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Original Paper

Decision Analysis of Game Behavior for the Fresh Food Industry: Potential Entrants, Incumbents and Consumers

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Abstract

This paper conducts a decision analysis of game behavior for the fresh food industry, including potential entrants, incumbents and consumers. Potential entrants are the key research object in the analysis of game behavior. The Stackelberg model, considering the uncertainty of market, consumer preference, freshness and greenness of fresh products, is used to analyze the best entry strategies for potential entrants. This paper then establishes an evolutionary game model to further analyze the most optimal entry mode of potential entrants. The combination of two game models can help potential entrants determine the optimal price, output, product freshness, greenness and sales channels.

Keywords

fresh retail, dynamic stackelberg game, evolutionary game, consumption preference

1. Introduction

In 2020, the sudden outbreak of the COVID-19 epidemic had an impact on traditional industries, but provided new development opportunities for the innovative economy. The total retail sales data of social consumer goods indicate that online retail formats such as fresh e-commerce and store-to-home commerce are growing rapidly, and online shopping has maintained rapid growth (National Bureau of Statistics, 2020). The scale of China's retail market exceeded RMB 5 trillion in 2020, and it is estimated that this scale will reach RMB 6.8 trillion by 2025 (Jiang et al., 2023).

The industrial chain of the fresh food industry in China can be divided into fresh food producers, primary wholesale market and secondary wholesale market. Products are then sold to end consumers through supermarkets, restaurants, farmers' markets and e-commerce (**Fig. 1**). The premium space available for mid-stream and upstream products is limited by the layout of the industrial chain. However, the bargaining power for downstream consumers is strong due to the degree of service differentiation or consumer preference. Therefore, the downstream profit space is very large, and there are more potential entrants.

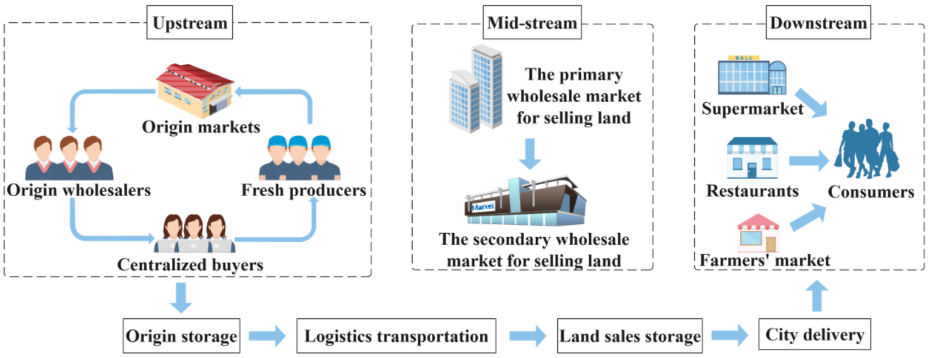

Figure 1. Schematic Diagram of China's Fresh Retail Industry Chain

China's fresh food retail consumption is mainly divided into online and offline channels. Online channels include e-commerce, pre-warehouse and community group purchase. Offline channels include vegetable markets, traditional supermarkets and community fresh food stores. Offline and online food retail channels account for 85.5% and 14.5%, respectively, of China's fresh food retail downstream channels, respectively, according to the data in 2022 (**Fig. 2**). However, the proportion of online sales channels will gradually increase in the future with the increase in the penetration rate of fresh online retail channels.

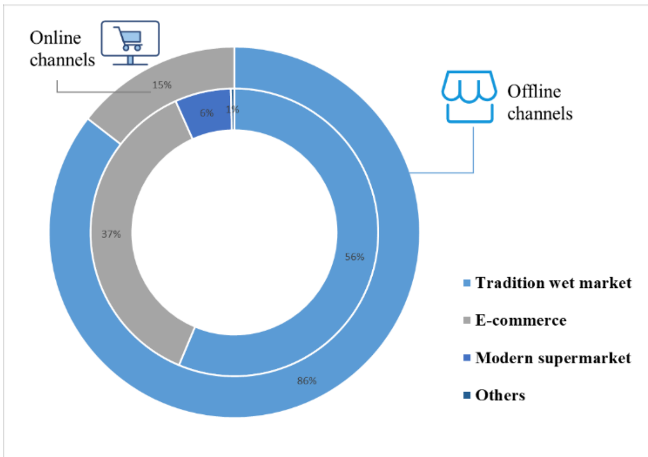

Figure 2. Distribution of Downstream Channels of China's Fresh Retail Products in 2022

It is highly important for potential entrants to make the best decisions in the face of the behaviors of incumbents and consumers. It is interesting and worth investigating whether potential entrants will enter the market and which offline or online channels will be more profitable.

2. Literature Review

Fresh e-commerce has gradually emerged and it has also attracted the attention of a wide range of researchers. Compared with other industries, fresh retail e-commerce needs to consider both the influence of consumers' purchase intentions (Lin, 2020), the green and organic attributes of products (Jin et al., 2017), freshness (Sebatjane & Adetunjithe, 2020) and the influence of green costs (Ghosh & Shah, 2015).

Some researchers start from the perspective of the supply chain by looking for optimal decisions to achieve overall optimization or "win–win" results in the fresh supply chain. Many scholars have begun to study two-level or three-level fresh produce supply chains in various forms in recent years, as shown in **Table 1**. However, the current research focuses on the analysis of the main existing roles of the fresh food industry, such as manufacturers, retailers, suppliers, and logistics providers. Very little research has been done from the perspective of potential entrants.

Table 1. Summary Table of Supply Chain Decision-making Research Literature

Types of supply chain		Literature
Two-level fresh product supply chain	Supplier – Retailer	Song et al. (2017), Tang and Yang (2020) , Xie et al.(2021)
	Manufacturer – Retailer	Ghosh and Shah (2015), Taleizadeh et al.[0] (2018), Ranjan and Jha (2022), Zhao and Li (2023)
	Supplier – E-commerce platform	Wang et al. (2019)
	Retailer – Logistics service provider	Song and He (2019)
	Farmers – Retailers	Dolat-Abadi (2021)
Three-level fresh product supply chain	Manufacturer – Retailer – Consumer	Liu et al. (2019)
	Manufacturer – Supplier – Retailer	Dey and Giri (2021)
	Manufacturer – Retailer – Logistics	Jamali and Barzoki (2019)
	Recycler – Manufacturer – Suppliers	Giri and Dey(2019)

Game theory is one of the standard analytical tools used in economics, and it has also been applied in a few studies in the fresh food industry. However, not much related research has been conducted. For example, Wang and Hu used the supply chain of fresh agricultural products to construct a game model from the perspectives of sharing preconditions, incentive mechanisms, channels and platforms (Wang and Hu, 2020). A game model was used to describe the best strategy under centralized and decentralized channels in a three-tier fresh agricultural product supply chain (Song et al., 2017). The operation strategy of omni-channel supply chain has been studied (Liu et al., 2019). In addition, several scholars have used the Stackelberg game model to study the optimal strategy of the main bodies of the secondary supply chain (Taleizadeh et al., 2018; Wang et al, 2019; Xie et al., 2021). Li et al. used the evolutionary game model to analyze the behavior of fresh produce enterprise groups participating in information sharing (Li et al., 2021). An evolutionary game model between food enterprises and regulatory agencies under bounded rationality is constructed, and the determinants of fluctuations in food safety regulatory cycles are analyzed in detail (Sun et al., 2022). An evolutionary game model of AFCS participants based on blockchain was established (Yang et al., 2023).

Although the Stackelberg model and evolutionary game model have been previously applied in the fresh food industry, no scholars have analyzed game behavior from the perspective of potential entrants. This paper explores the optimal decision-making problem of potential entrants in the fresh retail industry as a response to this research agenda. The distinction of the results of the present study from those of previous studies is that the Stackelberg model and evolutionary game model are applied separately in two stages to provide practical suggestions for potential entrants, as shown in **Fig. 3**. The Stackelberg model is used to analyze the game process between the incumbent and the potential entrant to help the potential entrant choose the optimal price and output in the first stage. When potential entrants enter the market at time T, the evolutionary game model between potential entrants and consumers can further assist them in choosing the best sale channel strategy in the second stage. The reason for this is that the game process between potential entrants and incumbents has a sequential order. The incumbents were the first to occupy the market, and the potential entrants were the followers. Potential entrants can make targeted responses after observing the incumbent's decision to better control their own market entry opportunities and strategies, and optimize market performance and profit. Therefore, it is more appropriate to use the Stackelberg model at this stage rather than directly using the tripartite evolutionary game model.

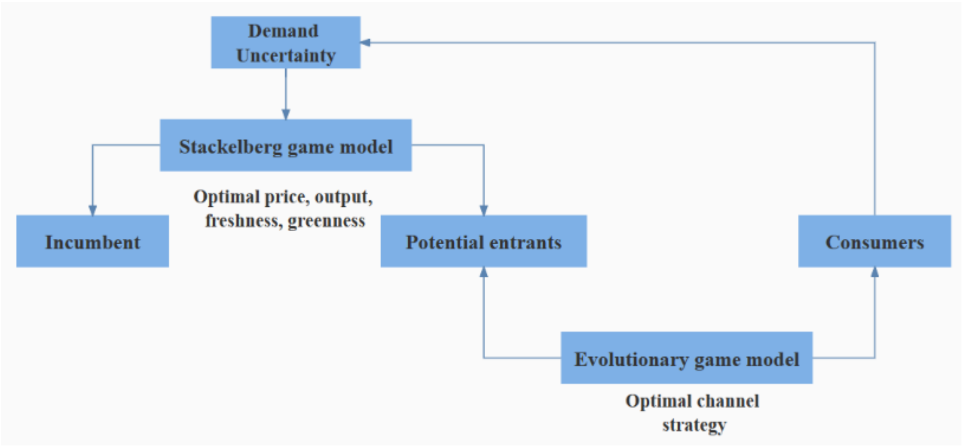

Figure 3. The Game Process Frame Diagram

The remainder of this paper is structured as follows: the problem is described, and some assumptions are proposed in section 3. Then, a dynamic Stackelberg game model is developed and discussed in section 4. Sections 5 and 6 include the evolutionary game process and simulation analysis. Finally, the key findings and limitations of this paper are outlined in section 7.

3. Problem Description and Basic Assumptions

3.1 Problem Description

This paper focuses on existing incumbents, potential entrants, and consumers in the fresh retail industry as research subjects. The product life cycle is divided into T periods to describe the market's dynamic evolution process. Potential entrants can choose to enter the market in any period, while existing incumbents in the fresh retail industry may take suppression measures to prevent them. If potential entrants do not harm the interests of incumbents, the incumbents will choose to tolerate them to save costs. When potential entrants choose to enter the market smoothly at time t, they should still consider whether it is more profitable to choose an online or offline sales channel. Both potential entrants and incumbents will be affected by the consumer market. Therefore, the key to the selection decision of potential entrants is to choose strategies to maximize their profits on the basis of changes in market demand, consumer preferences and price sensitivity.

3.2 Research Hypotheses

This study posits that incumbents, potential entrants, and consumers are rational economic agents whose primary objective is to maximize their respective profits. In the context of a fresh produce market featuring distinct product categories, potential entrants have the opportunity to launch one specific product. Incumbents can monopolize certain offerings, thereby assuming the role of leaders in a Stackelberg game model, while potential entrants act as followers. Due to initial financial constraints, potential entrants are limited to selecting a single entry channel. Furthermore, it is also assumed that the incumbents' decisions in the initial stage remain static, allowing them to refrain from interfering with the interactions between potential entrants and consumers in subsequent stages. Additionally, consumers demonstrate a strong preference for the greenness and freshness of products, indicating a willingness to pay a premium for goods that meet these criteria.

3.3 Symbol Description

Table 2. Notations

Symbol	Description
a	Total potential demand of the market
b	Effective coefficient of the final market price on the demand
c	Influence factor of fresh products on market demand
d	Influence factor of green products on market demand
P	Selling price of the product set by the incumbents
ε	Random factor of market demand which indicates the influence of other factors
D_i	Demand function of fresh food industry
N_i	Market share of incumbents or potential entrants
M_i	Cost function of incumbents or potential entrants
q_i	Product output of incumbents or potential entrants
t_i	Product freshness incumbents or potential entrants
g_i	Product greenness f incumbents or potential entrants
Q_j	Sales volume of online or offline sales
I_j	Technology input cost of online or offline sales

δ_j	Products quality of online or offline sales
λ_0	Quality preference coefficient of consumers for fresh products

4. Dynamic Stackelberg Game

The Stackelberg game model is a classic model in game theory that is often used to study the competitive strategy of the market. The model involves two participants: a leader and a follower. The leader makes strategic decisions before the follower who then makes decisions after observing the leader' decisions. The model's key feature is that the decisions of leaders and followers mutually influence each other, and the result depends on the values of these decision variables.

4.1 Construction of the Dynamic Stackelberg Game Model

The demand functions are similar to those used in most related studies (Xie, 2015; Hafezalkotob, 2017; Taleizadeh et al., 2018; Jamali & Morteza, 2019). We consider that the demand function of products in fresh industry will be uncertain due to the influence of price, freshness and greenness of products, and is formulated as follows:

$$D_i = a - bP + ct_i + dg_i + \varepsilon, \ (i=1, 2) \quad \textbf{(1)}$$

where a is the total potential demand of the market; which is irrelevant to the product price, green and freshness, and is affected by the brand, the customers' inherent preferences etc. (Xie, 2015). b is the effective coefficient of the final market price on demand. Similarly, c means that the influence factor of fresh products on demand of the market, and d is the influence factor of green products on market demand. Obviously, the demand D_i is positively correlated with t_i and g_i, and negatively correlated with P. This means that selling low-priced, green and fresh products can expand market demand beyond market potential and increase sales. In addition, the random factor ε is added, which represents the influence of other factors on the market demand and can also ensure that the market demand is nonnegative (Taleizadeh et al., 2018). Like Xie (2015) and Hafezalkotob (2017), we defined the cost function as follows:

$$M_i = f + v_i D_i + w_i t_i^2 + r_i g_i^2, \ (i=1, 2) \quad \textbf{(2)}$$

in which f represents the fixed costs independent of t_i and g_i, $v_i D_i$ is the variable cost, $w_i t_i^2$ indicates a fixed input cost dependent on t_i, $r_i g_i^2$ indicates a fixed input cost dependent on g_i.

Potential entrants can choose any product in the fresh retail market, and enter the market at any period **t** of the product life cycle. In addition, the incumbent, as the leader in the Stackelberg game, prioritizes the output q_1 and price P. Then the potential entrants choose the initial output q_2 of entering the market based on the incumbents' decisions. Once potential entrants' benefits meet their expectations, they will choose to enter the market without hesitation.

The profit function of the incumbents is

$$\Pi_1 = (P - C_1)(a - bP + ct_1 + dg_1 + \varepsilon)N_1 - M_1, \quad \textbf{(3)}$$

where P is the selling price of the incumbents' products. C_1 is the purchasing cost of the incumbents' products. The sales of incumbents are $q_1 = (a - bP + ct_1 + dg_1 + \varepsilon)N_1$, and N_1 denotes the market share of the incumbents.

Similarly, considering consumers' preferences for price, green and fresh products, and corresponding costs, the profit function of potential entrants is set as shown in **Formula (4)**. Because it is easier for potential entrants to enter the market by choosing a low-price strategy, we set the price of potential entrants as αP, where α is the price discount.

$$\Pi_2 = (\alpha P - C_2)(a - \alpha bP + ct_2 + dg_2 + \varepsilon)N_2 - \mathrm{M}_2, \tag{4}$$

4.2 Solution to the Dynamic Stackelberg Game Model

The game process between incumbents and potential entrants can be divided into two parts. In period ***t-1***, the potential entrants waited for the entry time, and the incumbents sold the products at price P, and the output was q_1. In period **t**, potential entrants choose to enter the market at price αP, and the expected sales volume is q_2. At this time, the incumbents make a decision whether to push potential entrants out of the market by adjusting the price and output. This paper focuses on the analysis of period **t**, and backward induction is used to solve this problem.

According to **hypothesis (1)**, incumbents will respond to the decision of potential entrants to enter the market with the goal of maximizing their own interests in period **t**. Moreover, potential entrants can predict the reactions of incumbents.

The objective function of the incumbents is

$$max\Pi_1 = \max[(P - C_1)(a - bP + ct_1 + dg_1 + \varepsilon)N_1 - \mathrm{M}_1]. \tag{5}$$

Then, the value of P can be obtained by setting the derivative of formula (5) with respect to P equal to 0.

$$\frac{d\Pi_2}{dP} = (a - 2bP + ct_1 + dg_1 + \varepsilon + bC_1)N_1 + v_1 b = 0 \tag{6}$$

Therefore, the optimal price strategy of the incumbent is P^*.

$$P^* = \frac{(a + ct_1 + dg_1 + \varepsilon + bC_1)N_1 + v_1 b}{2bN_1} \tag{7}$$

Moreover, $P^* > 0$ always holds. The incumbents' optimal output Q_1^* can be obtained by substituting the optimal price P^*.

$$q_1^* = D_1 \cdot N_1 = \frac{(a + ct_1 + dg_1 + \varepsilon - bC_1)N_1 - v_1 b}{2} \tag{8}$$

In addition, we can determine the optimal freshness t_1^* and greenness g_1^* of the incumbents' products after determining the optimal selling price.

$$t_1^* = \frac{c[(P^* - C_1)N_1 - v_1]}{2w_1} \tag{9}$$

$$g_1^* = \frac{d[(P^* - C_1)N_1 - v_1]}{2r_1} \tag{10}$$

Finally, potential entrants make decisions based on profit maximization according to the optimal strategies of the incumbents, that is,

$$max\Pi_2 = \max[(\alpha P - C_2)(a - \alpha bP + ct_2 + dg_2 + \varepsilon)N_2 - M_2]. \tag{11}$$

Similarly, we can find the optimal price $\alpha^* P^*$ of potential entrants.

$$\alpha^* P^* = \frac{(a + ct_2 + dg_2 + \varepsilon + bC_2)N_2 + v_2 b}{2bN_2} \tag{12}$$

Among them, the best discount α^* is as follows:

$$\alpha^* = \frac{N_1[(a + ct_2 + dg_2 + \varepsilon + bC_2)N_2 + v_2 b]}{N_2[(a + ct_1 + dg_1 + \varepsilon + bC_1)N_1 + v_1 b]} \tag{13}$$

In the same way, the optimal initial output of potential entrants can be obtained.

$$q_2^* = D_2 \cdot N_2 = \frac{(a + ct_2 + dg_2 + \varepsilon - bC_2)N_2 - v_2 b}{2} \tag{14}$$

In addition, we can also detemine the optimal freshness t_2^* and greenness g_2^* of potential entrants' products after determining the optimal selling price.

$$t_2^* = \frac{c[(\alpha^* P^* - C_2)N_2 - v_2]}{2w_2} \tag{15}$$

$$g_2^* = \frac{d[(\alpha^* P^* - C_2)N_2 - v_2]}{2r_2} \tag{16}$$

In summary, the optimal price and optimal output of incumbents and potential entrants are affected by market demand D_i, product cost price P^*, market share N_i, price sensitivity coefficient **b** and variable cost coefficient v_i from the formulas (7), (8), (12), and (14), respectively. Moreover, we can see that the market share N_i is very important for decision-making from formulas (13)-(16). It may still be difficult to survive when potential entrants use a low-price strategy and sell fresh and green products in a monopoly market. There are industry giants in China's fresh food retail industry, such as Freshippo, Meituan, Ding Dong and so on. However, a market monopoly has not yet formed, which belongs to the complete market competition, and potential entrants have more opportunities to make profits. This is the reason why there are many potential entrants and why this paper analyses potential entrants. In addition, it is also highly significant to control the optimal freshness and greenness of products. Excessive standards will lead to a sharp increase in costs, but low standards will be dissatisfied with better meeting market demand. Potential entrants will enter the market when their profit is maximized on the premise of the maximum tolerance of the incumbents. And the optimal price strategy is $\alpha^* P^*$, and the optimal initial output is q_2^*.

5. Evolutionary Game Process

It is necessary to further analyze what kind of entry mode to adopt to choose "online" or "offline" sales channels, when potential entrants in the fresh retail industry choose the strategy of entering the market. The choice is based on whether consumers "pay the bill", that is, compare the benefits of online sales and offline sales. Thus, this paper constructs an evolutionary game model between potential entrants and consumers and analyzes their decisions.

5.1 Construction of the Evolutionary Game Model

The research subjects in this section are potential entrants and consumers in the fresh retail industry, which are denoted as P_e and P_c, respectively. The selection strategies of potential entrants are "online sales" and "offline sales", and the selection probabilities are *x* and 1-*x*, respectively. The main choice strategies of consumers are "buy" and "do not buy", and the choice probabilities are *y* and 1-*y*, respectively.

In the first case, consumers choose the "purchase" strategy, and potential entrants choose "online sales". Similar to Ghosh and Shah (2015), the income of potential participants can be expressed as the difference between possible income, transportation cost, purchase cost and the technical input cost of fresh products. Therefore, it can be expressed as $\pi_1 = bP_1Q_1 - I_1 - S_1 - S_0$, where **b** also expressed price preference, P_1 is the sales price of online products, Q_1 is the estimated sales volume, I_1 is the technical input cost of fresh products in online sales, S_1 is the transportation cost, and S_0 is the purchase cost of products.

If the strategy of "offline sales" is selected, the income of potential entrants can be expressed as the difference between possible income and green input cost, service cost and purchase cost, that is, $\pi_3 = bP_2Q_2 - I_2 - S_2 - S_0$. Similarly, P_2 is the sales price of online products, Q_2 is the estimated sales volume, I_2 is the technical input cost of fresh products in offline sales, and S_2 is the service cost. Because the potential entrant has the same source of goods whether he or she chooses "online sales" or "offline sales", the purchase costs of online sales and offline sales are also the same; therefore, S_0 is also the purchase cost of the product.

The technical input cost refers to the technical cost of improving the freshness and greenness of products, including storage costs, transportation technology and equipment research on fresh food. The technical input can be fed back through the quality of products. Assume that the technical input cost coefficients of online sales and offline sales are η_1 and η_2 respectively. δ_1 represents the quality of fresh products in online and δ_2 represents the quality of fresh products offline. Therefore, the specific expression of the technical input costs can be expressed as $I_j = \frac{1}{2}\eta_j\delta_j^2 \ (j = 1, 2)$.

Similar to Xie (2015), we esteem that product sales Q is inversely proportional to the sales price and proportional to consumer preferences. Therefore, the product sales volume of online e-commerce can be set to $Q_1 = a - bP_1 + \lambda_0\delta_1$, and the product sales volume of offline physical stores is

$Q_2 = a - bP_2 + \lambda_0\delta_2$. Here, **a** still represents the potential total market demand, **b** is the price preference coefficient of consumers, and λ_0 is the quality preference coefficient of consumers for fresh products. Consumer utility is closely related to consumer preferences according to Bowles and Hwang (2008). When consumers choose to purchase from online e-commerce platforms or offline stores, the consumer utility obtained is $U_1 = \lambda_0\delta_1 - bP_1$ and $U_3 = \lambda_0\delta_2 - bP_2$, respectively.

When consumers choose the "do not buy" strategy, the potential income of potential entrants is **0**, and the consumer utility is also **0**. In this case, incomes of potential entrants choosing "online sales" and "offline sales" are $\pi_2 = -I_1 - S_1 - S_0$ and $\pi_4 = -I_2 - S_2 - S_0$, respectively. In summary, the income matrix of both sides of the game is established (**Table 3**).

Table 3. Income Matrix of Both Players in the Game

		P_e Online sales	 Offline sales
P_c	Buy	$\pi_1,\ U_1$	$\pi_3,\ U_3$
	Do not buy	π_2, 0	π_4, 0

For potential entrants P_e, the expected return is E_x when choosing the "Online sales" strategy; otherwise, the expected return is E_{1-x}, and the average expected return is $\overline{E_x}$. Then,

$$E_x = y\pi_1 + (1-y)\pi_2 \quad \textbf{(17)}$$

$$E_{1-x} = y\pi_3 + (1-y)\pi_4 \quad \textbf{(18)}$$

$$\bar{E}_x = x[y(\pi_1 - \pi_2) + \pi_2] + (1-x)[y(\pi_3 - \pi_4) + \pi_4] \quad \textbf{(19)}$$

Therefore, the replication dynamic equation for the strategy selection of potential entrants is shown in equation (12).

$$F(x) = \frac{dx}{dt} = x(1-x)[yb(P_1Q_1 - P_2Q_2) + I_2 - I_1 + S_2 - S_1] \quad \textbf{(20)}$$

Likewise, for consumers P_c, the expected utility when choosing the "buy" strategy is E_y, the expected utility when choosing the "do not buy" strategy is E_{1-y}, and the average expected utility is $\overline{E_y}$.

$$E_y = xU_1 + (1-x)U_3 \quad \textbf{(21)}$$

$$E_{1-y} = 0 \quad \textbf{(22)}$$

$$\bar{E}_y = yE_y + (1-y)E_{1-y} = y[xU_1 + (1-x)U_3] \quad \textbf{(23)}$$

The replication dynamic equation for the behavior strategy of consumer selection is as follows:

$$F(y) = \frac{dy}{dt} = y(1-y)[\lambda_0\delta_2 - bP_2 + x(\lambda_0\delta_1 - \lambda_0\delta_2 + bP_2 - bP_1)] \quad \textbf{(24)}$$

The replication dynamic equations F(x) and F(y) for the decision-making behavior strategy selection of potential entrants and consumers in the fresh food market constitute an evolutionary game model, as shown in (17).

$$\begin{cases} F(x) = x(1-x)[y(P_1Q_1 - P_2Q_2) + I_2 - I_1 + S_2 - S_1] \\ F(y) = y(1-y)[\lambda_0\delta_2 - bP_2 + x(\lambda_0\delta_1 - \lambda_0\delta_2 + bP_2 - bP_1)] \end{cases} \quad \textbf{(25)}$$

5.2 Evolutionary Game Equilibrium Analysis

This section will solve and analyze the Nash equilibrium solution of the evolutionary game model. First, the partial derivatives of F(x) and F(y) with respect to x and y are calculated, and the Jacobian matrix is constructed. Moreover, the determinant and trace of the Jacobian matrix are further obtained, and the expressions are (18) and (19).

$$|J| = \frac{\partial F(x)}{\partial x}\frac{\partial F(y)}{\partial y} - \frac{\partial F(x)}{\partial y}\frac{\partial F(y)}{\partial x} \quad \textbf{(26)}$$

$$trJ = \frac{\partial F(x)}{\partial x} + \frac{\partial F(y)}{\partial y} \quad \textbf{(27)}$$

Let the replication dynamic equations (12) and (16) be equal to 0, that is, F(x) = 0 and F(y) = 0. Because the probabilities $x(0 \le x \le 1)$ and $y(0 \le y \le 1)$ are selected, there are only 4 or 5 equilibrium points in all the scenarios. Next, this paper analyses various scenarios.

Any initial point and its evolved point must be in a two-dimensional space $V = \{(x,y)|x \in [0,1], y \in [0,1]\}$ to be meaningful. If $\frac{-(\lambda_0\delta_2 - bP_2)}{(\delta_1-\delta_2)\lambda_0 + b(P_2-P_1)}$ is in the interval [0, 1] and $\frac{-(I_2-I_1+S_2-S_1)}{P_1Q_1-P_2Q_2}$ is also in the interval [0, 1], there are two situations in which the dynamic replication equation has five equilibrium points: $E_1(0,0)$, $E_2(1,0)$, $E_3(0,1)$, $E_4(1,1)$, $E_5(\frac{-(\lambda_0\delta_2 - bP_2)}{(\delta_1-\delta_2)\lambda_0 + b(P_2-P_1)}, \frac{-(I_2-I_1+S_2-S_1)}{P_1Q_1-P_2Q_2})$.

① If the input cost of online e-commerce is higher than that of offline stores, the income obtained is greater than that of those, in that the consumer effect of online e-commerce sales is greater than that of offline stores. The mathematical expressions are $\lambda_0\delta_2 - bP_2 < 0$, $(\delta_1-\delta_2)\lambda_0 + b(P_2 - P_1) > 0$, $I_2 - I_1 + S_2 - S_1 < 0$, $P_1Q_1 - P_2Q_2 > 0$, and $P_1Q_1 - P_2Q_2 + I_2 - I_1 + S_2 - S_1 > 0$. In this case, $E_1(0,0)$ and $E_4(1,1)$ are the stable points, $E_2(1,0)$ and $E_3(0,1)$ are the unstable points and E_5 is the saddle point.

② When the input cost of offline stores is greater, more consumers will be attracted. Therefore, the consumer effect is greater than that of online e-commerce. The mathematical expressions are $\lambda_0\delta_2 - bP_2 > 0$, $(\delta_1-\delta_2)\lambda_0 + b(P_2-P_1) < 0$, $I_2 - I_1 + S_2 - S_1 > 0$, $P_1Q_1 - P_2Q_2 < 0$ and $P_1Q_1 - P_2Q_2 + I_2 - I_1 + S_2 - S_1 < 0$. Here, $E_2(1,0)$and $E_3(0,1)$ are the stable points, $E_1(0,0)$ and $E_4(1,1)$ are the unstable points and the E_5 point is the saddle point.

The above two scenarios show that those who invest more in online sales or offline sales will obtain more income. In addition, when either $\frac{-(\lambda_0\delta_2-bP_2)}{(\delta_1-\delta_2)\lambda_0+b(P_2-P_1)} < 0$ or $\frac{-(\lambda_0\delta_2-bP_2)}{(\delta_1-\delta_2)\lambda_0+b(P_2-P_1)} > 1$ or $\frac{-(I_2-I_1+S_2-S_1)}{P_1Q_1-P_2Q_2} < 0$ or $\frac{-(I_2-I_1+S_2-S_1)}{P_1Q_1-P_2Q_2} > 1$, the dynamic replication equation has only four equilibrium points, namely, $E_1(0,0), E_2(1,0), E_3(0,1), E_4(1,1)$. Moreover, there are four scenarios, as shown in **Table 4**.

Table 4. Scenario Summary of the Four Equilibrium Points of the Dynamic Equation

Scenario	Numerical situation		Stable point	Unstable point	Saddle point
1	$\lambda_0\delta_2 - bP_2 \geq 0$, $(\delta_1-\delta_2)\lambda_0 + b(P_2-P_1) > 0$	$P_1Q_1 - P_2Q_2 + I_2 - I_1 + S_2 - S_1 \geq 0$, $I_2 - I_1 + S_2 - S_1 \geq 0$	E_4	E_1	E_2, E_3
2		$P_1Q_1 - P_2Q_2 + I_2 - I_1 + S_2 - S_1 \leq 0$, $I_2 - I_1 + S_2 - S_1 < 0$	E_4	E_2	E_1, E_3
3	$\lambda_0\delta_2 - bP_2 \leq 0$, $(\delta_1-\delta_2)\lambda_0 + b(P_2-P_1) < 0$	$P_1Q_1 - P_2Q_2 + I_2 - I_1 + S_2 - S_1 \leq 0$, $I_2 - I_1 + S_2 - S_1 < 0$	E_1	E_4	E_2, E_3
4		$P_1Q_1 - P_2Q_2 + I_2 - I_1 + S_2 - S_1 \geq 0$, $I_2 - I_1 + S_2 - S_1 \geq 0$	E_2	E_3	E_1, E_4

To avoid unnecessary discussion, this paper proposes the following assumptions based on practicality: 1) Only when the consumers' utility is greater than 0 will they choose the strategy. 2) Under the condition of known information, potential entrants will inevitably choose a strategy that can obtain higher profits.

The sudden outbreak of the COVID-19 epidemic in 2020 accelerated the development of community fresh e-commerce. Due to the emergence of the "lazy economy" in the post epidemic stage, consumers have cultivated the habit of shopping online. At present, there are many business models for fresh community e-commerce, such as front warehouse, store-warehouse integration, O2O platform models, and community group purchase models. Fresh e-commerce with different business models can meet the consumption needs of consumers at different levels. However, no matter what kind of business model is adopted, all enterprises should attach great importance to the greenness and freshness of food. It is necessary for the development of fresh food industry to continuously strengthen infrastructure, strictly control product quality and implement cold chain logistics distribution. The success of Guangzhou Money Aunt Agricultural Ltd was also achieved in this way. Therefore, based on practical assumptions and the development status of fresh food e-commerce, it can be seen that $(\delta_1 - \delta_2)\lambda_0 + b(P_2 - P_1) > 0$, $\lambda_0\delta_2 - bP_2 < 0$, $P_1Q_1 - P_2Q_2 > 0$, $P_1Q_1 - P_2Q_2 + I_2 - I_1 + S_2 - S_1 < 0$, and $I_2 - I_1 + S_2 - S_1 < 0$. This is the first case of the five equilibrium points of the copy dynamic equation.

Based on the above analysis, $E_1(0,0)$ and $E_4(1,1)$ are the stable points. $E_2(1,0)$ and $E_3(0,1)$ are the unstable points. E_5 is a saddle point. Therefore, we can draw the dynamic evolutionary difference between potential sellers' and consumers' decisions (**Fig. 4**). Potential sellers and consumers eventually converge to $E_1(0,0)$ or $E_4(1,1)$, and the corresponding strategy combinations are (offline sales, do not buy) and (online sales, buy).

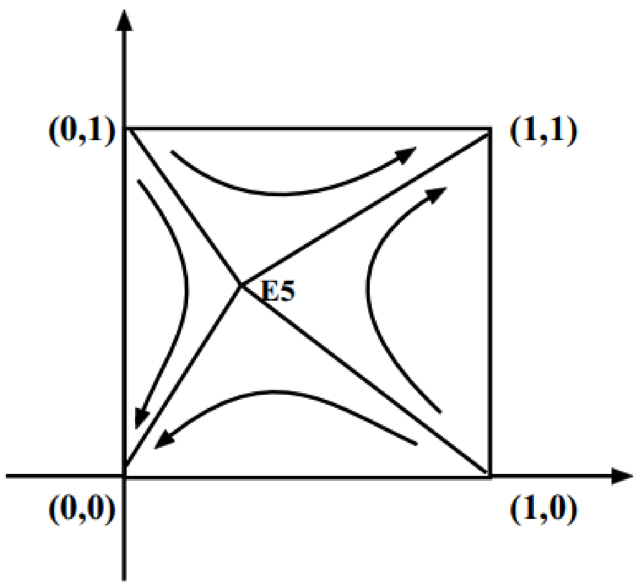

Figure 4. Phase Diagram of System Dynamic Evolution

The potential entrants and consumers in the fresh food market ultimately converge to $E_1(0,0)$ and $E_4(1,1)$, whose corresponding strategic combinations are (offline sales, do not buy) and (online sales, buy), respectively. The final convergence position of the game subject depends on the relative position between the initial scales, the countermeasures taken by both sides of the game, and the saddle point E_5. In the competitive region, over time, the initial ratio will eventually converge to point $E_1(0,0)$. In the variable region, with the evolution of time, the initial ratio may converge to point $E_1(0,0)$ or $E_4(1,1)$. Generally, when the area of the cooperation region is larger than that of the competition region, the region may converge to point $E_4(1,1)$ more easily; otherwise, it may converge to point $E_1(0,0)$. Next, the factors influencing the saddle point E_5 also need to be analyzed. The value of the point changes in the opposite direction with **F** (the difference in consumption utility brought by online e-commerce sales and offline physical store sales) and **C** (the income of potential sellers using online e-commerce sales and offline physical store sales). When **F** and **C** increase, point E_5 moves to point $E_1(0,0)$, the range of $E_2E_3E_4E_5$ increases, and the points in the area will converge to point $E_4(1,1)$. This shows that potential sellers tend to choose the "online sales" strategy and consumers tend to choose the "buy" strategy when consumers have a better online shopping experience (including product quality, logistics and distribution speed, after-sales service attitude, etc.). The reasons are that the consumption utility of online e-commerce is far greater than that of offline physical stores and that online e-commerce sales have more income than physical stores. In contrast, potential market entrants tend to choose the "offline sales" strategy, while consumers tend to choose the "do not buy" strategy.

6. Simulation Analysis

6.1 Numerical Simulation

To better simulate actual decision-making, through the investigation of online e-commerce and offline stores in the fresh food industry, the parameter values in this paper are shown in **Table 5**.

Table 5. Parameter Values

a	b	λ_0	δ_1	δ_2	P_1	P_2	η_1	η_2	S_1	S_2
1	0.5	0.5	6	5	4.99	6.5	0.8	0.6	3	4

The above parameters are substituted into the dynamic replication equation, and the probabilities *x* and *y* are set to cycle from 0 to 1. MATLAB is used to simulate the decision-making game process of both parties (**Fig. 5**).

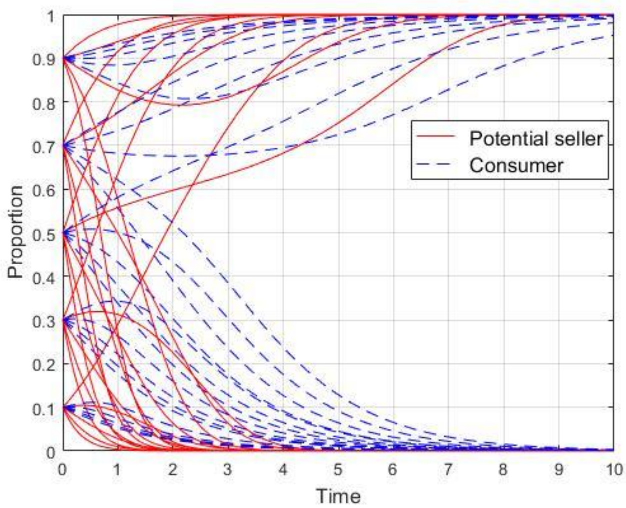

Figure 5. Evolutionary Path Diagram of the Two Sides of the Game

The evolutionary path diagram reveals that when the selection probability *x*, *y* is less than 0.5, both potential sellers and consumers eventually converge to (0, 0). This is the strategy of choosing (offline sales, do not buy). When the selection probability *x*, *y* is not less than 0.5, potential sellers may choose "online sales" or "offline sales". Consumers may choose the "buy" or "do not buy" strategy. However, as the selection probability *x* and *y* increase, potential sellers will be more inclined to choose the "online sales" strategy, and consumers will be more inclined to choose the "buy" strategy.

6.2 Sensitivity Analysis

To further study the final decision-making factors that affect potential sellers and consumers, this article analyzes consumer price preference, quality preference, the products' quality in online e-commerce platforms and offline stores, technology input costs, product prices, and transportation costs.

6.2.1 Sensitivity Analysis of Consumer Price Ppreference and Quality Preference

Under the condition that other conditions remain unchanged, the numerical simulation comparison analysis is performed by changing the size of the consumer price preference coefficient **b** and the quality preference coefficient λ_0. It is found that the consumer chooses the "do not buy" strategy when the consumers' price preference coefficient is larger, and the commodity price exceeds the consumers' maximum acceptable price (**Fig. 6(a)**). When the consumers' quality preference coefficient is greater, consumers will be more inclined to buy products in channels with higher technology input costs (**Fig. 6(b)**). And consumer strategy choice will also affect the decision-making of potential entrants over time.

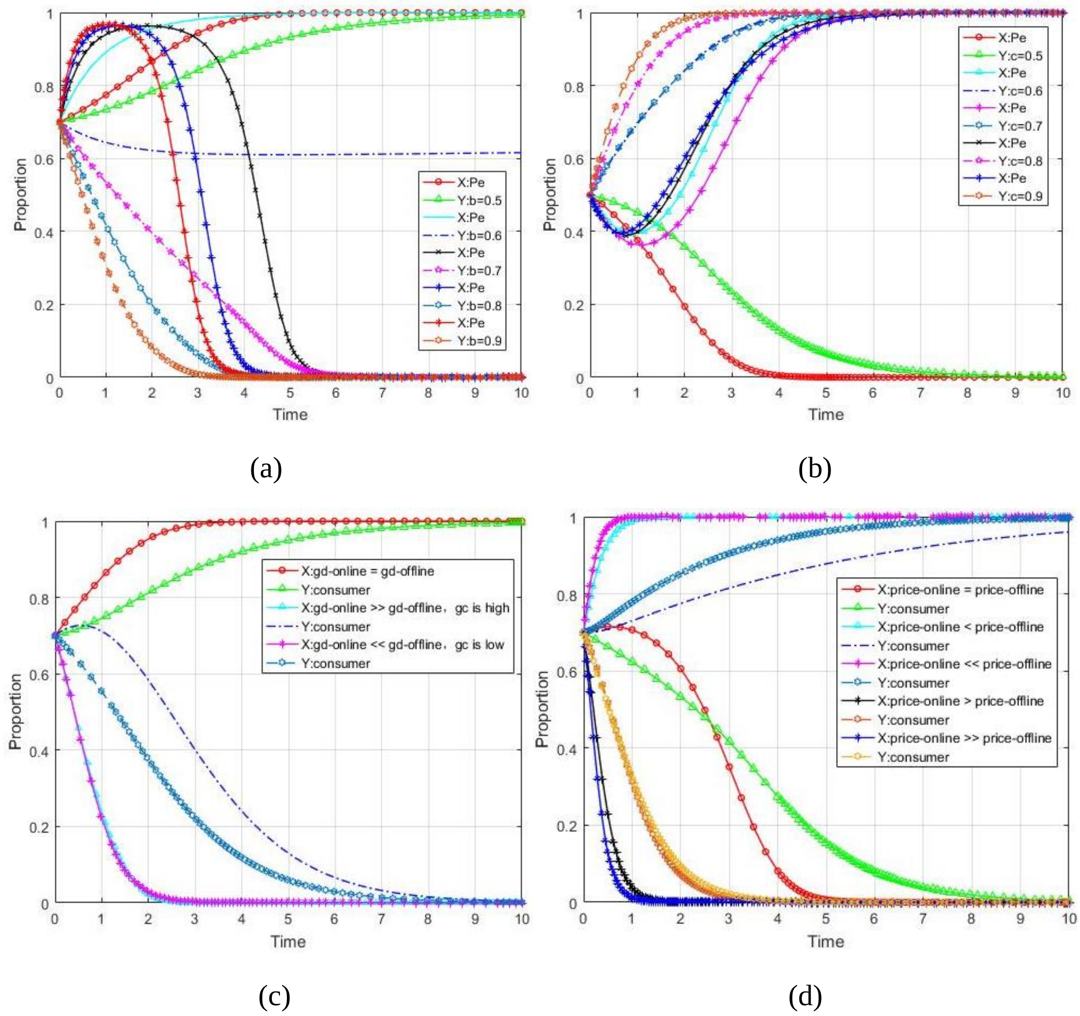

Figure 6. Sensitivity Analysis of Consumer Price Preference, Quality Preference and Product Quality, Technology Input Cost and Product Price

6.2.2 Sensitivity Analysis of Product Quality and Technology Input Cost

The technology input costs **I** are a function of product quality and are closely related to each other. Therefore, this paper carries out a sensitivity analysis of product quality and technology input costs together. MATLAB software is used to substitute for the numerical simulation for three cases, and the technology input cost is controlled by changing the quality coefficients δ_1 and δ_2 of the product (**Fig. 6(c)**). The results show that potential entrants will choose the strategy of “online sales” and consumers choose the “buy” strategy when the quality of products on the e-commerce platform is similar to that of offline stores. However, potential entrants choose “offline sales”, and consumers choose the “do not buy” strategy when the technology input cost of the e-commerce platform is too high or too low. This indicates that the technology input cost of potential entrants should not be too high or too low, and the product quality should be consistent with the quality of offline sales stores.

6.2.3 Sensitivity Analysis of Product Price

By adjusting the values of product prices P_1 and P_2, five situations, as shown in **Figure 6(d)**, are simulated. It can be seen from the simulation that when the price of an e-commerce platform is slightly lower than that of offline stores, consumers will choose the “buy” strategy, and potential sellers will also choose the “online sales” strategy. This scenario fully demonstrates the phenomenon of small profits but quick turnover. However, when the price of the e-commerce platform is similar to or higher than the price of the offline physical store, the choice of potential sellers will converge to the “offline sales” strategy, and the consumer’s choice will converge to the “do not buy” strategy.

Therefore, they should adopt a low-price strategy if potential entrants choose “online sales”, lower than offline stores. In real life, various forms of promotional activities, such as the group purchase mode, hourly spikes, and “cut one knife”, can be adopted in e-commerce sales. Compared with those in offline physical stores, e-commerce promotion activities are novel and inexpensive and can be quickly adjusted and controlled according to changes in consumer demand. Through message pushes, consumers can be quickly attracted. Thus, online e-commerce will expand the scope of sales and have greater influence.

6.2.4 Sensitivity Analysis of the Difference between Transportation Cost and Service Cost

In this paper, five situations shown in **Figure 7** are simulated by changing the sizes of S_1 and S_2. The purpose of this measure is to explore whether the transportation cost S_1 of online sales and the service cost S_2 of offline stores have an impact on the decision of potential entrants.

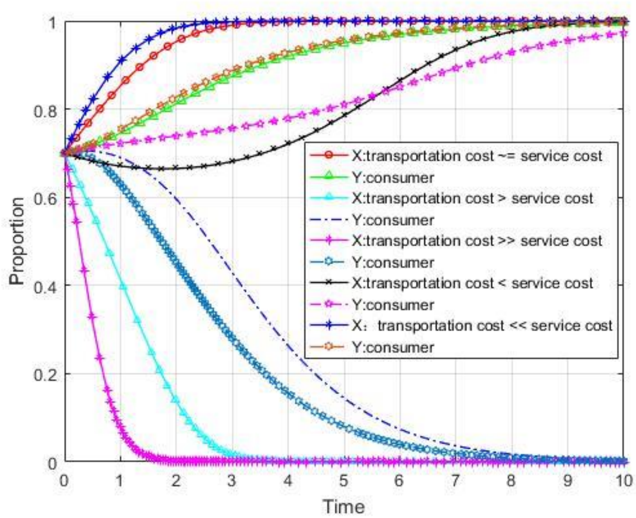

Figure 7. Sensitivity Analysis of the Difference between Transportation Cost and Service Cost

The simulation results show that transportation and service costs significantly affect the decision-making choices of both parties in the game. When the online e-commerce transportation cost is not higher than the service cost needed for physical store sales, potential sellers and consumers choose the “online sales” and “buy” strategies, respectively. In contrast, it chooses to converge on the “offline sales” and “do not buy” strategies.

7. Conclusion

7.1 Key Findings

Potential entrants should fully consider the uncertainty of market demand before entering the market. This approach can help potential entrants make more favorable decisions that predict the behaviors of incumbents and consumers. We establish a Stackelberg game model between potential entrants and incumbents considering the freshness and greenness of fresh produce under the uncertain market demand. This model can help potential entrants choose the optimal price, optimal output, optimal freshness and greenness of products after fully predicting the behaviors of incumbents. Then, we further analyze how potential entrants entering the market will be more popular with consumers by establishing an evolutionary game model. Furthermore, MATLAB software is used for numerical simulation and sensitivity analysis. The main conclusions are as follows:

The results suggest that a strong price preference among consumers is a challenge for both incumbents and potential entrants; conversely, an increased preference for product quality tends to benefit the fresh food retail industry. When potential entrants choose to sell online, consumers show considerable uncertainty in their purchasing decisions, which leads these entrants to adopt a low-price strategy, as lower prices compared to offline stores increase the likelihood of consumer purchases. In addition, it is important that the technology input costs associated with online and offline sales remain moderate—not excessively high or low—while ensuring that the quality of online products is comparable to that of their offline counterparts. Meanwhile, the transport costs associated with online sales should not exceed the service costs of offline stores. Given that consumers have a certain tolerance for transport time in online transactions, potential entrants can afford to keep their transport input costs at a reasonable level without significantly affecting consumer satisfaction.

In summary, potential entrants in the fresh food retail industry should seize the opportunity to enter the market. In the context of the current perfectly competitive market, they can choose to enter the market according to the optimal product strategy and the optimal channel strategy to achieve the maximum profit. At the same time, potential entrants need to pay attention to improving the technology, and controlling the quality of fresh products, such as freshness, organicity, traceability of process, and tracking of distribution logistics. In addition, improving innovation in management modes and product diversity will further increase the chances of success. For example, they can adopt lean stock levels, just-in-time supply, and a quality management system to advance to the supplier. Moreover, the supply of fresh products can be timely and individualized to consumers' needs and enhance consumers' shopping experience. It is also very important for downstream fresh retailers to build a stable, systematic and streamlined supply chain, such as reducing intermediaries. Potential entrants can choose the most appropriate strategies and management mode according to their own and the market situation.

7.2 Limitations

We innovatively study the game process between incumbents, potential entrants and consumers from the perspective of potential entrants in the case of uncertain market demand. Many factors, such as consumer preference, the greenness and freshness of fresh products, product quality, and technology input costs, are fully considered. This can guide potential entrants to make optimal decisions, control their market entry strategies more accurately, and optimize market performance and profits.

This study also has several limitations. First of all, this paper assumes that potential entrants can choose only one channel through which to enter the market, without considering the mode of combining online and offline channels. Secondly, the model proposed in this paper is not suitable for long-term decision analysis, because incumbents' decisions may change in the long-term.

In the future, we can analyze dynamic games from a long-term perspective, and increase the use of online and offline dual-channel development modes. In addition, we can join more decision makers such as suppliers or logistics providers in the fresh market for expanded research.

Data Sharing

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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