

Research on the Evolution Game of The Digital Transformation of Cold Chain Logistics Enterprises Under the Government's Participation

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Abstract: Whether cold chain logistics enterprises choose to carry out digital transformation is a process of evolutionary game. By analyzing the evolution and stability strategy in the process of digital transformation of cold chain logistics enterprises under the participation of the government, and using matlab for simulation, we discuss the influence of each parameter on the decision-making of cold chain logistics enterprises. The results show that the cost of digital transformation of cold chain logistics enterprises will hinder their transformation, and the increase coefficient of enterprise income, the increase of government subsidies and the reduction of tax rate will all promote the implementation of digital transformation of cold chain logistics enterprises. Finally, corresponding countermeasures are put forward to accelerate the digital transformation of cold chain logistics enterprises, so as to lay a solid foundation for the further economic development of the whole country.

Keywords: Cold chain logistics, digital transformation, evolutionary game.

1. Introduction

When the government makes decisions, most of them will take the steady development of the country and long-term social stability as the fundamental goal, and promote the progress of different industries through reasonable allocation of resources and formulating policies in line with the current stage and future development trend, so as to achieve the purpose of social development. Nowadays, cold chain logistics is booming, and the demand of consumer market is increasing, which also urges the government to constantly introduce policies to help its development.

In the past three years, the state has paid close attention to the construction of cold chain logistics infrastructure, cold chain logistics network, technology improvement and other aspects, emphasizing the digital development of the industry, and pointing out the development of the cold chain industry under the new pattern. Government through policy measures of cold chain logistics enterprise digital transformation correct guidance and support, formulate rewards and punishment mechanism to regulate the behavior of the main body, strengthen digital transformation positive propaganda, encourage enterprises positive transformation, to promote cold chain logistics industry to solve existing problems, promote the transformation and upgrading of cold chain logistics industry as a whole. At the same time, when there is conflicts of interest among multiple participants, the government can take timely measures to deal with it, protect the rights and interests of multiple parties, and provide strong support for the digital transformation of cold chain logistics enterprises.

Based on this, this paper will carry out the game analysis between the government and the cold chain logistics enterprises on the digital transformation, build the game matrix, and explore how the cold chain logistics enterprises will make decisions when facing the background of digital economy under the influence of the government.

2. Evolutionary Game Model: Construction and Analysis

2.1. Basic assumptions

When the government participates in the transformation decision of cold chain logistics enterprises, the enterprise chooses between whether to implement digital transformation, with the principle of profit maximization, the decision will be affected by government policies; and the government also maximizes its own interests. Therefore, taking the government and cold chain logistics enterprises as the game objects, and from the perspective of their limited rationality and the pursuit of benefit maximization, the following assumptions are put forward:

Hypothesis 1: Assuming that the probability of cold chain logistics enterprises choosing "implementing digital transformation" is p , the probability of choosing "not implementing digital transformation" is $1-p$; if the government chooses "incentive" is q , the probability of choosing "no incentive" is $1-q$, where p and q are between $[0,1]$.

Hypothesis 2: For the government, the government's tax rate for the profits of cold chain logistics enterprises is assumed as h . When the government chooses the "incentive" strategy, the subsidy value for the digital transformation strategy is set as G ; and the government will obtain corresponding benefits, namely government credibility H . When the government chooses the "no incentive" strategy, it will cause certain interest damage, which is recorded as D . ($D_1 < D_2$)

Hypothesis 3: For cold chain logistics enterprises, when they choose the strategy of "implementing digital transformation", the cost of digital transformation is C_1 , and the income increase coefficient of cold chain logistics enterprises is μ . At this time, the pre-tax profit obtained by the enterprise will be recorded as F . When the cold chain logistics

enterprise chooses the strategy of "not implementing digital transformation", and it operates in the usual way, the income of the cold chain logistics enterprise at this time is R, and the pre-tax profit is E.

2.2. Evolutionary game model construction

According to the basic assumptions, the revenue function under the different strategy selection conditions of the government and the cold chain logistics enterprises is obtained, as shown in Table 1:

Table 1. Payment matrix of the evolution game model of the government and the cold chain logistics enterprises

		Cold chain logistics enterprises	
		Implementing the Digital Transformation (q)	No digital transformation is implemented (1-q)
government	encourage (p)	$hF + H - G$ $(1 + \mu) R + G - C_1 - hF$	$hE + H$ $R - hE$
	Don't motivate (1-p)	$hF - D_1$ $(1 + \mu) R - C_1 - hF$	$hE - D_2$ $R - hE$

2.3. Stability analysis of the model

According to the income payment matrix, the benefits of the implementation of the incentive strategy for the government can be obtained (Eg1), The gain of not implementing the incentive strategy (Eg2) And the average government revenue (\bar{E}_g) respectively:

$$E_{g1} = q(hF + H - G) + (1 - q)(hE + H) \quad (1)$$

$$E_{g2} = q(hF - D_1) + (1 - q)(hE - D_2) \quad (2)$$

$$\bar{E}_g = pE_{g1} + (1 - p)E_{g2} \quad (3)$$

For cold chain logistics enterprises, the benefits of the implementation of digital transformation strategy (Ee1), Procenings from not implementing digital transformation strategy (Ee2) And the average corporate return (\bar{E}_e) respectively:

$$E_{e1} = p[(1 + \mu)R + G - C_1 - hF] + (1 - p)[(1 + \mu)R - C_1 - hF] \quad (4)$$

$$E_{e2} = R - hE \quad (5)$$

$$\bar{E}_e = qE_{e1} + (1 - q)E_{e2} \quad (6)$$

Then the replication dynamic equation of the government and cold chain logistics enterprises is:

$$F(p) = p(E_{g1} - \bar{E}_g) = p(1 - p)[q(D_1 - G - D_2) + H + D_2] \quad (7)$$

$$F(q) = q(E_{e1} - \bar{E}_e) = q(1 - q)(pG + \mu R + hE - C_1 - hF) \quad (8)$$

From the hypothesis, the $D_2 > D_1$, $1 > \mu$, $h > 0$, from $F(x) = F(y) = 0$, it can be concluded that the five equilibrium points in the dynamic process of evolutionary game equilibrium are: O (0,0), M (1,0), N (0,1), P (1,1) and Q (p0, q0). among p0 $\frac{C_1 + hF - \mu R - hE}{G} =$, q0 $\frac{-H - D_2}{D_1 - G - D_2} =$, this moment (p0, q0) Is the equilibrium point of its evolutionary game.

According to the game dynamic relationship and the replication dynamic equations, the asymptotic stability of the evolutionary game is analyzed by using the Jacobian matrix:

$$J = \begin{bmatrix} \frac{dF(p)}{dp} & \frac{dF(p)}{dq} \\ \frac{dF(q)}{dp} & \frac{dF(q)}{dq} \end{bmatrix} = \begin{bmatrix} (1 - 2p)[q(D_1 - G - D_2) + H + D_2] & p(1 - p)(D_1 - G - D_2) \\ qG(1 - q) & (1 - 2q)(pG + \mu R + hE - C_1 - hF) \end{bmatrix} \quad (9)$$

The determinant of the Jacobian matrix is:

$$Det(J) = (1 - 2p)[q(D_1 - G - D_2) + H + D_2](1 - 2q)(pG + \mu R + hE - C_1 - hF) - p(1 - p)(D_1 - G - D_2)qG(1 - q) \quad (10)$$

The trace of the Jacobian matrix is:

$$Tr(J) = (1 - 2p)[q(D_1 - G - D_2) + H + D_2] + (1 - 2q)(pG + \mu R + hE - C_1 - hF) \quad (11)$$

Then each equilibrium point is brought into the Jacobian matrix. If the system locally meets $Det(J) > 0$ and $Tr(J) < 0$, then the point is the stability point of the system and corresponds to the evolutionary stability strategy. Take each equilibrium point into the Jacobian matrix below to obtain the eigenvalues corresponding to each equilibrium point, as shown in Table 2:

Table 2. The determinants and traces of the Jacobian matrix

equantequation	D et (J)	Tr (J)
(0, 0)	$(H + D_2)(\mu R + hE - C_1 - hF)$	$H + D_2 + \mu R + hE - C_1 - hF$
(1, 0)	$-(H + D_2)(G + \mu R + hE - C_1 - hF)$	$-H - D_2 + G + \mu R + hE - C_1 - hF$
(0, 1)	$-(D_1 - G + H)(\mu R + hE - C_1 - hF)$	$D_1 - G + H - (\mu R + hE - C_1 - hF)$
(1, 1)	$(D_1 - G + H)(G + \mu R + hE - C_1 - hF)$	$-(D_1 - G + H) - (G + \mu R + hE - C_1 - hF)$
(p0, q0)	0	0

According to $0 \leq p_0 \leq 1$, $0 \leq q_0 \leq 1$, whereas p0

$$\frac{C_1 + hF - \mu R - hE}{G} =, q_0 \frac{-H - D_2}{D_1 - G - D_2} =, \text{ Can be obtained.}$$

According to the hypothesis, condition D $h \leq \frac{\mu R - C_1 + G}{F - E}; h \geq \frac{\mu R - C_1}{F - E}; H \geq G - D_1; D_1 - G - D_2 \leq 0 \quad 1 <$

D2 And G is positive, so it is true. Therefore, the evolutionary game stabilization strategy of the equilibrium points is discussed in the following cases.

Case 1: When satisfied $h \geq \frac{\mu R - C_1}{F - E}; H \geq G - D_1$, conduct a stability analysis to determine whether it meets $\text{Det}(J) > 0$ and $\text{Tr}(J) < 0$, so as to determine whether the equilibrium point is locally stable state. The results are shown in the following table:

Table 3. Stability analysis of the equilibrium points in case 1

equantequation	D et (J)	Tr (J)	bear fruit
O (0, 0)	-	indeterminacy	saddle point
M (1, 0)	indeterminacy	-	saddle point
N (0, 1)	+	+	Unstable point
P (1, 1)	indeterminacy	indeterminacy	saddle point

As can be seen from Table 3, when the system meets situation 1, the decision adopted by the government is "no incentive", and the system does not have a stability point. Multiple conditions such as the cost of digital transformation will limit the transformation of cold chain logistics enterprises. Therefore, it is inevitable to be affected by the government when considering whether to adopt digital transformation strategies. When the government takes "no incentive" decisions, cold chain logistics enterprises will measure their own comprehensive profits and losses and make decisions with the goal of maximizing benefits.

Table 5. Initial values of each parameter

parameter	R	C ₁	μ	H	G	D ₁	D ₂	h	E	F
assignment	5	4	0.5	2	2	1	2	0.2	6	7

It is assumed that the government incentive intention and the initial intention of digital transformation of cold chain logistics enterprises are the same, and the initial value is: $p=q=0.5$

Case 2: When satisfied $h \leq \frac{\mu R - C_1 + G}{F - E}; H \geq G - D_1$, conduct

stability analysis of the system in Case 2, and the results are shown in the following table:

Table 4. Stability analysis of equilibrium points in Case 2

equantequation	D et (J)	Tr (J)	bear fruit
O (0, 0)	indeterminacy	+	saddle point
M (1, 0)	-	indeterminacy	saddle point
N (0, 1)	indeterminacy	indeterminacy	saddle point
P (1, 1)	+	-	ESS

As can be seen from Table 4, when the system meets situation 2, (1,1) is the stable state of the system, that is, the government adopts the "incentive" strategy, and the cold chain logistics enterprises choose to "implement digital transformation". The digital transformation of the cold chain logistics enterprises needs a large amount of funds. At this time, if the government adopts the "incentive" strategy, under the influence of the government's supportive policies and financial subsidies, the cold chain logistics enterprises will choose to implement the digital transformation, so as to improve their market competitiveness.

3. Simulation Analysis of The Evolutionary Game

In this paper, through the relevant literature, the actual government subsidies, enterprise websites and other case data collection,

Considering the actual situation and with reference to the previous literature, the initial value of the parameter is set as follows:

- (1) The total cost of implementing the digital transformation is C1 Impact on the evolution behavior of the cold chain logistics enterprises and the government

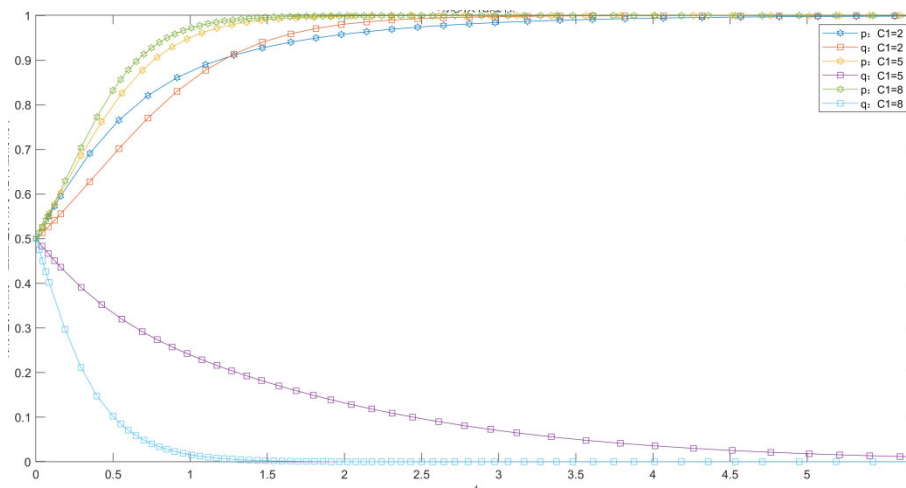


Figure 1. Evolution diagram of the change in the total cost of implementing the digital transformation

As can be seen from the figure, when the transformation cost is 2, the enterprise has a trend evolution towards probability 1; when the value increases, the curve gradually converges to 0 and with the value increasing faster and faster. This shows that when the digital transformation cost of cold chain logistics enterprises is low, enterprises are willing to implement digital transformation; however, when the transformation cost keeps increasing, the high digital transformation cost makes cold chain logistics enterprises more willing to maintain the status quo. For the government, when the transformation cost is 2, the cold chain logistics enterprises themselves are

willing to carry out digital transformation, the government takes incentive measures for a long time; and when the transformation cost gradually increases, in order to encourage enterprises to actively transform, the government has accelerated the time to adopt incentives, so as to promote the cold chain logistics enterprises to implement digital transformation as soon as possible.

(2) The impact of government interests damage $D1$ and $D2$ on the evolution of cold chain logistics enterprises and the government

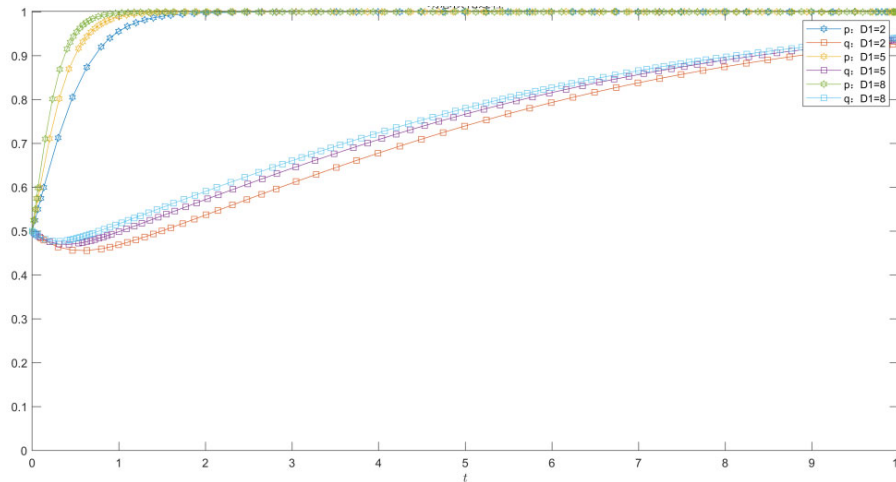


Figure 2. The evolutionary diagram of the interest damage caused by the implementation of digital transformation

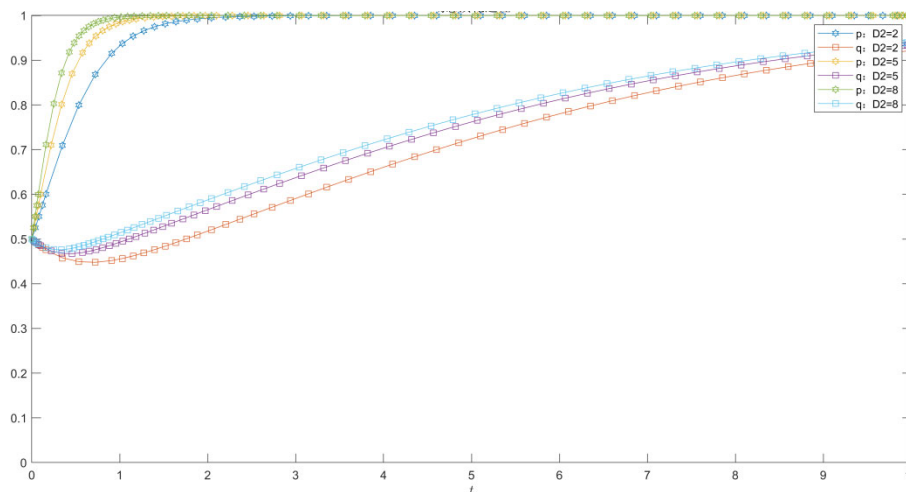


Figure 3. Evolution map of interest damage caused by no digital transformation and no government policies

Under the two strategies of cold chain logistics enterprises implementing digital transformation and not implementing digital transformation, the impact of the interest damage caused by the government's no policies on the strategies of enterprises and the government is shown in the figure. As can be seen from the figure, no matter whether the enterprise implements digital transformation or not, with the increasing damage of government interests, the government will accelerate the time of adopting incentive policies, reduce

losses, and make the curve gradually converge to 1. At the same time, the government accelerated the adoption of incentives, which also promoted the active transformation of cold chain logistics enterprises, and accelerated the pace of digital transformation of cold chain logistics enterprises.

(3) The influence of the government's tax rate on corporate profits h on the evolution behavior of cold chain logistics enterprises and the government

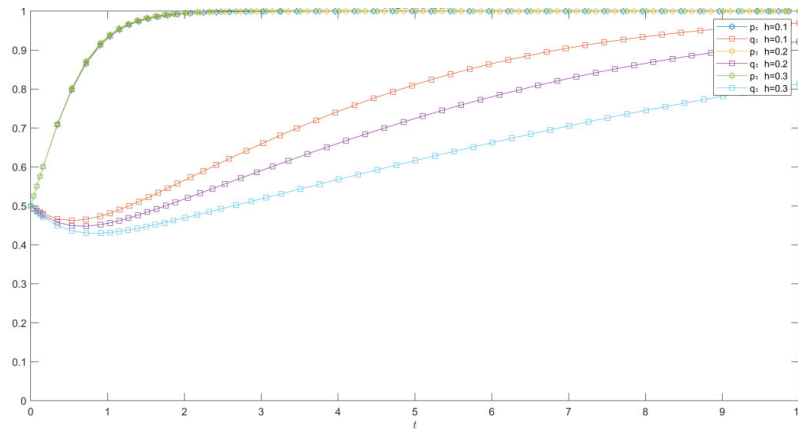


Figure 4. Evolution diagram of government tax rate changes on corporate profits

As can be seen from the figure, with the continuous increase of tax rate, cold chain logistics enterprises have slowed down the balance speed of digital transformation. That is to say, the higher the tax rate, the greater the cost paid by cold chain logistics enterprises, and the implementation of digital transformation, which may cause enterprises to make

ends meet and hesitate in the decision of whether to transform, thus reducing the speed of their digital transformation, and the longer the final curve approaches to probability 1.

(4) Income increase coefficient of enterprise digital transformation μ influence on the evolution behavior of cold chain logistics enterprises and government

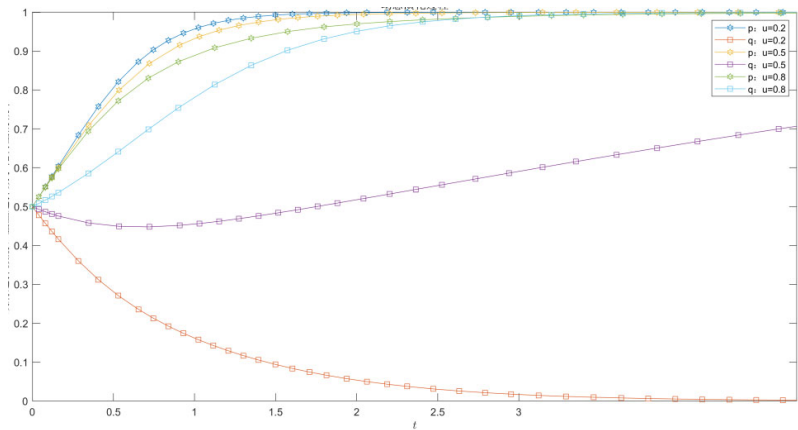


Figure 5. Evolution diagram of the revenue increase coefficient change of enterprise digital transformation

As can be seen from the figure, when the value of μ keeps increasing, the curve gradually converges from 0 to 1, that is, when the benefits brought by the implementation of digital transformation are increasing, cold chain logistics enterprises themselves are willing to actively carry out digital transformation and bring profits to the enterprises. For the government, when the revenue increase coefficient is low, the cold chain logistics enterprises are unwilling to undertake the digital transformation, the government provides subsidies to

encourage the enterprise to actively transform, thus encouraging the enterprise to implement the digital transformation as soon as possible; when the revenue increases, the government takes incentive measures for a long time.

(5) The influence of the government's subsidy value G for digital transformation enterprises on the evolution behavior of cold chain logistics enterprises and the government

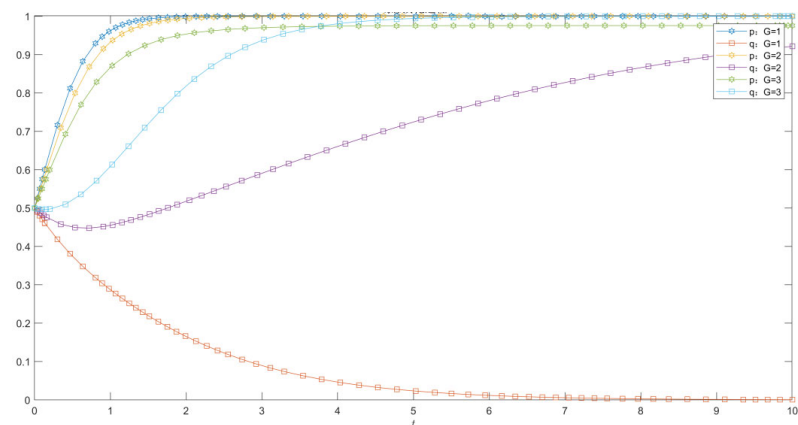


Figure 6. Evolution diagram of the change of government subsidy value

As can be seen from the figure, with the increasing value of G , cold chain logistics enterprises evolve from not implementing the digital transformation to implementing the digital transformation strategy, that is, when the government subsidies continue to increase, cold chain logistics enterprises themselves actively carry out the digital transformation to reduce the cost of digital transformation and bring benefits to the enterprises. For the government, when the subsidy value is low, the government is willing to actively provide subsidies to promote the digital transformation of cold chain logistics enterprises; as the subsidy value increases, the government will slow down the time to take incentive measures for its own consideration.

4. Conclusions and Countermeasures

(1) Optimize government services and reduce tax rates to help the transformation of cold-chain logistics enterprises

Cold-chain logistics enterprises are facing many challenges in the process of digital transformation. On the one hand, cold chain logistics enterprises face many difficulties in data collection, storage and processing, such as the application of sensors, Internet of Things (IoT) equipment and the application of artificial intelligence (AI) technology; on the other hand, the digital transformation requires large capital investment, including the purchase and maintenance of software and hardware facilities, as well as the training of employees. These challenges have deterred many companies from keeping pace with digital development.

In order to promote the implementation of digital transformation of cold chain logistics enterprises, the government can reduce the tax burden of enterprises by lowering the tax rate, increase the cash flow of enterprises, ensure the effective use of funds and the healthy and sustainable development of enterprises, so as to help enterprises to carry out the investment and operation of digital transformation. Reducing the tax rate can reduce the economic pressure of enterprises, so that they have more capital and energy into the digital transformation, including purchasing and maintenance of hardware and software facilities, training employees, optimizing supply chain management, improving operational efficiency, etc., so as to promote the digital process of the cold chain logistics industry.

(2) Establish a scientific and technological innovation fund to reduce the cost of digital innovation of cold-chain logistics technology

The government may establish special science and technology innovation funds and venture capital funds to provide necessary financial support for science and technology enterprises by means of investment, loan and guarantee. At the same time, it may introduce policies including technical support, intellectual property protection and tax incentives to encourage enterprises to carry out technology research and development. At the same time, market mechanism is introduced in the development process of cold chain logistics enterprises, digital technology sharing and innovation among enterprises are promoted through innovation competitions and other ways, enterprises are guided to understand the importance of digital technology for

the development of cold chain logistics industry, and enterprises are encouraged to compete and cooperate in the field of technological innovation.

(3) Layout and construction of digital cold chain logistics distribution center to reduce the transportation cost of cold chain logistics

Due to the underdeveloped transportation network, the cold chain logistics distribution centers in various regions are not reasonably arranged, which leads to the increase of the cold chain logistics transportation costs. Therefore, the government can organize experts and enterprise representatives to carry out preliminary research and project evaluation, take into account multiple factors such as transportation, market and population density, and formulate reasonable layout plans and construction plans. By building roads, install freight equipment, temperature sensors and intelligent identification system, digital equipment and other measures to improve the center of distribution facilities and service quality, at the same time, using the rent reduction to attract more enterprises in distribution center, give full play to its radiation ability, improve the cold chain logistics overall operation efficiency.

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