-coupled subsidies	Output-coupled subsidy
Optimal unit subsidy	$\frac{\sqrt{\Delta_P}-a(\alpha r_H+\bar{\alpha}r_L)+c}{2}$	$\frac{\sqrt{\Delta_H}-r_H(a(\alpha r_H+\bar{\alpha}r_L)-c)}{2r_H(\alpha r_H+\bar{\alpha}r_L)}$
Optimal planting quantity	$\frac{1}{2}y_{No}^*+\frac{\sqrt{\Delta_P}}{4b(\alpha r_H^2+\bar{\alpha}r_L^2)}$	$\frac{1}{2}y_{No}^*+\frac{\sqrt{\Delta_H}}{4br_H(\alpha r_H^2+\bar{\alpha}r_L^2)}$
Optimal expected return	$\frac{1}{2}\mathrm{E}[\pi_{No}]^*+\frac{1}{2}\bar{S}+\frac{(a(\alpha r_H+\bar{\alpha}r_L)-c)\sqrt{\Delta_P}}{8b(\alpha r_H^2+\bar{\alpha}r_L^2)}$	$\frac{1}{2}\mathrm{E}[\pi_{No}]^*+\frac{1}{2r_H}\bar{S}+\frac{(a(\alpha r_H+\bar{\alpha}r_L)-c)\sqrt{\Delta_H}}{8br_H(\alpha r_H^2+\bar{\alpha}r_L^2)}$

where, $\Delta_P=(a(\alpha r_H+\bar{\alpha}r_L)-c)^2+8b\bar{S}(\alpha r_H^2+\bar{\alpha}r_L^2)$, $\Delta_H=r_H^2(a(\alpha r_H+\bar{\alpha}r_L)-c)^2+8br_H\bar{S}(\alpha r_H^2+\bar{\alpha}r_L^2)$.

Proof: (1) Planting-coupled subsidy.

When the subsidy per unit is s_P, according to the optimal decision $y_P^*(s_P)$ of farmers, the total subsidy required is

$$S(s_P)=s_P\cdot y_P^*(s_P)=\frac{s_P^2+(a(\alpha r_H+\bar{\alpha}r_L)-c)s_P}{2b(\alpha r_H^2+\bar{\alpha}r_L^2)}.$$

As $y_P^*(s_P)$ and $\mathrm{E}[\pi_P]^*(s_P)$ both increase with s_P, and $S(s_P)$ monotonously increases with s_P at $[0,+\infty)$, the optimal solution will be obtained at the endpoint. Make $S(s_P)=\bar{S}$ solution available $s_P^*=\frac{\sqrt{\Delta_P}-a(\alpha r_H+\bar{\alpha}r_L)+c}{2}$, where $\Delta_P=(a(\alpha r_H+\bar{\alpha}r_L)-c)^2+8b\bar{S}(\alpha r_H^2+\bar{\alpha}r_L^2)$.

At this point, the farmers' optimal decision-making and optimal expected return are

$$y_P^*(s_P^*)=\frac{a(\alpha r_H+\bar{\alpha}r_L)-c+s_P^*}{2b(\alpha r_H^2+\bar{\alpha}r_L^2)}$$
$$=\frac{1}{2}y_{No}^*+\frac{\sqrt{\Delta_P}}{4b(\alpha r_H^2+\bar{\alpha}r_L^2)}$$

and

$$\mathrm{E}[\pi_P]^*(s_P^*)=\frac{(a(\alpha r_H+\bar{\alpha}r_L)-c+s_P^*)^2}{4b(\alpha r_H^2+\bar{\alpha}r_L^2)}$$
$$=\frac{1}{2}\mathrm{E}[\pi_{No}]^*+\frac{1}{2}\bar{S}+\frac{(a(\alpha r_H+\bar{\alpha}r_L)-c)\sqrt{\Delta_P}}{8b(\alpha r_H^2+\bar{\alpha}r_L^2)}$$

respectively.

(2) Output-coupled subsidies.

When the subsidy per unit output is s_H, the total subsidy required is $S(s_H)=s_H\cdot q$. Due to the limitation of the total subsidy, if the unit subsidy is solved according to the expected output, when $q=q_H$, the total subsidy will exceed the budget and cannot be completed. Therefore, the subsidy per unit output needs to meet $s_H\cdot q_H\le\bar{S}$.

According to Theorem 2, $y_H^*(s_H)$ and $\mathrm{E}[\pi_H]^*(s_H)$ both increase with s_H, and $S(s_H)$ monotonically increases with s_H at $[0,+\infty)$, so the optimal solution will be obtained at the endpoint. Therefore, $s_H \cdot r_H y_H^*(s_H) = \bar{S}$ is available.

Then we have

$$s_H^* = \frac{\sqrt{\Delta_H} - r_H(a(\alpha r_H + \bar{\alpha} r_L) - c)}{2r_H(\alpha r_H + \bar{\alpha} r_L)}, \text{where}$$

$$\Delta_H = r_H^2(a(\alpha r_H + \bar{\alpha} r_L) - c)^2 + 8br_H\bar{S}(\alpha r_H^2 + \bar{\alpha} r_L^2)$$

At this point, the farmers' optimal decision-making and optimal expected return are respectively

$$y_H^*(s_H^*) = \frac{(a + s_H^*)(\alpha r_H + \bar{\alpha} r_L) - c}{2b(\alpha r_H^2 + \bar{\alpha} r_L^2)}$$

$$= \frac{1}{2} y_{No}^* + \frac{\sqrt{\Delta_H}}{4br_H(\alpha r_H^2 + \bar{\alpha} r_L^2)}$$

and

$$\mathrm{E}[\pi_H]^*(s_H^*) = \frac{((a + s_H^*)(\alpha r_H + \bar{\alpha} r_L) - c)^2}{4b(\alpha r_H^2 + \bar{\alpha} r_L^2)}$$

$$= \frac{1}{2}\mathrm{E}[\pi_{No}]^* + \frac{\bar{S}}{2r_H} + \frac{(a(\alpha r_H + \bar{\alpha} r_L) - c)\sqrt{\Delta_H}}{8br_H(\alpha r_H^2 + \bar{\alpha} r_L^2)}.$$

Proof is completed.

According to the above analysis, besides the related factors mentioned in the previous analysis, the optimal unit subsidy is mainly affected by the unit output at high output. It can be seen that the optimal unit subsidy, the optimal planting quantity and the optimal expected income of farmers all increase with the increase of the total subsidy. However, the incentive effects of the two subsidy strategies on increasing production and income need further discussion.

For the optimal unit subsidy under each subsidy strategy, there is no absolute size relationship between them due to the interaction of various factors. That is to say, the optimal unit subsidy under the planting-coupled subsidy may be higher or lower than the optimal unit subsidy under the output-coupled subsidy.

Theorem 5. When $r_H \geq 1$, $y_P^*(s_P^*) \geq y_H^*(s_H^*)$, and $\mathrm{E}[\pi_P]^*(s_P^*) \geq \mathrm{E}[\pi_H]^*(s_H^*)$; when $r_H < 1$, $y_P^*(s_P^*) < y_H^*(s_H^*)$, and $\mathrm{E}[\pi_P]^*(s_P^*) < \mathrm{E}[\pi_H]^*(s_H^*)$.

Proof: for farmers, the results of comparison of optimal planting quantity comparing under the two strategies can be obtained as

$$y_P^*(s_P^*) - y_H^*(s_H^*) = \frac{r_H\sqrt{\Delta_P} - \sqrt{\Delta_H}}{4br_H(\alpha r_H^2 + \bar{\alpha} r_L^2)}.$$

Since when $r_H \geq 1$, we have $r_H\sqrt{\Delta_P} - \sqrt{\Delta_H} > 0$ and then $y_P^*(s_P^*) - y_H^*(s_H^*) > 0$ at this time. Comparing the optimal expected returns, there is

$$\mathrm{E}[\pi_P]^*(s_P^*) - \mathrm{E}[\pi_H]^*(s_H^*)$$

$$= \frac{(r_H - 1)\bar{S}}{2r_H} + \frac{(a(\alpha r_H + \bar{\alpha} r_L) - c)(r_H\sqrt{\Delta_P} - \sqrt{\Delta_H})}{8br_H(\alpha r_H^2 + \bar{\alpha} r_L^2)}.$$

Therefore, when $r_H \geq 1$, there must be $\mathrm{E}[\pi_P]^*(s_P^*) - \mathrm{E}[\pi_H]^*(s_H^*) > 0$.

Proof is completed.

It can be seen that the incentive effect on increasing production and income of farmers is synchronous when the coupled subsidy is adopted. But when the budget is fixed, the better method depends on the state of optimum output. When the optimum output is relatively high, the planting-coupled subsidy is more effective in stimulating the increase of production and income. However, when the optimum output is relatively low, the farmers are vulnerable to the incentive of the output-coupled subsidy. It should be pointed out that although the expected output will be relatively high when the optimum output is high, the incentive effect of subsidy mode does not depend on it.

NUMERICAL ANALYSIS

This part will be further discussed by means of numerical experiments. According to Theorem 2, no matter what kind of coupled subsidy, it will be beneficial to increase income and income. That is, compared with the case without subsidies, farmers are motivated to increase the planting quantity, and at the same time get more income. However, the incentive effect between the two subsidy methods needs to be revealed more clearly. Therefore, we will mainly discuss the influence of different subsidy methods under different environmental parameters.

Without loss of generality, values are assigned to each parameter as follows: $a = 20$, $b = 3$, $c = 0.5$, $\alpha = 0.6$, $r_L = 0.5$, $r_H = \{0.8, 1.0, 1.5, 2.0\}$.

Figure 1
Comparison of The Effects of Different Subsidy Methods on Increasing Production When The Unit Subsidy is The Same

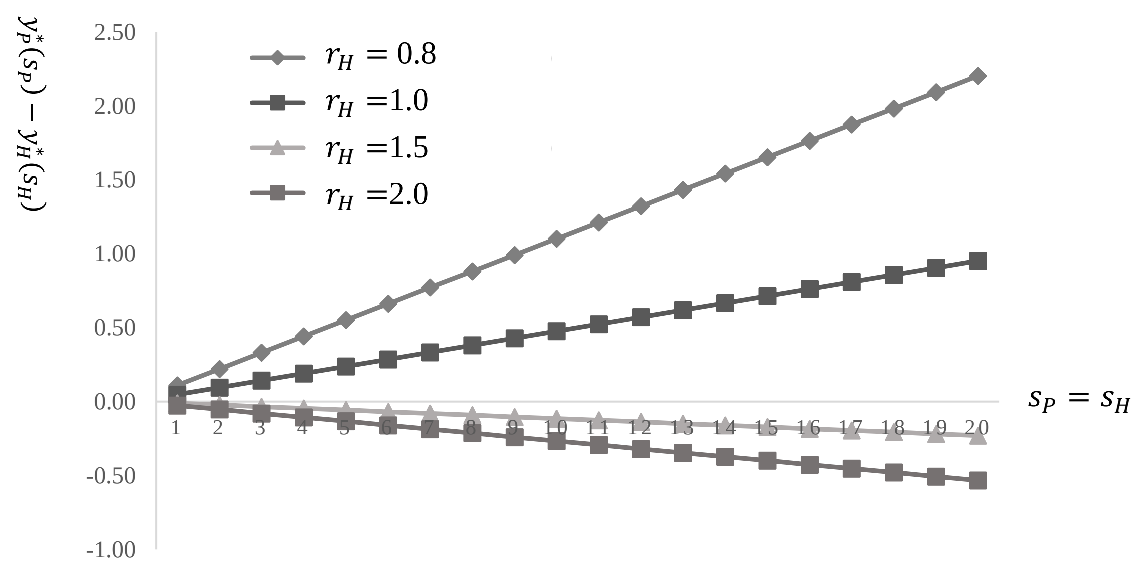
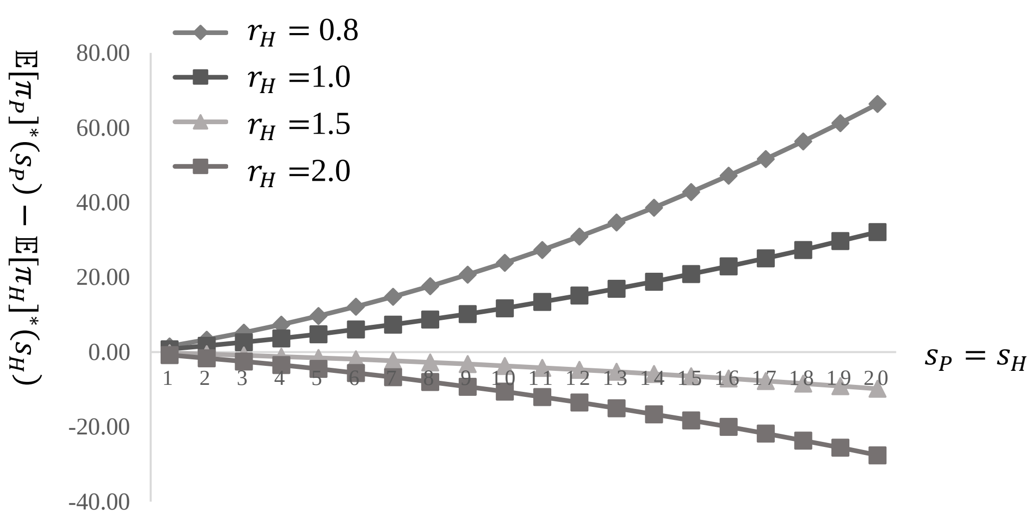


Figure 2
Comparison of The Effects of Different Subsidy Methods on Income Increase When The Unit Subsidy is The Same



First of all, if the same amount of unit subsidy is provided, when it increases from 1 to 20, the effects of different subsidy methods on output increase and income increase are shown in Figures 1 and 2, respectively. The former shows the difference of the optimal planting quantity under the planting-coupled subsidy method and the output-coupled subsidy method, while the latter shows the difference of the optimal expected income under the two subsidy methods. It can be seen that the incentive effect of coupled subsidies on increasing production and income is the same. When

$r_H = \{0.8, 1.0\}$, the planting-coupled subsidies are superior to the output-coupled subsidies. With the increase of unit subsidies, the advantages are obvious. At this time, $\alpha r_H + \bar{\alpha} r_L \in \{0.68, 0.8\}$ is less than 1, which is consistent with the previous theoretical deduction.

Then, when the total subsidy is given, the incentive effects of different subsidy methods are shown below. Figures 3 and 4 show the difference of planting quantity and expected income between the two subsidy methods under the planting-coupled subsidy method and the output-coupled subsidy method when the total subsidy $\bar{S}$ increases from 10 to 110. It can be observed that, different from the given unit subsidy amount, the planting-coupled subsidy mode is inferior to the output-coupled subsidy mode at $r_H = 0.8$, and there is no difference between the two modes at $r_H = 1.0$ .When $r_H = \{1.5, 2.0\}$, the planting-coupled subsidy is better than the output-coupled subsidy. However, the incentive effects of the two subsidy methods on increasing production and income are still the same. That is, if the optimal planting quantity under this subsidy method is better than that of the other subsidy method, its optimal expected income will certainly be better than that of the other subsidy method, and its advantages will increase obviously with the increase of the total subsidy amount. This is also consistent with the previous theoretical analysis results. When the total amount of subsidies is fixed, the advantages and disadvantages of subsidies are determined by the high output.

Figure 3
Comparison of The Effects of Different Subsidy Methods on Increasing Production When The Total Amount of Subsidies is The Same

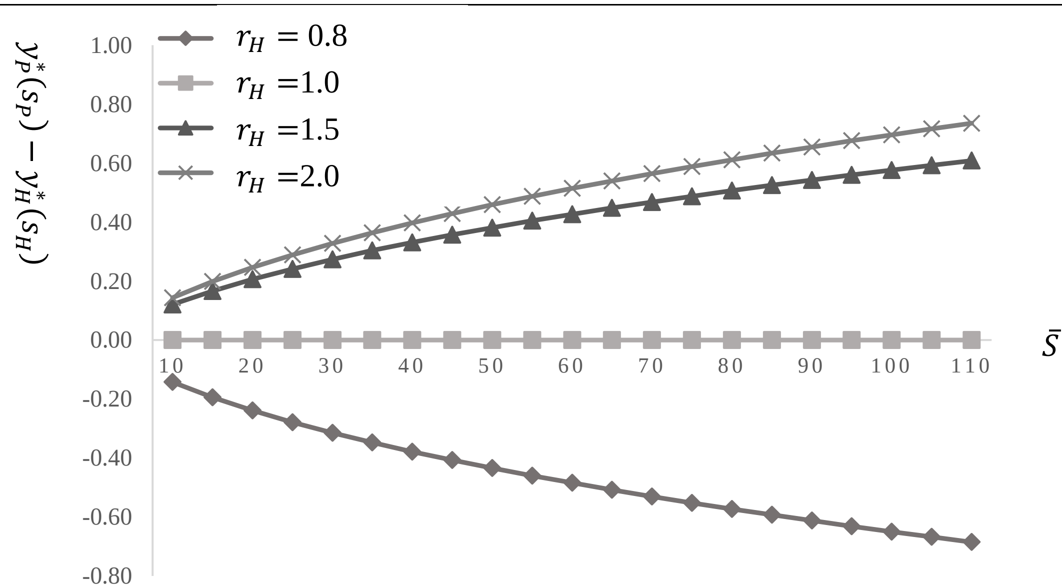
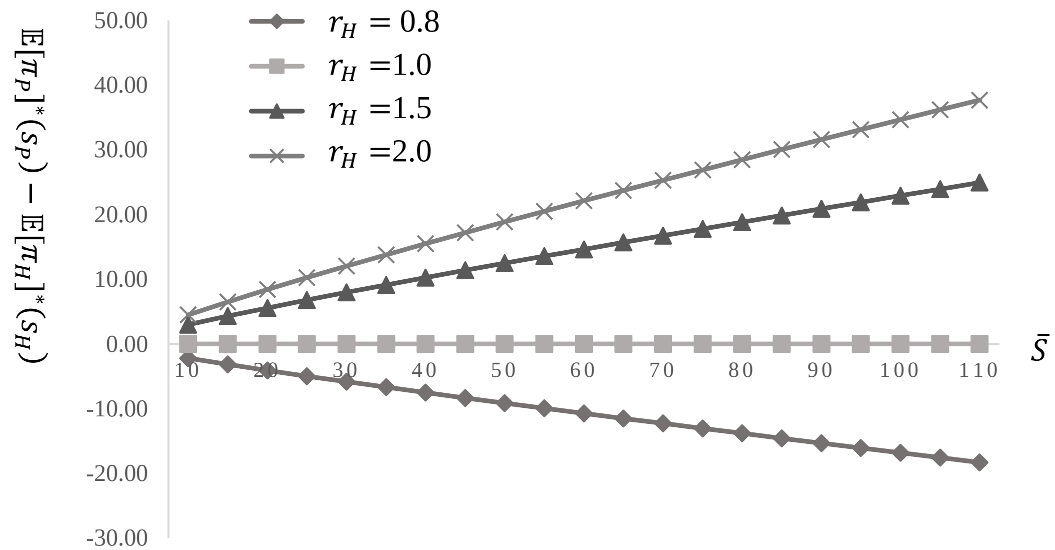


Figure 4
Comparison of The Effects of Different Subsidy Methods on Income Increase When The Total Amount of Subsidies is The Same



CONCLUSION

This paper studies the commonly used coupled subsidies in agricultural subsidies, which can also be applied in the development of tobacco agriculture. Considering the output uncertainty, it is deeply analyzed that the planting subsidies coupled to planting quantity and the output subsidies coupled to output. It is found that the incentive effects of the two coupled subsidies on increasing production and income are consistent. The results show that coupled subsidies can be used as a way to achieve the goal of increasing production and income.

Further research shows that in the specific implementation plan, if equal unit subsidies are maintained, the advantages and disadvantages of the two subsidies will be determined by the expected output. When the expected output is high, the incentive effect of the output-coupled subsidy will be less due to planting-coupled subsidies, while when the expected output is low, the incentive effect of the planting-coupled subsidy will be more obvious. At the same time, whether the output-coupled subsidy or planting-coupled subsidy is better, its advantages will increase with the increase of the unit subsidy amount. If the subsidy scheme is implemented by limiting the total amount of subsidies, the unit output at the time of optimum output will determine which subsidy method has better incentive effect. When the unit output is high, the planting-coupled subsidy will be superior to the output-coupled subsidy. When it is low, the opposite is true. The main reason is that when the total amount is limited, it is still necessary to consider the subsidy restriction for meeting the optimum output, so the unit subsidy of the output-coupled subsidy in this situation is reduced to a certain extent. But the advantage of the subsidy with better incentive effect still increases with the increase of the total amount of subsidies.

The research complements and perfects the current explanation of the intrinsic incentive mechanism of the coupled subsidy mode, and also provides a theoretical basis for improving the formulation of tobacco agricultural subsidy policies and tools. At the same time, there are some limitations. In future research, we will consider increasing the output uncertainty, take into account of the uncertainty of demand, or make further expansion and research according to different characteristics of agricultural products.

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Conflicts of Interest Disclosure Statement

The authors declare no conflict of interest in the authorship or publication of this work.

Author Declaration

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