

# Research on the Influence Mechanism of China's Cold Chain Logistics Subsidy Policy

-- Based on Stackelberg Game

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**Abstract:** China's cold chain logistics subsidy policies includes multiple related subjects in its introduction and implementation. First of all, the government is the implementer and maker of the subsidy policy; cold chain logistics equipment production and R&D enterprises, cold chain logistics infrastructure construction enterprises and cold chain logistics carriers are the main beneficiaries of the cold chain logistics subsidy policy. On the issue of policies promoting the development of the cold chain logistics industry, there is a certain game relationship between the government and the three parties. Therefore, this paper uses the Stackelberg game to establish three government-enterprise two-party game models to study the impact mechanism of cold chain logistics subsidy policies.

**Keywords:** China's cold chain logistics subsidy policies, Stackelberg game, Influence Mechanism.

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## 1. Introduction

China's cold chain logistics subsidy policy includes multiple related subjects in its introduction and implementation. First of all, the government is the implementer and maker of the subsidy policy; cold chain logistics equipment production and R&D enterprises, cold chain logistics infrastructure construction enterprises and cold chain logistics carriers are the main beneficiaries of the cold chain logistics subsidy policy. On the issue of policies promoting the development of the cold chain logistics industry, there is a certain game relationship between the government and the three parties. The purpose of the government and the other three parties is different: for the government, its purpose is to promote the development of the cold chain logistics industry through the introduction of subsidy policies, so as to achieve the purpose of maximizing the overall social benefits, while the purpose of the other three parties is to maximize their own economic benefits. The tripartite stakeholders are directly related to the development and construction of the cold chain logistics industry. Compared with the government, they have more information about promoting the development of the cold chain logistics industry. At the same time, because the main bodies of the three stakeholders are not the same, there are also differences in their influence mechanisms to promote the development of the cold chain logistics industry to a certain extent. Due to the differences in the goals of the government and the three stakeholders, the asymmetry of the information they have, and the differences in their respective driving and influencing mechanisms, the government should consider all factors when distributing policy subsidies to the three stakeholders, and at the same time determine A subsidy allocation plan that maximizes the interests of all parties can enable all parties to actively jointly promote the development of the cold chain logistics industry.

## 2. Literature Review

Under the insurance subsidy mechanism of agricultural

insurance provided by the government, Yu Xing et al. constructed a three-stage Stackelberg game model among agricultural enterprises, retailers and the government, and obtained the optimal production scale of agricultural enterprises, the optimal purchase price of retailers, and the optimal subsidy of the government. The explicit expression of the rate, analyzing the impact of parameters on the interests of the three parties [1]; Wen Hui et al. established a three-stage Stackelberg game model among the government, retailers and farmers under the background that retailers have cooperative preference behavior. Comparative analysis The impact of different government subsidy policies and retailers' cooperative preference behavior on the government's optimal subsidy rate, retailer's optimal purchase price, farmers' optimal production input and tripartite interests[2]; Nie Tengfei et al. Under the background of stochastic and demand, and based on the government's tax subsidy policy for retailers, the optimization decision-making problem of the supply chain is studied in the case of only one producer and one retailer, and the Stackelberg between the producer and the retailer is established. The game proved that the government subsidy policy can increase the overall profit of the supply chain[3]; Liu Lei et al. used the Buyer-Stackelberg model, the Seller-Stackelberg model in the non-cooperative game and the related cooperative game model to compare and study the relationship between supermarkets and supermarkets in the agricultural-supermarket docking mode. The cooperative game mode can improve the quality and safety level of fresh agricultural products, reduce the retail price of agricultural products, and expand the market demand of fresh agricultural products. Conclusion [4]; Zhang Xumei et al. aimed at how to choose the appropriate subject to subsidize the fresh food supply chain, by establishing the Stackelberg game model of four situations: no government subsidies, subsidized suppliers, subsidized sellers, and subsidized consumers. Considering the impact of public welfare in an environment of uncertain demand, three conclusions have been drawn that the cooperative game model can improve the quality and safety of agricultural products, reduce the retail price of agricultural products, and expand the market demand for agricultural

products [4].

At present, there are many game studies considering the impact of government subsidy policies, and the research on the establishment of game models between the government and enterprises is relatively mature. Therefore, this study uses the Stackelberg game to establish a model to study the interaction mechanism between the government and enterprises under China's cold chain logistics policies.

### 3. Model Description

China's cold chain logistics subsidy policy includes multiple related subjects in its introduction and implementation. First of all, the government is the implementer and maker of the subsidy policy; cold chain logistics equipment production and R&D enterprises, cold chain logistics infrastructure construction enterprises and cold chain logistics carriers are the main beneficiaries of the cold chain logistics subsidy policy. On the issue of policies promoting the development of the cold chain logistics industry, there is a certain game relationship between the government and the three parties. The purpose of the government and the other three parties is different: for the government, its purpose is to promote the development of the cold chain logistics industry through the introduction of subsidy policies, so as to achieve the purpose of maximizing the overall social benefits, while the purpose of the other three parties is to maximize their own economic benefits. The tripartite stakeholders are directly related to the development and construction of the cold chain logistics industry. Compared with the government, they have more information about promoting the development of the cold chain logistics industry. At the same time, because the main bodies of the three stakeholders are not the same, there are also differences in their influence mechanisms to promote the development of the cold chain logistics industry to a certain extent. Due to the differences in the goals of the government and the three stakeholders, the asymmetry of the information they have, and the differences in their respective driving and influencing mechanisms, the government should consider all factors when distributing policy subsidies to the three stakeholders, and at the same time determine A subsidy allocation plan that maximizes the interests of all parties can enable all parties to actively jointly promote the development of the cold chain logistics industry.

According to the actual situation, the government is mainly concerned about the development of cold chain logistics technology, the construction of cold chain logistics infrastructure, the preservation rate of cold chain goods, and the coverage of cold chain logistics in the transportation industry. comprehensive utility. At the same time, refer to the "2023-2027 China Cold Chain Logistics Industry Investment Analysis and Prospect Forecast Report", "China Cold Chain Logistics Development Report (2017-2022)", "Zhejiang Provincial People's Government General Office on Supporting the High-quality Development of Cold Chain Logistics Several Opinions", "Implementation Opinions of Quanzhou Municipal People's Government Office on Promoting the Accelerated Development of Cold Chain Logistics" and other industry reports and cold chain logistics subsidy policy texts. The game model between infrastructure construction enterprises and government subsidized cold chain logistics carriers. There is a Stackelberg game between the government and the three stakeholders, and the decision-

making sequence of the three game models is the same: first, the government is the leader in the model, and it promotes cold chain logistics based on maximizing the overall welfare of the society. The purpose of industry development, so as to determine the allocation plan of the policy subsidy amount; secondly, the three stakeholders are followers in the model, based on the purpose of maximizing their own benefits, make decisions on their own efforts; finally, give the government The influence mechanism of the distribution coefficient of the policy subsidy amount among the tripartite stakeholders is analyzed and studied.

### 4. Government Subsidizes Cold Chain Equipment Production and R & D Enterprises

In the case where the government subsidizes cold chain equipment production and R&D enterprises, the relationship between the government and cold chain equipment production and R&D enterprises satisfies the assumptions and elements of analysis using game theory. The purpose of government subsidies is to maximize the overall welfare of the society and promote the development of the cold chain logistics industry. For cold chain equipment production and R & D enterprises, the goal is to maximize their own benefits. First of all, the government has introduced subsidy policies to support the development of cold chain equipment R&D enterprises and related necessary resources; secondly, cold chain equipment R&D enterprises have accelerated the R&D and upgrading of cold chain equipment by using government subsidies. The production speed of equipment, gaining the benefits of R&D and production, making up for the company's own losses, and reducing the relative competition risks of the industry. As the leader of subsidy behavior, the government first makes relevant decisions, and cold chain equipment production and R&D enterprises then determine their own investment and effort level based on the strength of government subsidy policies and related costs. The meanings of the symbols are as follows:

Assumption 1: In a purely competitive market, the price of cold chain equipment is  $E_S$ , the tax rate paid by cold chain equipment production and development enterprises to the government is  $t_S$ , the post tax income of cold chain equipment production and development enterprises is  $I_S$ , and the production of cold chain equipment is  $O$ . After-tax income of cold chain equipment production and research and development enterprises:

$$I_S = (1 - t_S) E_S O \quad (1)$$

Assumption 2: The production cost of cold chain equipment is  $P_S$ , the unit production cost of cold chain equipment is  $P_O$ , and the production capacity of cold chain equipment is  $O$ . The cost of producing cold chain equipment is:

$$P_S = OP_O \quad (2)$$

symbol	meaning
$O$	Cold chain equipment production
$I_j$	After-tax income of cold chain equipment production and research and development enterprises
$E_s$	Price of cold chain equipment
$t_s$	Tax rates paid by cold chain equipment production and research and development enterprises to the government
$P_o$	Unit production cold chain equipment cost
$P_s$	Cost of production cold chain equipment
$P_{s_i}$	Innovation and R&D Costs of Cold Chain Equipment Production and R&D Enterprises
$\gamma$	Technical maturity of cold chain equipment
$T_s$	Tax amount for cold chain equipment production and research and development enterprises
$H(\alpha_s)$	The subsidy amount provided by the government to cold chain equipment production and research and development enterprises
$\alpha_s(0 < \alpha_s < 1)$	The subsidy rate for government subsidies to cold chain equipment production and research and development enterprises

Assumption 3: Assumption 3: The innovation and research and development costs of cold chain equipment production and development enterprises is  $P_{s_i}$ . It is related to the production of cold chain equipment and the technological maturity of cold chain equipment.  $\gamma$  represents the technological maturity of cold chain equipment. The innovation and research and development costs of cold chain equipment production and development enterprises are[6]:

$$P_{s_i} = \gamma O^2 \quad (3)$$

Assumption 4: The tax amount of the cold chain equipment production and development enterprise is  $T_s$ ,  $t_s$  is the tax rate. The tax amount received by the government for cold chain equipment production and research and development enterprises:

$$T_s = O t_s E_s \quad (4)$$

Assumption 5: The subsidy amount provided by the government to cold chain equipment production and research and development enterprises is  $H(\alpha_s)$ , and the subsidy rate is  $\alpha_s(0 < \alpha_s < 1)$ . Subsidy amount:

$$H(\alpha_s) = \alpha_s \gamma O^2 \quad (5)$$

In the utility of cold chain equipment production and research and development enterprises, it includes the after-tax income of cold chain equipment production and research and development enterprises, the cost of producing cold chain equipment, the innovation and research and development costs of cold chain equipment production and research and

development enterprises, and the subsidy amount provided by the government to cold chain equipment production and research and development enterprises. The utility function of cold chain equipment production and research and development enterprises can be obtained:

$$\begin{aligned} MAX \omega_s &= I_s - P_s - P_{s_i} + H(\alpha_s) \\ &= (1 - t_s) E_s O - P_o - \gamma O^2 + \alpha_s \gamma O^2 \end{aligned} \quad (6)$$

In government utility, including the subsidy amount for cold chain equipment production and research and development enterprises and the tax amount for cold chain equipment production and research and development enterprises, the government utility function can be obtained:

$$\begin{aligned} MAX \omega_g &= T_s - H(\alpha_s) \\ &= O t_s E_s - \alpha_s \gamma O^2 \end{aligned} \quad (7)$$

Game sequence: Firstly, cold chain equipment production and research and development enterprises determine the level of innovation and research and development efforts of cold chain equipment production and research and development enterprises based on the subsidy allocation ratio in government policies, thereby determining the maturity of cold chain technology and related equipment production with the goal of maximizing their own benefits and utility. Finally, the best strategy for the government to subsidize cold chain equipment production and research and development enterprises is determined.

In the case of a game between the government and cold chain equipment production and development enterprises, the equilibrium result is:

$$O^* = (4\gamma_s E_s + 2)[(1 - t_s) E_s - P_o] \quad (8)$$

$$\alpha_s^* = \frac{8\gamma^2 t_s E_s + 4\gamma^2 - 1}{4\gamma^2 (2t_s E_s + 1)} \quad (9)$$

Substitute  $\alpha_s^*$  into equation (4.5) to obtain the optimal subsidy amount given by the government to cold chain equipment production and research and development enterprises:

$$H(\alpha_s)^* = O^2 \left[ \frac{8\gamma^2 t_s E_s + 4\gamma^2 - 1}{4\gamma (2t_s E_s + 1)} \right] \quad (10)$$

Take the partial derivative of  $H(\alpha_s)^*$  about  $O$ ,  $E_s$ ,  $t_s$  and  $\gamma$ :

$$\frac{dH(\alpha_s)^*}{dO} = 2O\gamma \left[ \frac{8\gamma^2 t_s E_s + 4\gamma^2 - 1}{4\gamma^2 (2t_s E_s + 1)} \right] \quad (11)$$

$$\frac{dH(\alpha_s)^*}{dE_s} = \frac{2\gamma^2 t_s}{(4\gamma^2 t_s E_s + 2\gamma^2)^2} \quad (12)$$

$$\frac{dH(\alpha_s)^*}{dt_s} = \frac{2\gamma^2 E_s}{(4\gamma^2 t_s E_s + 2\gamma^2)^2} \quad (13)$$

$$\frac{dH(\alpha_s)^*}{d\gamma} = \frac{O^2(2\gamma - 8\mu_s E_s)}{(4\gamma^2 t_s E_s + 2\gamma^2)^2} \quad (14)$$

According to the game model results, it can be concluded that the policy subsidies provided by the government to cold chain equipment production and research and development enterprises are influenced by the production of cold chain equipment, the price level of cold chain equipment, the tax rate paid by cold chain equipment production and research and development enterprises to the government, and the technological maturity of cold chain equipment. Due to  $\frac{dH(\alpha_s)^*}{dO} > 0$ , the amount of policy subsidies provided by the government to cold chain equipment production and research and development enterprises is positively correlated with the production of cold chain equipment. The higher the production of cold chain equipment, the more subsidies the government provides. Because of  $\frac{dH(\alpha_s)^*}{dE_s} > 0$ , the amount of policy subsidies provided by the government to cold chain equipment production and research and development enterprises is positively correlated with the price level of cold chain equipment. A decrease in the price of cold chain equipment indicates that cold chain technology is gradually maturing. Therefore, the government should reduce relevant policy subsidies when the price of cold chain equipment decreases. Because of  $\frac{dH(\alpha_s)^*}{dt_s} > 0$ , it indicates that the policy subsidy amount provided by the government to cold chain equipment production and research and development enterprises is positively correlated with the tax rate paid by cold chain equipment production and research and development enterprises to the government. Because of  $\frac{dH(\alpha_s)^*}{d\gamma} < 0$ , it indicates a negative correlation between the amount of policy subsidies provided by the government to cold chain equipment production and research and development enterprises and the degree of maturity of cold chain technology. Therefore, as cold chain technology becomes more mature, the subsidies provided by the government should also be reduced.

According to the same method, the impact mechanism of government subsidies on cold chain logistics infrastructure construction enterprises and carriers is obtained: the more infrastructure (capacity) such as cold storage, the more subsidies the government provides; The higher the revenue brought by the basic equipment of the unit cold chain, the higher the subsidy amount provided by the government; The policy subsidy amount provided by the government to cold chain logistics infrastructure construction enterprises is positively correlated with the tax rate paid by cold chain logistics infrastructure construction enterprises to the government; The policy subsidy amount provided by the government to cold chain logistics infrastructure construction enterprises is negatively correlated with the degree of improvement of cold chain infrastructure; The more goods the cold chain logistics carrier carries, the more subsidies the government provides; The higher the unit profit of choosing a cold chain logistics carrier, the higher the subsidy amount provided by the government; The policy subsidy amount

provided by the government to cold chain logistics carriers is positively correlated with the tax rate of cold chain logistics carriers; The policy subsidy amount provided by the government to cold chain logistics carriers is negatively correlated with the preservation rate of cold chain goods.

## 5. Conclusion

This article constructs a Stackelberg game model based on the development of cold chain logistics technology, production and manufacturing of cold chain logistics equipment, infrastructure construction of cold chain logistics, and selection of cold chain logistics carriers with key stakeholders from the government. This study analyzes the impact mechanism of policy subsidies provided by the government to all parties. The model results show that the policy subsidies provided by the government to cold chain equipment production and research and development enterprises are influenced by the production of cold chain equipment, the price level of cold chain equipment, the tax rate paid by cold chain equipment production and research and development enterprises to the government, and the technological maturity of cold chain equipment. The policy subsidies provided by the government to cold chain logistics infrastructure construction enterprises are influenced by the quantity (capacity) of infrastructure such as cold storage, the benefits brought by unit cold chain infrastructure, the tax rate paid by cold chain equipment manufacturers to the government, and the degree of improvement of cold chain infrastructure. The policy subsidies provided by the government to cold chain logistics carriers are influenced by the quantity of cold chain logistics goods, the unit income of cold chain logistics carriers, the tax rate paid by cold chain logistics carriers to the government, and the preservation rate of cold chain goods.

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