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# PRICE STRATEGY OF COMMUNITY FRESH FOOD E-COMMERCE CONSIDERING THE HETEROGENEOUS NEEDS OF CONSUMERS AND FRESH QUALITY TRANSPARENCY

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**Abstract.** High online operating costs and low consumer utility still need to be addressed in the sales of community fresh e-commerce. Herein, we develop a new community fresh marketing model composed of retailers for online operating costs and consumers for low consumer utility by dividing community consumers into essential type and expectant type in this study. Then, the profit functions of community fresh retailers are developed in this study according to utility theory. Finally, a revised model of the fresh quality transparency (FQT) factor is conducted and discussed in this study. The results suggest that the profits obtained from essential consumers and expectant consumers by the community fresh e-commerce retailers are higher within a certain range of freshness costs compared to the basic model's projection; meanwhile, the profits from expectant consumers contribute more than those from essential consumers. However, if the freshness cost exceeds a certain critical value, the abovementioned profits predicted from the new model will be lower. This study enriches the supply chain theory of community fresh food and provides retailers with theoretical guidance on differentiated services and pricing to better match the needs of community consumers.

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## 1. Introduction

Fresh food possesses the characteristics of perishability and short lifecycle, which necessitate the adoption of cold chain distribution for fresh food delivery in the e-commerce sector in recently decades. Consequently, this entails additional distribution costs, rendering online sales of fresh food devoid of advantages when compared to offline sales. For example, fresh e-commerce as one of online sale has encountered many problems with a large number of losses since 2021, and many early established fresh e-commerce enterprises have gone out of business. Here's another example, a giant fresh e-commerce company named Hemaxiansheng started to close some of its

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stores in 2019. The academic community has conducted extensive researches on the development of fresh food e-commerce. The primary areas of fresh food e-commerce revolve around cold chain logistics for fresh food, the preservation efforts by members of the fresh food supply chain, and the factors influencing consumers' online purchase of fresh food [1–6], especially in the field of community fresh food e-commerce.

Community fresh food e-commerce is an integral component of the fresh food e-commerce sector, that include the community retailers, consumers, information platforms, etc. The purpose of community fresh e-commerce is to serve the life of community groups. Community groups view the information of fresh agricultural products and place orders through internet platforms such as mobile clients or WeChat applets. These applets commonly have the problems of high operating costs and, thus, a very difficult time achieving profits [7, 8]. However, community fresh e-commerce has developed rapidly, especially under the impact of COVID-19 in recent years, so it has been further accepted by more consumers. With the rise of "new retail" in recent years, community fresh e-commerce is also accelerating the integration of online and offline sales [9]. Previous research has paid limited attention to the preferences of different community fresh food consumers (mainly for heterogeneous consumers) and their impact on pricing and profits for fresh food retailers. Currently, research on community fresh food e-commerce remains relatively scarce. Existing studies primarily focus on community group buying and the business models of community fresh food e-commerce [8, 10, 11]. For example, it has done through the establishment of community WeChat groups made in China, that the community fresh food e-commerce is carried out for the group purchases by WeChat after releasing relative information from WeChat. Therefore, this study aims to investigate the influence of heterogeneous consumers on pricing and profits for community fresh food e-commerce retailers. In this study, community fresh food consumers are distinguished based on two primary characteristics: fresh food prices and fresh food quality [10]. So far in more developed regions of China, the numerous consumers who prioritize fresh food quality and are relatively insensitive to price, are named as the "expectant consumers" in this study. On the other hand in third- and fourth-tier cities in China, the majority of consumers who considering the order of the fresh food prices and the fresh food quality, respectively [4, 5, 12], are named as the "essential consumers".

Concurrently, there is a phenomenon that in first-tier and second-tier cities, there are a large number of community fresh e-commerce retailers, such as Hema Fresh, Ding Dong Food, and Jingdong Fresh, and they have abundant consumers. In third- and fourth-tier cities, most community fresh retailers only have offline channels. These community fresh e-commerce retailers find it difficult to make a profit, primarily because they had failed to consider the heterogeneity of community consumers. The attributes of the fresh food products sold by retailers do not meet the demands of community heterogeneous consumers. Therefore, to meet the needs of community fresh food consumers becomes the primary concern for community fresh food e-commerce retailers. And some studies in recent years indicate that the community fresh food consumers had increasingly concerned on the quality of fresh food and then desired to purchase the high-quality fresh food products [10, 12]. However, information asymmetry between community fresh food e-commerce and community consumers still remains prevalent. Due to numerous food safety issues in recent years, community fresh food consumers have low trust in the quality of fresh food products sold by retailers. Therefore, scholars have conducted extensive research to address the issue of consumer trust [3], that for example, by using blockchain technology for traceability of fresh food products was order to gain the consumer trust [10, 12–15]. Additionally, researchers have studied the technologies for assessing fresh food quality, including the molecular detection and the intelligent packaging [16–18]. The showcasing by consumers for these technologies is live streaming on fresh food e-commerce platforms [38]. The application of these technologies inevitably incurs additional costs for members of the fresh food supply chain, and leads to an increase in the cost of fresh food. Consequently, price fluctuations can affect the purchasing decisions of community consumers. However, community fresh food e-commerce retailers can eliminate information asymmetry between retailers and consumers by adopting corresponding technologies. For example, not only the JD can provide blockchain services to businesses. But also, opening a store in a JD mall allows businesses to set up their own blockchain. Importantly, consumers can trace the source of purchased goods through JD stores with blockchain services, and manufacturers can upload videos of fresh production processes, fresh preservation efforts and quality assurance processes to the chain for consumers

to browse, thus enhancing consumer trust. Another example, the Amazon is also deploying blockchain on its platform.

The fresh food e-commerce sectors by blockchain technology, such as the JD and Amazon, not only increase the fresh quality transparency (FQT), but also provide additional utility to consumers. However, the FQT research obtained by a qualitative perspective and quantitative perspective [19, 20] is still greatly limited and a little information of FQT so far. Therefore, one of the innovations of this study is to link the FQT provided by community fresh food e-commerce retailers with the total cost of fresh food, and investigate the impact of price fluctuations resulting from investments in the FQT on the purchasing decisions of heterogeneous community consumers. Based on the above analysis, to achieve profit and development, community fresh food e-commerce must solve the following problems:

(1) How can the utility of consumers be improved?
(2) How can the needs of heterogeneous consumers be met and the cost of fresh food be controlled to improve the total demand?
(3) How can community fresh food e-commerce retailers control the cost increase of fresh food resulting from investments in FQT, thereby obtaining a greater profit margin?

Based on the above issues, in this study, a community fresh food model consisting of one community fresh e-commerce retailer and two types of consumers is to be established. And introduces the FTQ factor (defined as providing consumers with reliable information about the whole life cycle of fresh production safety, transportation, quality assurance efforts, etc.). Community fresh food e-commerce is aimed at consumers in nearby communities, where demand for fresh food is relatively stable. Community consumers in the form of membership and community fresh retailers constitute a fresh food model for food community sales. Community Fresh retailers build a relatively stable trust relationship by providing consumers in their communities with reliable, fresh food quality information. Community Fresh retailers can classify community consumers into the types of expectant consumers and essential consumers by analyzing membership information and historical purchase records of community consumers. The effect on the pricing and profit of retailer corresponding to essential and expectant consumers is analyzed. The main innovations and contributions of this study are to: (1) Enriching the existing theory of community fresh food e-commerce. (2) Introducing the FQT and quantifying it as a cost factor, thereby influencing fresh food pricing. (3) Defining the two types of heterogeneous consumers (expectant consumers and essential consumers) in the community fresh food context, and analyzing the impact of changes in FQT on pricing and profits for the retailer.

The remainder of this paper is organized as follows: Section 2 provides a literature review. Section 3 is the definition of the problem and the construction of the model, the establishes by the factor model with and without considering the FQT, and the obtains from corresponding optimal pricing and profit. Next, the profit changes of community fresh food retailers are analyzed for two types of consumers in Sections 3.3 and 3.4. The impact of different purchase prices caused by FQT on retailers' profits will be analyzed for the two types of consumers in Section 4 including one relative example analysis. Finally, Section 5 presents the conclusion and management suggestions.

## 2. Literature review

According to the research content of this paper, the literature involved mainly includes three parts: (1) research on community fresh e-commerce; (2) heterogeneous consumers; and (3) the impact of fresh food quality inputs on pricing and profits for retailers.

Research on community fresh e-commerce mainly focuses on community group buying, community-supported agriculture and logistics, etc. Zhan and Jiang [21] studied the distribution cost and time of community fresh e-commerce logistics and designed an MGA algorithm that can effectively reduce the cost of fresh distribution. Marie and Ludwig [22] studied the common values of participants and nonparticipants in community-supported agriculture and proposed effective strategies to promote the development of community-supported agriculture.

Liu and Zhao [8] studied a game model composed of a community fresh food e-commerce platform and community leaders based on the concept of value cocreation and analyzed its coordination and influence on the supply chain. With the development of new retail, the development trend of community fresh food is multi-channel coexistence and effective integration. Optimizing the supply chain and maximizing the benefits of the supply chain are also the focus of many scholars [23]. Some factors such as the COVID-19 pandemic have also led to the emergence of new models in community fresh food e-commerce, significantly impacting traditional community fresh food sales models [24]. For instance, a crowdsourcing and crowdfunding community fresh food sales approach is reported, that a localized community fresh food supply model form community retailers and consumers was designed [23]. Community retailers or agents recommended by community consumers supervise the quality assurance process of fresh food production, the optimal quality efforts and the wholesale prices for producers are discussed. This creates a closed-loop flow of fresh food quality feedback and the improvement among consumers, retailers, and producers [25]. In contrast to the aforementioned research, the community fresh food e-commerce model is to developed in this study by conducting the factor of heterogeneous consumers. In this study by selecting fresh food quality and price as differentiating factors of consumer heterogeneity [10, 26] is to innovated as a community fresh food e-commerce model, mainly by FQT and between the heterogeneous consumers and retailers for fresh food pricing and relative profits.

In recent years, scholars have paid more attention to the impact of heterogeneous consumers on the fresh supply chain, and Li *et al.* [7]. Taking Nanchang city as an example, community consumers are divided into three categories: trending type, intermediate type and insensitive type. The questionnaire is designed according to multiple dimensions of consumers' attention. Studies have shown that three types of consumers have different factors affecting the purchase of fresh food, and precision marketing strategies have been proposed for these three types of consumers. Wu *et al.* [27] studied the sensitivity of heterogeneous consumers to the price increase caused by four pork quality monitoring indicators. The results showed that age, family monthly income and education level were the main characteristics used to distinguish the heterogeneity of consumers. Clinton and Rodney [28] studied the impact of safe food labels on heterogeneous consumers of different ages. Avi Herbon [29–31] studied the different sensitivities of heterogeneous consumers to the freshness of fresh products, and the dynamic pricing model was designed. Research shows that the application of the model can effectively improve the profits of retailers. Jin *et al.* [26] studied the influencing factors of heterogeneous consumers' demand for fresh milk. Yan *et al.* [32] studied fresh consumers, which can be divided into strategy, short-sighted, and buying on dips, and studied the strategy type consumer impact on fresh pricing and profits of the supply chain. From the aforementioned studies, it is evident that consumers exhibit various heterogeneous characteristics. However, when purchasing fresh food products, consumers uniformly value fresh food quality including the quality assurance of production, storage, transportation processes, etc.

Currently, research on fresh food quality primarily focuses on two aspects: (1) the detection of fresh food quality using technologies such as wireless sensor networks, intelligent packaging, molecular techniques, and 3D laser scanning for assessing the quality level of fresh food [16–19, 33, 34]. (2) The communication of fresh food quality information to consumers for enhancing their trust. Research has mainly been conducted on utilizing blockchain technology for traceability of fresh food, with numerous studies in this area of fresh food quality information [12–15]. Wang and Zhao [1] consider the role of consumers' food safety awareness, and an optimized fresh food supply chain model was established by studying and analyzing the optimal investment level of cold chain preservation and advertising expenditure. The analysis shows that collaborative cold chain investment and collaborative pricing are the optimal strategies of the supply chain. Strong consumer awareness of food safety can promote mutual cooperation among supply chain members, strengthen cold chain investment, and realize the improvement of supply chain members' profits [11, 32, 35–37]. Research also suggests that enhancing consumer trust enhances their willingness to purchase fresh food [3]. Consumers primarily obtain information about fresh food quality through introductions from retailers or platforms, often conveyed through images, videos, and brief textual descriptions. However, due to the roles of consumers and retailers, consumers tend to have low trust in the display of fresh food quality information provided by retailers [7]. The innovation of this study is to lies in investigating how retailers, based on the demands of two types of heterogeneous consumers,

can deliver a certain level of information about the quality of fresh food to consumers while controlling the cost of fresh food in order to achieve profit growth. In this study, the fresh quality information that consumers care about is defined as the FQT. The FQT is defined as community fresh retailers providing consumers with credible information about the whole life cycle of fresh safety production, transportation, quality assurance efforts and so on.

The above literature discusses the problem of the supply chain model, raw quality detection and heterogeneous consumers in the community, and there is very little literature that studies the influence of the supply chain to link the community fresh, fresh quality information and consumers of different demand types. Research on the impact of fresh consumer demand on the supply chain is insufficient, and there is little research on the utility of community fresh consumers and the effect of different types of consumers on the pricing and profit of fresh retailers. Therefore, this paper takes community fresh e-commerce as the research object and introduces two key factors: heterogeneous consumers and FQT. Community fresh consumers who pay more attention to price are defined as essential consumers, and community fresh consumers who pay more attention to FQT, followed by fresh price, are defined as expectant consumers. According to the utility functions of the two types of consumers, the basic model of community fresh without considering the TFQ and the community fresh sales model considering the TFQ were established. The critical conditions of the two types of consumers affecting the optimal decision of the current community fresh retailers were discussed, and the impact of the demand difference caused by the different fresh utilities of the two types of consumers on the profit and pricing of community fresh retailers was analyzed.

## 3. Problem descriptions and model establishment

In this study, a one-period fresh sales model composed of a fresh consumer group and a community of fresh retailers is assumed. Community fresh retailers adopt the sales mode combining online and offline, and the consumers targeted by community fresh retailers are consumers in nearby communities. Due to the strong timeliness of fresh food, it is assumed that community fresh retailers adopt the preposition warehouse and booking mode to ensure that community consumers can obtain fresh food in time. When purchasing fresh food, community fresh food consumers mainly focus on the utility size brought by fresh food quality to decide whether to buy or not [11]. Retailers establish two channels, including online and offline. This study assumes that the pricing of fresh food is the same in both channels, but does not consider the difference in pricing between the online and offline channels. And meantime, the online channel enables the full display of fresh food quality, but does not consider the logistics and distributions of fresh food for online orders by community fresh food consumers in this study.

According to utility theory, the utility level of essential and expectant consumers decreases as the price of fresh food increases. However, the sensitivity to fresh food prices is different for the two types of consumers, which means that there are two kinds of consumers with different utility prices. In the first- and second-tier cities, the online pricing of community fresh is generally higher than that of the traditional vegetable market, but it provides better experience and FQT than the traditional vegetable market, and there is often a large proportion of expectant consumers in the first- and second-tier cities, so the development of community fresh e-commerce is better than that of the third- and fourth-tier cities. In third- and fourth-tier cities, essential consumers in the community account for a large proportion, and they are sensitive to price. In addition, relatively few consumers buy fresh food online, so they will turn to other channels. This also explains why a small number of profitable community fresh foods are concentrated in first- and second-tier cities.

Fresh products have important characteristics, that is, seasonal and timeliness, perishable and vulnerable. Once fresh food enters the sales link, its freshness will continue to decline. In this paper, the FQT factor is introduced to distinguish the existing models. The FQT is defined as the credible information of the whole life cycle of fresh food safety production, transportation, quality assurance efforts and so on provided by community fresh food retailers to consumers. This information is mainly presented online and can be realized through modern communication technology and artificial intelligence technology. This is how we consider that FQT includes

TABLE 1. Description of relevant parameters of the model.

| Variable | Meaning description |
|---|---|
| $\phi$ | Proportion of essential consumers to the initial value of expectant consumers' utility ($0 < \phi < 1$) |
| $a_1, a_2$ | Consumer price sensitivity coefficient of essential and expectant type |
| $b_1, b_2$ | Perception coefficient of freshness for essential and expectant consumers |
| $c$ | FQT coefficient |
| $m$ | Cost coefficient of FQT |
| $L$ | Fresh quality level |
| $\theta$ | The increment of utility brought to consumers by optimal freshness (offline) |
| $\upsilon$ | Initial utility value of fresh food (online) |
| $p_1, p_2$ | Fresh utility price of essential and expectant consumers |
| $g_1, g_2$ | The purchase cost of fresh food for essential and expectant consumers when considering the FQT |
| $\pi_1^{\mathrm{ET}}, \pi_2^{\mathrm{ET}}$ | Expectant profit of community fresh retailers when considering the FQT for essential and expectant consumers |
| $p$ | Fresh price |
| $g$ | Purchase price of fresh food without considering the FQT |
| $\pi_1^E, \pi_2^E$ | Expectant profit of community fresh retailers for essential and expectant consumers when they do not consider the FQT |
| $U_1, U_2$ | Utility function of essential and expectant consumers |

the information on quality effort during the fresh production stage, the quality testing after fresh maturity, the fresh transportation and preservation effort, and the fresh storage and quality assurance. For example, the quality effort of the fresh production process can be shown to community consumers through live video and through the community fresh retailer's online platforms [14,38,39], and the community fresh retailer can organize community fresh member representatives to go to local fresh production areas for relevant experiences. All these specific means can enhance the FQT while strengthening the trust of community consumers. Based on the relevant literature [10,12,23,35], a model was established, and the parameters involved in the model are shown in Table 1 in this study.

Essential consumers are more sensitive to the price of fresh food, while expectant consumers are less sensitive to the price of fresh food. According to random utility theory, we can consider the FQT and establish the utility function for essential consumers and expectant consumers as follows:

$$U_1 = \phi\upsilon - a_1 p_1 + b_1\theta + cL \tag{1}$$

$$U_2 = \upsilon - a_2 p_2 + b_2\theta + cL. \tag{2}$$

The freshness of fresh food is an important factor, and the model assumes that the freshness perceived by consumers online is less than that perceived offline. Therefore, the freshness perceived offline by consumers has an incremental $\theta$, which also increases the utility of consumers. The community fresh food retailers and community fresh food consumers are concerned, but fresh food producers do not be considered in this study. The fresh mass produced by the producer is assumed to be a constant, which is denoted as $L$. The $c$ is the degree of information presented about the quality of the fresh produce. In this study, the $c$ is associated with the cost of the fresh produce. The fresh cost of a community fresh food e-commerce retailer is composed of the fresh purchase cost $g$ and the cost incurred by $c$. The $cL$ represents the utility values generated by the FQT for the consumers. Whether $cL$ has the same impact on essential and expected consumer types has not been confirmed in the fresh food field. To emphasize the main research question, this study assumes that the utility generated by FQT is the same for both essential and expected consumer types.

From the above formula:

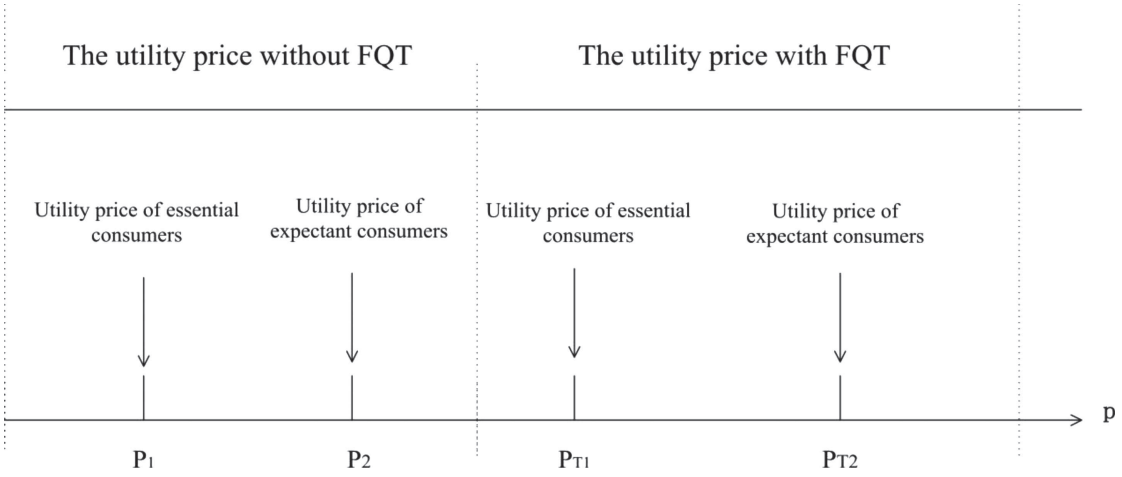


FIGURE 1. Difference in utility prices between essential and expectant consumers considering FQT and not considering FQT.

**Proposition 1.** *The maximum utility price of essential consumers and expectant consumers for the same fresh food is different. The maximum utility price of expectant consumers is greater than that of essential consumers.*

*Proof of Proposition 1.* When $U_1 >= 0$, $U_2 >= 0$, community fresh consumers will buy online. When $U_1 < 0$, $U_2 < 0$, consumers will turn to other fresh sales channels to buy. This paper only considers consumers' online purchases, so there are $\phi v - a_1 p_1 + b_1\theta + cL >= 0$ and $v - a_2 p_2 + b_2\theta + cL >= 0$, obtain $p_1 <= \frac{\phi v + b_1\theta + cL}{a_1}$ and $p_2 <= \frac{v + b_2\theta + cL}{a_2}$.

Because $p_1 - p_2 = \frac{v(a_2\phi - a_1) + \theta(a_2 b_1 - a_1 b_2) + L(a_2 c - a_1 c)}{a_1 a_2}$. According to the characteristics of essential and expectant consumers, for the same fresh products of a community fresh retailer, the essential and expectant types have the same FQT coefficient and freshness perception coefficient, which $b_1 = b_2, a_2 < a_1, \phi < 1$ can be obtained. When other parameters are greater than zero, $p_1 < p_2$. When FQT is not considered, the formula (1) and (2) will do not contain the $cL$ term, and the proof procedure is similar to above. Thus, Proposition 1 is proved. □

Proposition 1 shows that the community consumer groups who consume a particular fresh food can be divided into two types, which are the essential consumers type and the expectant consumers type. The differences in utility prices without FQT and with FQT for essential and expectant consumers are shown in Figure 1.

From Figure 1, there is a case of $P_{T1} > P_1$ for expectant consumers and $P_{T2} > P_2$ for expectant consumers. Whether a consumer purchases fresh food or not is determined by his or her fresh food utility [35], which can be discussed in two cases: considering FQT and not considering FQT. Since there are some similarities between the two cases, only the case without FQT is discussed in this paper. By sales price, the corresponding relationship is:

(1) When the sales price of a specific fresh food $P < P1$.

At this time, the selling price of fresh food is less than the utility price of the essential type and the expectant type. The total utility of consumers is greater than or equal to zero for both types. Both the essential type and the expectant type will choose to buy fresh food. When considering the location of fresh food, community fresh food retailers should consider opening stores in communities mainly composed of essential consumers. On the basis of considering the cost of fresh food, when pricing is close to $P1$ and more relevant services are provided, the maximum profit can be obtained.

(2) When the sales price of a specific fresh food $P1 < P <= P2$.

At this time, the sales price of fresh food is greater than the utility price of the essential type, and the total utility of the essential type consumers will be less than zero. Therefore, the essential type consumers will choose other sales channels to buy fresh food, while the utility price of the expectant type consumers is greater than or equal to the sales price of fresh food, and the expectant type consumers still choose to buy. When considering the layout of community fresh food, retailers should consider that current community consumers are mainly expectant consumers. On the basis of considering the cost of fresh food, when pricing is close to $P2$ and more relevant services are provided, they can obtain the maximum profit.

(3) When the sales price of a specific fresh food $P > P2$.

The sales price of fresh food at this time is greater than the utility price of the essential type and the expectant type. The total utility of both types of consumers is less than zero. Therefore, the essential type and the expectant type consumers will not choose to buy fresh food, and they will select other channels to buy fresh food.

In this study, $P <= P1$ and $P1 < P <= P2$ are considered, and the factor of FQT is included in the fresh procurement cost. Based on the discussion of the boundary conditions of fresh procurement cost. Two models with and without FQT are established for the essential and expectant consumers, respectively, and the optimal pricing and profits are compared between the two models.

### 3.1. Basic model without considering the FQT

A basic model is established according to random utility theory. The research objects of the model are the current community fresh retailers and two types of community fresh consumers, and the utility functions of the two types of consumers are as follows:

$$U_1 = \phi\upsilon - a_1 p_1 + b_1\theta \tag{3}$$

$$U_2 = \upsilon - a_2 p_2 + b_2\theta \tag{4}$$

$\upsilon$ is the probability uniform distribution that obeys $[0, 1]$. When $U_1 >= 0, U_2 >= 0$, $\bar{\upsilon} >= \frac{a_1 p_1 - b_1\theta}{\phi}$ and $\bar{\bar{\upsilon}} >= a_2 p_2 - b_2\theta$ are derived. From formulas (3) and (4), the corresponding demand functions of the two types are:

$$D_1 = \int_{\bar{\upsilon}}^{1} f(\upsilon)\,\mathrm{d}\upsilon = 1 - \frac{a_1 p_1 - b_1\theta}{\phi} \tag{5}$$

$$D_2 = \int_{\bar{\bar{\upsilon}}}^{1} f(\upsilon)\,\mathrm{d}\upsilon = 1 - a_2 p_2 + b_2\theta. \tag{6}$$

When the FQT is not considered, the profit function of community fresh food retailers for essential consumers and expectant consumers is as follows:

$$\pi_1^E = (p_1 - g)D_1 = \frac{p_1\phi - a_1 p_1^2 + b_1\theta p_1 - g\phi + a_1 g p_1 - b_1 g\theta}{\phi} \tag{7}$$

$$\pi_2^E = (p_2 - g)D_2 = p_2 - a_2 p_2^2 + b_2\theta p_2 - g + a_2 g p_2 - b_2 g\theta. \tag{8}$$

**Proposition 2.** *When the FQT factor is not considered, $\pi_1^E$ and $\pi_2^E$ show concavity strictly with respect to $p_1$ and $p_2$; that is, there is optimal pricing $p_1^*$ for the essential consumer and optimal pricing $p_2^*$ for the expectant consumer, which maximizes profits $\pi_1^{E^*}$ and $\pi_2^{E^*}$ of fresh food retailers. Its $p_1^*$, $p_2^*$, $\pi_1^{E^*}$ and $\pi_2^{E^*}$ are, respectively:*

$$p_1^* = \frac{\phi + b_1\theta + a_1 g}{2a_1} \tag{9}$$

$$p_2^* = \frac{1 + b_2\theta + a_2 g}{2a_2} \tag{10}$$

$$\pi_1^{E^*} = \frac{(\phi + b_1\theta - a_1 g)^2}{4a_1\phi} \tag{11}$$

$$\pi_2^{E^*} = \frac{(1 + b_2\theta - a_2 g)^2}{4a_2}. \tag{12}$$

*Proof of Proposition 2.* Due to $\frac{\partial^2_{\pi_1^E}}{\partial_{p_1^2}} = -2\frac{a_1}{\phi} < 0$ and $\frac{\partial^2_{\pi_2^E}}{\partial_{p_2^2}} = -2a_2 < 0$, community fresh produce retailers have optimal pricing for essential consumers and expectant consumers. When $\frac{\partial_{\pi_1^E}}{\partial_{P_1}} = 0$ and $\frac{\partial_{\pi_2^E}}{\partial_{P_2}} = 0$, equations (9) and (10) hold.

Formula (9) is substituted into formula (7) and formula (10) into formula (8) to obtain the community fresh retailers target maximum profits for both types of consumers. Proposition 2 is proved. □

It can be seen from Proposition 2 that $\frac{\partial p_1^*}{\partial_\phi} > 0$, $\frac{\partial p_1^*}{\partial_\theta} > 0$, $\frac{\partial p_1^*}{\partial_g} > 0$, $\frac{\partial p_1^*}{\partial_{a_1}} = \frac{-(\phi+b_1\theta)}{2a_1^2} < 0$; therefore, there is a positive correlation between the optimal pricing of essential consumers and the proportion of essential consumers to the initial utility of expectant consumers, freshness and procurement cost and a negative correlation with the price sensitivity coefficient. In this study, $\emptyset$, $b_1$ and $\theta$ are assumed to be constant for two specific types of consumers, focusing on the impact of $a_1$ and $g$ on the pricing and profits of community fresh retailers.

If the community fresh retailer increases the purchase price, on the basis that the fresh price is less than the essential utility price, the community fresh retailer will inevitably increase the fresh price. With the rise of the price, the demand of the essential consumer will inevitably decline, which will reduce the profits of the fresh retailer. However, the profits of community fresh food retailers can increase by reducing the price sensitivity coefficient of essential consumers and appropriately increasing the fresh food price. Therefore, when considering the location of stores, community fresh retailers should also consider the potential of a large number of fresh consumers in the community to become expectant consumers in the future, which also brings the potential for future profit growth. Similarly, there is a positive correlation between the optimal pricing of expectant consumers and freshness and procurement cost and a negative correlation with the price sensitivity coefficient. Community fresh retailers also consider reducing the purchase price and price sensitivity coefficient as much as possible to obtain the best profit.

### 3.2. Model considering the FQT factor

After adding the factor of FQT on the basis of the base model, the new model is constructed. Then, the two types of consumer utility functions corresponding to the model are as follows:

$$U_1 = \phi\upsilon - a_1 p_1 + b_1\theta + cL \tag{13}$$

$$U_2 = \upsilon - a_2 p_2 + b_2\theta + cL. \tag{14}$$

The demand functions corresponding to the two consumption types are obtained from formulas (13) and (14) as follows:

$$D_1^T = \int_{\bar{\upsilon}}^1 f(\upsilon)\,\mathrm{d}\upsilon = 1 - \frac{a_1 p_1 - b_1\theta - cL}{\phi} \tag{15}$$

$$D_2^T = \int_{\bar{\bar{\upsilon}}}^1 f(\upsilon)\,\mathrm{d}\upsilon = 1 - a_2 p_2 + b_2\theta + cL. \tag{16}$$

There are $\bar{\upsilon} = \frac{a_1 p_1 - b_1\theta - cL}{\phi}$, $\bar{\bar{\upsilon}} = a_2 p_2 - b_2\theta - cL$. When considering the FQT, it is assumed that the cost of the FQT is fully included in the procurement cost of the community fresh retailer for the fresh. The increase in FQT will lead to an increase in the marginal purchase cost of community fresh retailers. Set $g_1 = g_2 = g + \frac{mc^2}{2}$, which is the fresh purchase cost of the corresponding essential and expectant consumers after considering the

FQT [23]. The profit function of community fresh retailers corresponding to essential consumers and expectant consumers is as follows:

$$\pi_1^{\mathrm{ET}} = (p_1 - g_1)D_1^T = \frac{p_1\phi - a_1p_1^2 + b_1\theta p_1 - g_1\phi + a_1g_1p_1 + cLp_1 - b_1g_1\theta - cLg_1}{\phi} \tag{17}$$

$$\pi_2^{\mathrm{ET}} = (p_2 - g_2)D_2^T = p_2 - a_2p_2^2 + b_2p_2\theta - g_2 + a_2g_2p_2 - b_2g_2\theta + p_2cL - g_2cL. \tag{18}$$

**Proposition 3.** *When considering the FQT, $\pi_1^{\mathrm{ET}}$ and $\pi_2^{\mathrm{ET}}$ show concavity strictly with respect to $p_1$ and $p_2$, respectively; that is, there is optimal pricing $p_1^*$ and FQT $c_1^*$ for the essential consumer and $p_2^*$ and $c_2^*$ for the expectant consumer for a certain fresh product, which maximizes the profits $\pi_1^{\mathrm{ET}}$ and $\pi_2^{\mathrm{ET}}$ of the community fresh retailers for essential and expectant consumers. Its $c_1^*$, $p_1^*$, $c_2^*$, $p_2^*$, $\pi_1^{\mathrm{ET}^*}$, and $\pi_2^{\mathrm{ET}^*}$ are, respectively:*

$$c_1^* = \frac{L}{a_1m} \tag{19}$$

$$p_1^* = \frac{\phi + b_1\theta + a_1g_1 + cL}{2a_1} \tag{20}$$

*where* $g_1 = g + \frac{mc^2}{2}$, $c = c_1^*$

$$c_2^* = \frac{L}{a_2m} \tag{21}$$

$$p_2^* = \frac{1 + b_2\theta + a_2g_2 + cL}{2a_2} \tag{22}$$

*where* $g_2 = g + \frac{mc^2}{2}, c = c_2^*$

$$\pi_1^{\mathrm{ET}^*} = \frac{(\phi + b_1\theta - a_1g_1 + cL)^2}{4a_1\phi} \tag{23}$$

*where* $g_1 = g + \frac{mc^2}{2}, c = c_1^*$

$$\pi_2^{\mathrm{ET}^*} = \frac{(1 + b_2\theta - a_2g_2 + cL)^2}{4a_2} \tag{24}$$

*where* $g_2 = g + \frac{mc^2}{2}, c = c_2^*$.

*Proof of Proposition 3.* According to the profit function of community fresh retailers for essential and expectant consumers, as shown in (17) and (18). Aiming at the maximum profit of community fresh retailers, the Hesse matrix of $p_1$ and $c$ profit function for essential consumers is as follows:

$$\begin{bmatrix} -\frac{2a_1}{\phi} & \frac{L+a_1cm}{\phi} \\ \frac{L+a_1cm}{\phi} & \frac{-m(3Lc-a_1p_1+b_1\theta+\phi)}{\phi} \end{bmatrix}.$$

Because, when $-\frac{2a_1}{\phi} < 0$, $\frac{2a_1m(3Lc-a_1p_1+b_1\theta+\phi)}{\phi^2} - \left(\frac{L+a_1cm}{\phi}\right)^2 > 0$, it is deduced that the matrix is negative definite, and we solve the system $\begin{cases} \frac{\partial_{\pi_1^{\mathrm{ET}}}}{\partial_{p_1}} = 0 \\ \frac{\partial_{\pi_1^{\mathrm{ET}}}}{\partial_c} = 0 \end{cases}$. Through calculation, we can obtain $p_1^*$ and $c_1^*$.

The Hesse matrix of $p_2$ and $c$ for the expectant consumer profit function is as follows:

$$\begin{bmatrix} -2a_2 & L + a_2cm \\ L + a_2cm & -m(3cL - a_2p_2 + b_2\theta + 1) \end{bmatrix}.$$

Because $-2a_2 < 0$, when $2a_2m(3cL - a_2p_2 + b_2\theta + 1) - (L + a_2cm)^2 > 0$, it is deduced that the matrix is negative definite. By solving the system $\begin{cases} \frac{\partial_{\pi_2^{\mathrm{ET}}}}{\partial_{p_2}} = 0 \\ \frac{\partial_{\pi_2^{\mathrm{ET}}}}{\partial_c} = 0 \end{cases}$ through calculation, we can obtain $p_2^*$ and $c_2^*$. Substitute $c_1^*, p_1^*, c_2^*, p_2^*$ into the profit function to obtain the maximum profit (23) and (24) and obtain the proof. □

It can be seen from Proposition 3 that when considering the FQT and assuming the optimal freshness, because $\frac{\partial p_1^*}{\partial \phi} > 0$, $\frac{\partial p_1^*}{\partial \theta} > 0$, $\frac{\partial p_1^*}{\partial g} > 0$, $\frac{\partial p_1^*}{\partial L} > 0$, $\frac{\partial p_1^*}{\partial a_1} = \frac{-(\phi + b_1\theta + cL)}{2a_1^2} < 0$, the optimal pricing of community fresh retailers for essential consumers and the proportion of essential consumers in the initial utility of expectant consumers, the freshness, the purchase price and the FQT are positively correlated, and it is negatively correlated with the price perception coefficient. In this study, $\phi$, $b_1$ and $\theta$ are assumed to be constant for two specific types of consumers, so it mainly depends on $a_1, g, c, L$.

If community fresh retailers improve the FQT, the purchase cost of fresh food will inevitably increase at the same time. On the basis that the fresh food price is less than the essential utility price, community fresh retailers will inevitably increase the fresh food price. With the rise in price, the demand of essential consumers will decline, which will reduce the profits of community fresh retailers for essential consumers. Community fresh retailers can only increase the fresh price appropriately by reducing the price perception coefficient of essential consumers and not increasing the procurement cost so that the profits of community fresh retailers will increase. Therefore, when considering the location of stores, community fresh retailers should also consider the potential of a large number of fresh consumers in the community to become expectant consumers in the future. Similarly, the optimal pricing of community fresh retailers for expectant consumers and the freshness, purchase price and FQT are positively correlated, and it is negatively correlated with the price perception coefficient. Therefore, community fresh retailers also consider reducing the purchase price and price perception coefficient as much as possible to obtain the best profit, which corresponds to the fact that the site selection of community fresh retailers tries to target the community where fresh consumers are mainly expected. In such communities, there are a large number of fresh food consumers with low price perception coefficients.

## 3.3. Analysis of the influence of FQT factors

In this section, the impact of essential and expectant consumers on the profits of community fresh retailers after the introduction of FTQ are analyzed.

### *3.3.1. Profit impact on essential consumers*

From equations (11) and (23):

$$\pi_1^{\mathrm{ET}^*} - \pi_1^{E^*} = \frac{(\phi + b_1\theta - a_1g_1 + cL)^2 - (\phi + b_1\theta - a_1g)^2}{4a_1\phi}. \tag{25}$$

In the case where $\phi$, $b_1\theta$, and $cL$ are determined, we discuss the impact of the increase in fresh purchase cost on the profits of community fresh retailers. According to formula (25), Corollary 1 can be obtained.

**Corollary 1.** *When both* $g \le \frac{\phi + b_1\theta}{a_1}$ *and* $g_1 \le g + \frac{cL}{a_1}$ *or both* $g > \frac{\phi + b_1\theta}{a_1}$ *and* $g_1 \le \frac{2\phi + 2b_1\theta + cL}{a_1} - g$, $\pi_1^{\mathrm{ET}^*} \ge \pi_1^{E^*}$; *otherwise,* $\pi_1^{\mathrm{ET}^*} < \pi_1^{E^*}$.

*Proof of Corollary 1.* When $\pi_1^{\mathrm{ET}^*} - \pi_1^{E^*} = \frac{(\phi + b_1\theta - a_1g_1 + cL)^2 - (\phi + b_1\theta - a_1g)^2}{4a_1\phi} \ge 0$, the community fresh retailers will gain greater profits when considering FQT factors. From the above equation, we obtain that as long as $\frac{[2\phi + 2b_1\theta - a_1(g_1 + g) + cL][a_1(g - g_1) + cL]}{4a_1\phi} \ge 0$, because $a_1 > 0$ and $\phi > 0$, $[2\phi + 2b_1\theta - a_1(g_1 + g) + cL] \ge 0$ and $[a_1(g - g_1) + cL] \ge 0$ are both true, or $[2\phi + 2b_1\theta - a_1(g_1 + g) + cL] \le 0$ and $[a_1(g - g_1) + cL] \le 0$ are both true. Considering FQT and other factors to determine the case, the lower the total cost of fresh produce is, the larger the profit for community fresh retailers. Therefore, the cases where the above equations are both less than 0 can be eliminated, so the total fresh cost can be solved as $g_1 \le g + \frac{cL}{a_1}$ and $g_1 \le \frac{2\phi + 2b_1\theta + cL}{a_1} - g$. When

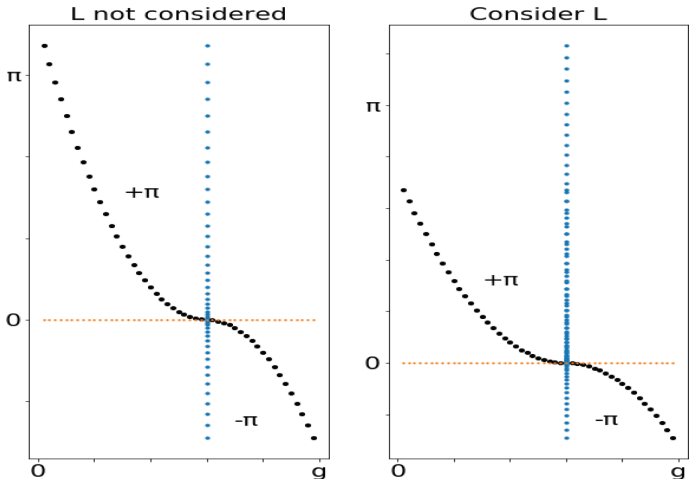


FIGURE 2. The changes in fresh food purchase costs and profits of community fresh retailers for essential consumers.

$g + \frac{cL}{a_1} \leq \frac{2\phi+2b_1\theta+cL}{a_1} - g$, that is, $g \leq \frac{\phi+b_1\theta}{a_1}$, we just need $g_1 \leq g + \frac{cL}{a_1}$. When $g + \frac{cL}{a_1} > \frac{2\phi+2b_1\theta+cL}{a_1} - g$, that is $g > \frac{\phi+b_1\theta}{a_1}$, we just need $g_1 \leq \frac{2\phi+2b_1\theta+cL}{a_1} - g$.

In addition to the above fresh costs, the continuous rise of procurement costs makes fresh prices rise, which leads to a decline in the demand of community fresh consumers. When the fresh purchase price exceeds a certain critical value, the community fresh retailers will start to lose money, that is, the profit is negative. Its changes are shown in Figure 2.

Therefore, for both $g \leq \frac{\phi+b_1\theta}{a_1}$ and $g_1 \leq g + \frac{cL}{a_1}$ or both $g > \frac{\phi+b_1\theta}{a_1}$ and $g_1 \leq \frac{2\phi+2b_1\theta+cL}{a_1} - g$, $\pi_1^{\mathrm{ET}^*} \geq \pi_1^{E^*}$; otherwise, $\pi_1^{\mathrm{ET}^*} < \pi_1^{E^*}$, and Corollary 1 is proved. □

After considering the FQT, community fresh retailers will inevitably increase the fresh cost, so the purchase price will certainly be greater than the purchase price without considering the FQT. Therefore, when $g_1 \in (g, \frac{cL}{a_1} + g)$, the community fresh retailers considering the FQT will obtain more profits than when not considering the FQT, and the smaller the purchase price in this range, the greater the profit will be obtained. When $g_1 = \frac{cL}{a_1} + g$, regardless of whether the FQT is considered, community fresh retailers will obtain the same profit. When $g_1 > \frac{cL}{a_1} + g$, the profit considering the FQT will be less than the profit without considering the FQT, and the same is true in the other interval. Thus, for communities dominated by essential consumers, community fresh retailers can strive to improve the FQT, reduce the price sensitivity coefficient of community fresh consumers by improving corresponding services, and realize the maximum profit of community fresh retailers in controlling fresh purchase costs.

*3.3.2. Profit impact on expectant consumers*

From equations (12) and (24), we can obtain:

$$\pi_2^{\mathrm{ET}^*} - \pi_2^{E^*} = \frac{(1 + b_2\theta - a_2g_2 + cL)^2 - (1 + b_2\theta - a_2g)^2}{4a_2}. \tag{26}$$

In the case where $b_2\theta$ and $cL$ are determined, we discuss the impact of the increase in fresh purchase cost on the profits of community fresh retailers, and Corollary 2 can be obtained from formula (26).

**Corollary 2.** *When both* $g \leq \frac{1+b_2\theta}{a_2}$ *and* $g_2 \leq g + \frac{cL}{a_2}$ *or both* $g > \frac{1+b_2\theta}{a_2}$ *and* $g_2 \leq \frac{2+2b_2\theta+cL}{a_2} - g$, $\pi_2^{\mathrm{ET}^*} \geq \pi_2^{E^*}$; *otherwise,* $\pi_2^{\mathrm{ET}^*} < \pi_2^{E^*}$.

TABLE 2. The profit change statement corresponding to the difference in fresh purchase costs when considering the FQT ($g \leq \frac{\phi+b_1\theta}{a_1}$).

| Consumer type | Purchase price range | | |
|---|---|---|---|
| | $\left(g, \frac{cL}{a_1}+g\right]$ | $\left(\frac{cL}{a_1}+g, \frac{cL}{a_2}+g\right]$ | $\left(\frac{cL}{a_2}+g, +\infty\right)$ |
| Essential type | $\pi_1^{\mathrm{ET}^*} \geq \pi_1^{E^*}$ | $\pi_1^{\mathrm{ET}^*} < \pi_1^{E^*}$ | $\pi_1^{\mathrm{ET}^*} < \pi_1^{E^*}$ |
| Expectant type | $\pi_2^{\mathrm{ET}^*} > \pi_2^{E^*}$ | $\pi_2^{\mathrm{ET}^*} \geq \pi_2^{E^*}$ | $\pi_2^{\mathrm{ET}^*} < \pi_2^{E^*}$ |

*Proof of Corollary 2.* When $\pi_2^{\mathrm{ET}^*} - \pi_2^{E^*} = \frac{(1+b_2\theta-a_2g_2+cL)^2-(1+b_2\theta-a_2g)^2}{4a_2} \geq 0$, the community fresh retailers will gain greater profits when considering FQT factors. From the above equations, we obtain as long as $\frac{[2+2b_2\theta-a_2(g_2+g)+cL][a_2(g-g_2)+cL]}{4a_2} \geq 0$ because $a_2 > 0$, so $[2+2b_2\theta-a_2(g_2+g)+cL] \geq 0$ and $[a_2(g-g_2)+cL] \geq 0$ are both true, or $[2+2b_2\theta-a_2(g_2+g)+cL] \leq 0$ and $[a_2(g-g_2)+cL] \leq 0$ are both true. Considering FQT and other factors to determine the case, the lower the total costs of fresh produce is, the larger the profits for community fresh retailers. Therefore, the cases that the above equations are both less than 0 can be eliminated, so the total fresh costs can be solved as $g_2 \leq g+\frac{cL}{a_2}$ and $g_2 \leq \frac{2+2b_2\theta+cL}{a_2}-g$, when $g+\frac{cL}{a_2} \leq \frac{2+2b_2\theta+cL}{a_2}-g$, and that is $g \leq \frac{1+b_2\theta}{a_2}$. It just needs $g_2 \leq g+\frac{cL}{a_2}$, when the $g+\frac{cL}{a_2} > \frac{2+2b_2\theta+cL}{a_2}-g$, and that is $g > \frac{1+b_2\theta}{a_2}$, it just need $g_2 \leq \frac{2+2b_2\theta+cL}{a_2}-g$. Therefore, $g \leq \frac{1+b_2\theta}{a_2}$, and $g_2 \leq g+\frac{cL}{a_2}$ are both true, or $g > \frac{1+b_2\theta}{a_2}$ and $g_2 \leq \frac{2+2b_2\theta+cL}{a_2}-g$ are both true. It can be derived that $\pi_2^{\mathrm{ET}^*} \geq \pi_2^{E^*}$; otherwise, $\pi_2^{\mathrm{ET}^*} < \pi_2^{E^*}$, and Corollary 2 is proved. □

After considering the FQT, community fresh retailers will inevitably bring an increase in fresh cost, so the purchase price will certainly be greater than the purchase price without considering the FQT. Therefore, when $g_2 \in (g, \frac{cL}{a_2}+g)$, considering the FQT will obtain more profits than not considering the FQT, and the smaller the purchase price in this range, the greater the profit will be obtained. When $g_2 = \frac{cL}{a_2}+g$, regardless of whether the FQT is considered, community fresh retailers gain the same profit. When $g_2 > \frac{cL}{a_2}+g$, the profit considering the FQT will be less than the profit without considering the FQT, and the same happens in the other interval. Therefore, for communities dominated by expectant consumers, because the price sensitivity coefficient of fresh food is smaller than that of the essential type, community fresh retailers should try to meet the needs of expectant consumers for fresh quality, so great FQT and better experience services are provided for expectant consumers. Community fresh retailers can obtain the maximum profit on controlling the procurement cost of fresh produce.

### 3.4. Analysis of the influence of the FQT factor on the change in fresh purchasing cost

For the same fresh food, the purchase price set by community fresh retailers is different, which affects different types of consumer demand. According to the discussion in Sections 3.3.1 and 3.3.2, the purchase price of fresh food has a certain range, corresponding to the profit changes of community fresh retailers. Corresponding to different types of consumers, compare the two critical points of profit change, because $a_2 < a_1$, then there is $g < g_1 < g_2$, then $\frac{cL}{a_1}+g < \frac{cL}{a_2}+g$. Assuming $b_1 = b_2$, when $g \leq \frac{\phi+b_1\theta}{a_1}$ and $g \leq \frac{1+b_2\theta}{a_2}$ are satisfied at the same time, and because $\frac{\phi+b_1\theta}{a_1} < \frac{1+b_2\theta}{a_2}$, so this is true as long as $g \leq \frac{\phi+b_1\theta}{a_1}$, the corresponding interval are $(g, \frac{cL}{a_1}+g]$, $(\frac{cL}{a_1}+g, \frac{cL}{a_2}+g]$ and $(\frac{cL}{a_2}+g, +\infty)$, and its profit comparison is shown in Table 2.

In the same way, when $g > \frac{\phi+b_1\theta}{a_1}$ and $g > \frac{1+b_2\theta}{a_2}$, we just need $g > \frac{1+b_2\theta}{a_2}$, and there is a corresponding interval $(g, \frac{2\phi+2b_1\theta+cL}{a_1}-g], (\frac{2\phi+2b_1\theta+cL}{a_1}-g, \frac{2+2b_2\theta+cL}{a_2}-g], (\frac{2+2b_2\theta+cL}{a_2}-g, +\infty)$. The profit comparison of fresh retailers is shown in Table 3.

It can be seen from Table 2 that if the fresh procurement cost of the community fresh retailer is within the range of $(g, \frac{cL}{a_1}+g]$. Under the condition of FQT, the utility of consumers is improved, and the profits of

TABLE 3. The profit change statement corresponding to the difference in fresh purchase costs when considering the FQT ($g > \frac{1+b_2\theta}{a_2}$).

| Consumer type | Purchase price range | | |
|---|---|---|---|
| | $\left(g, \frac{2\phi+2b_1\theta+cL}{a_1}-g\right]$ | $\left(\frac{2\phi+2b_1\theta+cL}{a_1}-g, \frac{2+2b_2\theta+cL}{a_2}-g\right]$ | $\left(\frac{2+2b_2\theta+cL}{a_2}-g, +\infty\right)$ |
| Essential type | $\pi_1^{\mathrm{ET}^*} \geq \pi_1^{E^*}$ | $\pi_1^{\mathrm{ET}^*} < \pi_1^{E^*}$ | $\pi_1^{\mathrm{ET}^*} < \pi_1^{E^*}$ |
| Expectant type | $\pi_2^{\mathrm{ET}^*} > \pi_2^{E^*}$ | $\pi_2^{\mathrm{ET}^*} \geq \pi_2^{E^*}$ | $\pi_2^{\mathrm{ET}^*} < \pi_2^{E^*}$ |

community fresh retailers corresponding to community fresh essential and expectant consumers will increase compared with those without considering the FQT. At this time, community fresh retailers will make profits if they choose to open stores in communities dominated by essential consumers or expectant consumers. Community fresh retailers can improve the FQT by optimizing logistics and adopting new information technology, which can improve the satisfaction of community fresh consumers and increase the demand of community fresh consumers. If the fresh food purchase cost of community fresh retailers is within the range of $(\frac{cL}{a_1}+g, \frac{cL}{a_2}+g]$, at this time, because the FQT has been enhanced by community fresh retailers, it increases the cost of fresh procurement. To protect profits, community fresh retailers have increased the fresh price. As a result, the satisfaction and demand of essential consumers with high price sensitivity to fresh food will decrease. The profit of community fresh retailers when considering the FQT is lower than that without considering the FQT. In this case, community fresh retailers should choose to open stores in communities dominated by expectant consumers and can also provide more value-added services to maximize the profits of community fresh retailers. If the fresh food purchase cost of community fresh retailers is $(\frac{cL}{a_2}+g, +\infty)$, community fresh retailers strive to improve the FQT. Due to the boundary diminishing effect of FQT [23], higher costs are generated, which makes the cost of fresh procurement rise more. To ensure profits, community fresh retailers have increased fresh prices. At this time, the fresh food price has exceeded the utility price of essential consumers and expectant consumers, which has resulted in a decrease in the satisfaction of essential consumers and expectant consumers and a decrease in the demand of two types of consumers. It will also make the profit of community fresh retailers decline when the FQT is considered compared with that without it. In addition, we are going to do the same thing in the other interval. In this case, community fresh retailers make maximum profit by choosing the expectant community, optimizing logistics and information, reducing procurement costs and increasing corresponding value-added services.

## 4. EXAMPLE ANALYSIS

### 4.1. The comparison of fresh utility prices between two types of consumers

Community fresh retailers should focus on improving the satisfaction of different types of consumers to improve the utility price of consumers. The FQT is an important factor that consumers pay attention to, and it is also an important component of consumers' fresh utility. Community fresh retailers incur corresponding costs when providing consumers with FQT, which include information on fresh production, the preservation of transportation processes and the process of consumer participation in the whole supply chain. There is a decreasing boundary effect in the measurement of FQT. The calculation model of FQT is not considered in this study. After considering the FQT, in this study, considering the complexity of defining the information transparency model, it do not discuss the range of transparency values. In this study, it mainly referred to the literature [36, 37], and randomly assigned values to the corresponding parameters that satisfy the constraints in equations (5), (6), (15), and (16) while also meeting the negative definiteness condition of the Hesse matrix, in order to obtain the corresponding results. According to $p_1 \leq \frac{\phi v+b_1\theta+cL}{a_1}$ and $p_2 \leq \frac{v+b_2\theta+cL}{a_2}$, the relevant

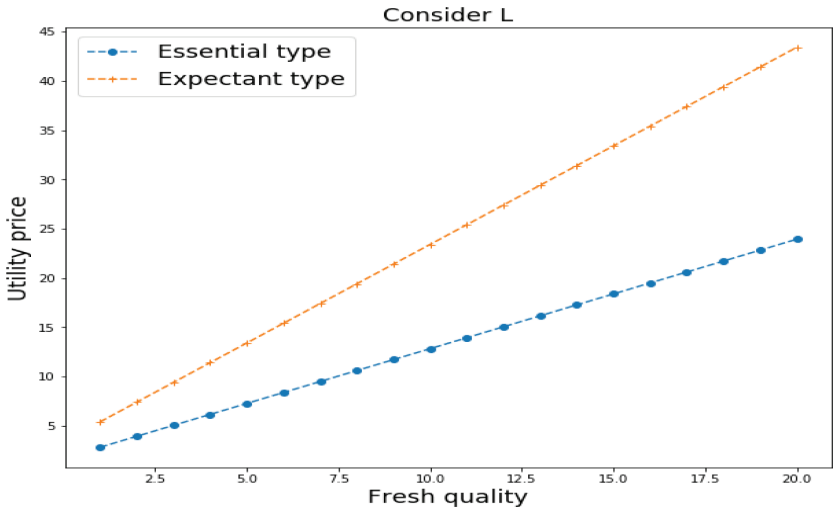


FIGURE 3. The effect of FQT on the utility prices of essential and expectant consumers.

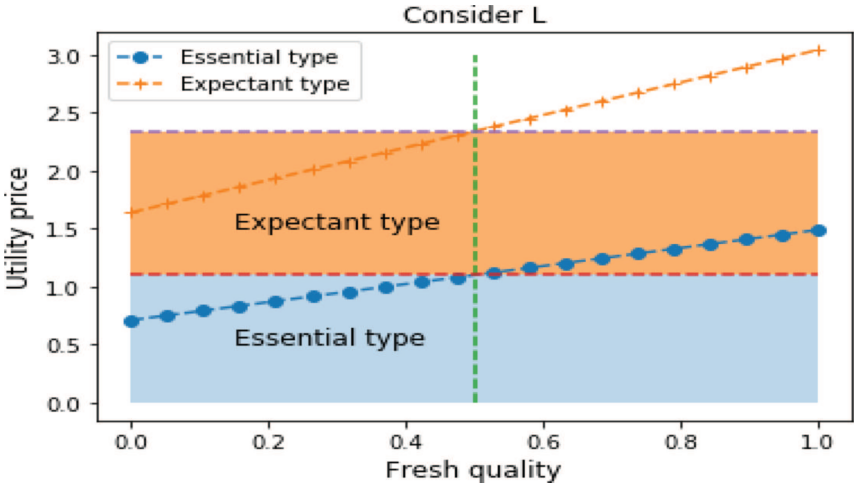


FIGURE 4. The utility price is divided into essential consumers and expectant consumers.

parameters are set as $\upsilon = 0.8$, $\phi = 0.8$, $a_1 = 0.9$, $a_2 = 0.5$, $b_1 = b_2 = 0.2$, $\theta = 0.1$, $c = 0.7$, $L$ continuously takes an integer in the range of 0.1–0.9, and the results are shown in Figure 3.

It can be seen from Figure 3 that when community fresh retailers provide the same FQT and fresh freshness, the price sensitivity coefficient of expectant consumers is lower than that of essential consumers. Therefore, with the increase in fresh quality, the fresh utility price of expectant consumers increases faster than that of essential consumers. Therefore, when considering the location of store opening, community fresh food retailers try to choose the community with expectant consumers as the main source of store opening to maximize profits without reducing the demand of community fresh food consumers when increasing the utility price of consumers. The essential consumers and the expectant consumers are mainly divided by utility price. When the quality of fresh is determined, as $L = 0.5$, the division of essential consumers and expectant consumers is shown in Figure 4.

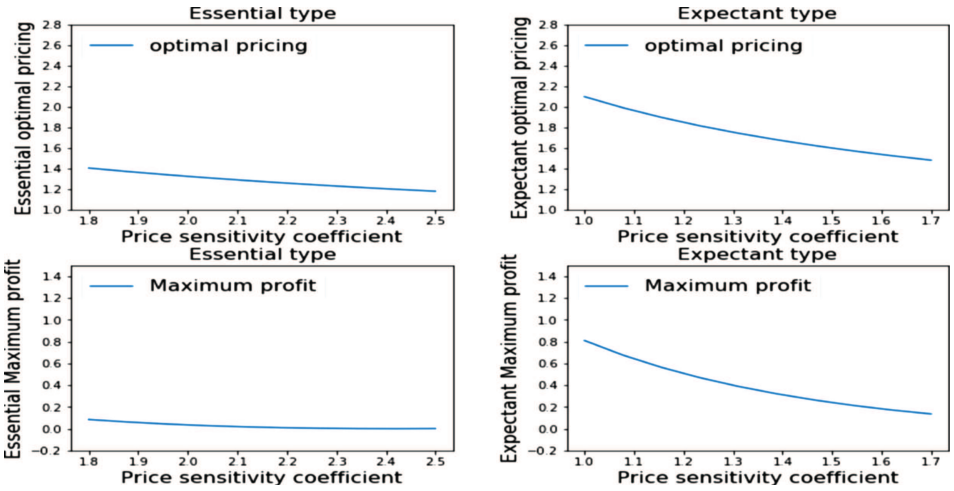


FIGURE 5. The impact of the consumer sensitivity coefficient on the optimal pricing and profits of community fresh retailers.

Figure 4 shows that when pricing lifetime fresh food, community fresh retailers should refer to the current type and proportion of consumers in the community. When the fresh food purchase cost is certain, the pricing of fresh food should try to approach the maximum utility price of the two consumers to obtain the maximum profit.

## 4.2. The analysis of the model without considering FQT

After discussing the utility price of community fresh consumers, we will next discuss the pricing of community fresh and how it affects the profits of community fresh retailers. According to the model without considering the FQT, when the freshness of fresh food is certain, the parameters that mainly affect the pricing and profit of fresh food are the consumer price sensitivity coefficient and the purchase cost of fresh food. Assuming a certain purchase cost, calculate the impact of changes in price sensitivity coefficients of two types of consumers on optimal pricing and profits, and the random value of relevant parameters is $\phi = 0.9$, $a_1 \in [1.8, 2.3]$, $a_2 \in [1, 1.5]$, $b_1 = b_2 = 2$, $\theta = 1$, $g = 1.2$, the model calculation results are shown in Figure 5.

It can be seen from Figure 5 that with the increase in the price sensitivity coefficient, the optimal pricing of fresh food by community fresh retailers declines, and the rate of decline in the optimal pricing for the essential consumer is smaller than that for the expectant consumer. As the price sensitivity coefficient of the two consumers increases, the decline rate of profits of community fresh retailers brought by expectant consumers is greater than that of essential consumers. Assuming that the consumer price sensitivity coefficient is certain, the influence of the change in fresh food purchase cost on the optimal pricing of community fresh retailers is randomly set according to the model, and the parameters $\phi = 0.7$, $a_1 = 0.3$, $a_2 = 0.1$, $b_1 = b_2 = 0.6$, $\theta = 1$, $g \in [0.1, 4]$ are brought into the model, and the results are shown in Figure 6.

It can be seen from Figure 6 that the optimal pricing of community fresh food retailers increases with the increase of fresh food purchase cost, and the profit decreases with the increase of purchase cost until it becomes negative profit. Figure 6 also shows that the profit decline rate of community fresh produce retailers for expectant consumers is slower than that for essential consumers. From the above, the expectant type consumers are most concerned about the quality of fresh food, followed by the price of fresh food.

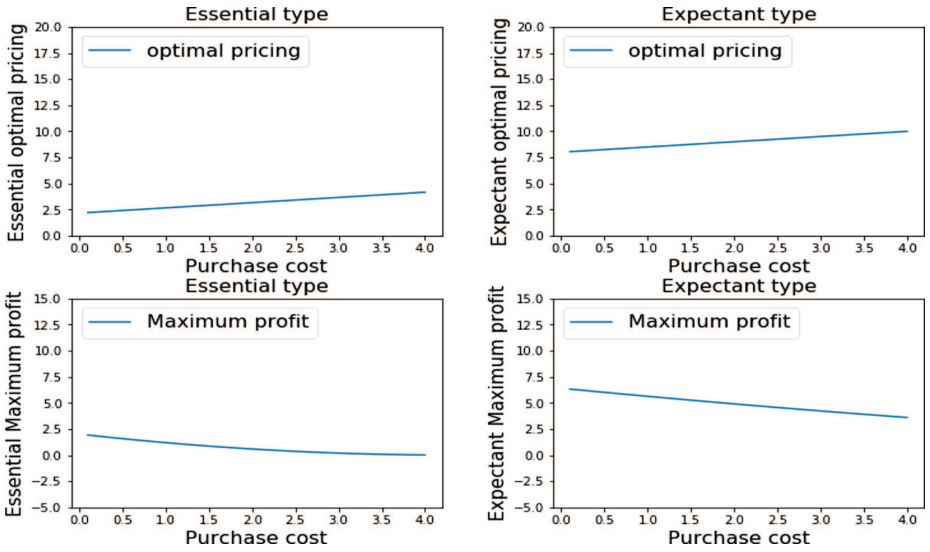


FIGURE 6. The changes in optimal pricing and profits of community fresh retailers caused by the rise of fresh food purchase costs.

### 4.3. The analysis of the model considering FQT

Next, this paper will focus on the impact of FQT on the optimal pricing and profits of community fresh retailers. Substituting $g_1 = g_2 = g + \frac{mc^2}{2}$ into (20)–(23). At this time, when the fresh purchase cost $g$ is certain, this paper focuses on the effects of $c_1$, $c_2$ and $L$ on the optimal pricing and maximum profit of the community fresh retailer. The setting parameters are as follows: $\phi = 0.9$, $a_1 = 0.5$, $a_2 = 0.4$, $b_1 = b_2 = 0.2$, $\theta = 0.1$, $g = 0.3$, $L = 0.6$, and $m = 2, c \in [0.1, 3]$. The relationship between the FQT and the optimal pricing and maximum profit of community fresh retailers is shown in Figure 7.

As shown in Figure 7, with the increase in fresh quality transparency, fresh procurement costs will rise. As a result, the optimal pricing of the community fresh retailer for both consumer types will increase, and the profits of the community fresh retailer for essential consumers slowly decline. When fresh procurement costs rise to a certain stage, the essential consumer's total utility for the product will be less than zero. Therefore, the profit of community fresh retailers for essential consumers declines rapidly to negative. However, expectant consumers have a low price sensitivity coefficient and pay attention to the FQT. It can be seen from the graph that with the improvement of FQT, the increase in fresh procurement cost leads to an increase in fresh price. At the beginning, the rise in fresh prices did not have a great impact on expectant consumers, and the community fresh retailer's profit rose. However, as the fresh prices continue to rise, ultimately, it will also affect the demand of expectant consumers; when the total utility of expectant consumers to fresh food is less than zero, the total profit of the community fresh retailers for expectant consumers will also decline to negative. From the above analysis, as long as the input cost of FQT in the community fresh retailers is controlled in a reasonable range, the fresh sales profit will gain a large increase, and selecting the location of stores in the community should be dominated by expectant consumers.

### 4.4. The profit comparison of the two models with different fresh procurement cost ranges

Now, under the condition that the initial utility value of consumers follows a uniform distribution on $[0, 1]$, the Hesse matrix with fresh price and FQT as decision variables is guaranteed to be negative definite. Therefore, let us say for a certain fresh, and the model parameters are set to $\phi = 0.9$, $a_1 = 0.9$, $a_2 = 0.8$, $b_1 = b_2 = 0.2$, $\theta = 0.2$, $g = 0.4$, $m = 0.2$, $L = 0.5$, $c \in [0.1, 1]$. Let $G1 = \frac{cL}{a_1} + g$ and $G2 = \frac{cL}{a_2} + g$; when FQT is not considered,

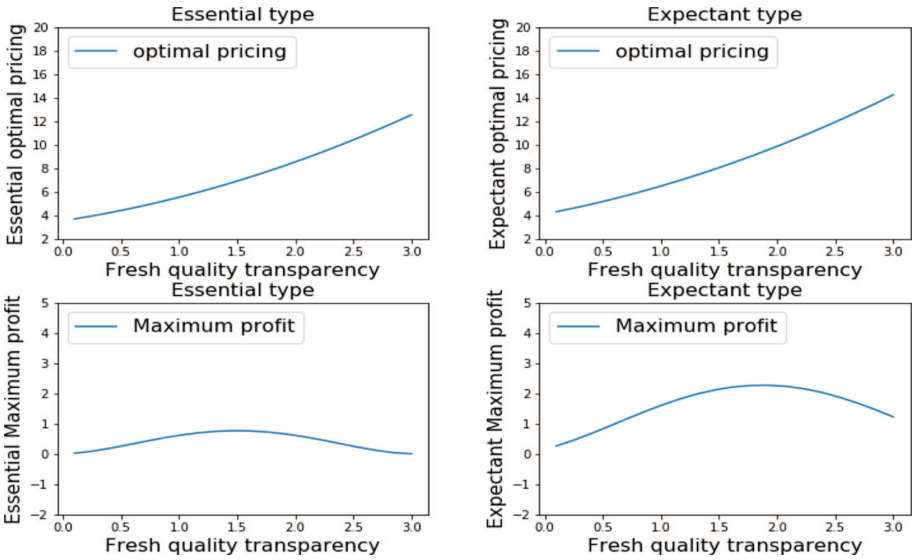


FIGURE 7. The influence of FQT on the optimal pricing and maximum profit of community fresh retailers.

TABLE 4. The impact of changes in FQT on the two types of consumers.

| FQT | | Essential consumer | | | Expectant consumer | |
|---|---|---|---|---|---|---|
| $c = 0.1$ | $G1 = 0.456$ | $\pi_1^{E^*} = 0.068$<br>$\upsilon = 0.678$ | $\pi_1^{\mathrm{ET}^*} = 0.078$<br>$\upsilon = 0.655$ | $G2 = 0.463$ | $\pi_2^{E^*} = 0.104$<br>$\upsilon = 0.640$ | $\pi_2^{\mathrm{ET}^*} = 0.116$<br>$\upsilon = 0.619$ |
| $c = 0.2$ | $G1 = 0.511$ | $\pi_1^{E^*} = 0.068$<br>$\upsilon = 0.678$ | $\pi_1^{\mathrm{ET}^*} = 0.084$<br>$\upsilon = 0.642$ | $G2 = 0.525$ | $\pi_2^{E^*} = 0.104$<br>$\upsilon = 0.640$ | $\pi_2^{\mathrm{ET}^*} = 0.124$<br>$\upsilon = 0.606$ |
| $c = 0.27$ | $G1 = 0.550$ | $\pi_1^{E^*} = 0.068$<br>$\upsilon = 0.678$ | $\pi_1^{\mathrm{ET}^*} = 0.085$<br>$\upsilon = 0.639$ | $G2 = 0.569$ | $\pi_2^{E^*} = 0.104$<br>$\upsilon = 0.640$ | $\pi_2^{\mathrm{ET}^*} = 0.127$<br>$\upsilon = 0.602$ |
| $c = 0.31$ | $G1 = 0.572$ | $\pi_1^{E^*} = 0.068$<br>$\upsilon = 0.678$ | $\pi_1^{\mathrm{ET}^*} = 0.084$<br>$\upsilon = 0.640$ | $G2 = 0.594$ | $\pi_2^{E^*} = 0.104$<br>$\upsilon = 0.640$ | $\pi_2^{\mathrm{ET}^*} = 0.128$<br>$\upsilon = 0.601$ |
| $c = 0.5$ | $G1 = 0.678$ | $\pi_1^{E^*} = 0.068$<br>$\upsilon = 0.678$ | $\pi_1^{\mathrm{ET}^*} = 0.074$<br>$\upsilon = 0.664$ | $G2 = 0.713$ | $\pi_2^{E^*} = 0.104$<br>$\upsilon = 0.640$ | $\pi_2^{\mathrm{ET}^*} = 0.119$<br>$\upsilon = 0.615$ |

the fresh procurement cost is certain, and specific profits can be obtained for the two types of consumers. On this basis, if FQT is considered, the procurement cost of fresh begins to change. The impact of FQT change on profit is shown in Table 4.

Table 4 shows that the profit of community fresh produce retailers is greater when FQT is considered than when it is not. With the increase in FQT, the model with FQT shows that the profits of community fresh retailers are increasing, and increasing the FQT also brings about an increase in fresh cost. The decreasing initial utility value of consumers brings about an increase in total demand. When the FQT exceeds a certain critical value, the initial utility value of consumers begins to increase, resulting in a continuous decrease in aggregate demand. Therefore, the profits of community fresh retailers will continue to decline. The above analysis results are shown in Figure 8.

As shown in Figure 8, after FQT is taken into account, the profits of community fresh retailers for the two types of consumers are greatly improved before the fresh procurement cost rises to the $G1$ and $G2$ points, and the

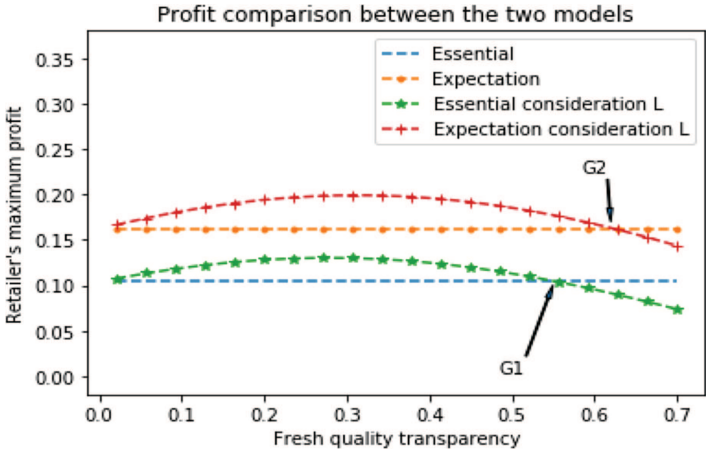


FIGURE 8. The profit comparison of the model with and without FQT.

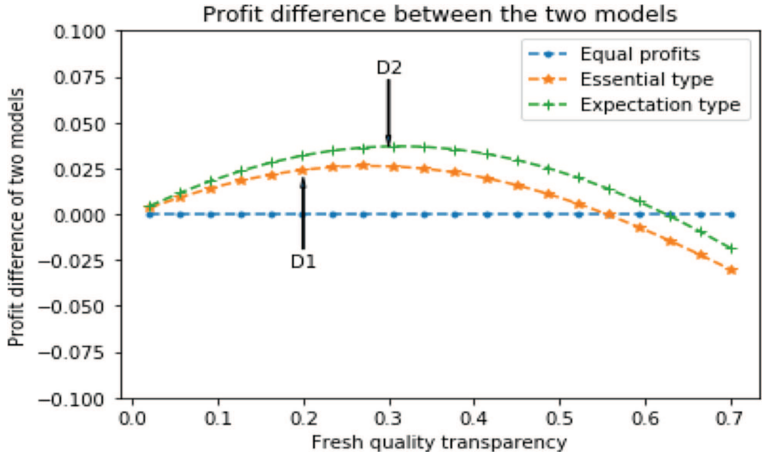


FIGURE 9. The profit difference between models with and without FQT.

lower the fresh procurement cost is, the greater the profit increase. After the fresh purchase cost exceeds the $G1$ and $G2$ points, the profits are lower than they were when FQT was not taken into account. Let $D1 = \pi_1^{\mathrm{ET}^*} - \pi_1^{E^*}$ and $D2 = \pi_2^{\mathrm{ET}^*} - \pi_2^{E^*}$. The profit difference calculated by the model is shown in Figure 9.

As shown in Figure 9, expectant consumers have more room for profit improvement than essential consumers. Therefore, community fresh retailers need to find the joint point of profit maximization between essential consumers and expectant consumers to maximize their own profits while improving the utility of consumers.

## 5. Conclusion

At present, there are many problems in community fresh e-commerce, including high online operating costs and low consumer utility, which hinder the development of community fresh e-commerce. Most existing research is mainly focused on cold chain logistics, fresh supply chain improvement, and other fields. This paper builds a community fresh consumption model that consists of community fresh retailers and consumers. From the perspective of consumer demand, community fresh consumers are divided into essential consumers and expectant

consumers. In the case of not considering fresh freshness changes, the optimal pricing and maximum profit of community fresh retailers for the different utilities of the two types of consumers are studied, which further enriches community freshness theory.

The main research results are as follows: (1) The profit model of a community fresh product retailer for two types of consumers is established, and the optimal pricing and maximum profit for a certain fresh product are determined according to the model. (2) Based on the existing literature, the FQT factor is introduced to establish the profit model of the community fresh retailer for the two types of consumers, and the optimal pricing and maximum profit are obtained according to the model. (3) The influences of different price sensitivity coefficients and fresh procurement costs on the optimal pricing and maximum profit of community fresh retailers are obtained. (4) The two profit models with and without FQT are compared, and the critical conditions affecting the profit growth of community fresh retailers are found. (5) The numerical analysis shows that both types of consumers increase the utility price of fresh products after the introduction of FQT by community fresh retailers, and expectant consumers contribute more to the profits of community fresh retailers than essential consumers.

Based on the research conclusions, this paper proposes the following suggestions for the management of community fresh retailers.

At present, few researchers have investigated the connection among these two types of heterogeneous consumers, fresh food pricing and profits. This study addresses this gap by considering the following findings:

(1) When determining fresh food pricing for community fresh food retailers, it is necessary to analyze the heterogeneity of community consumers and meet correspondingly their needs to achieve a win–win situation.
(2) After introducing FQT, community fresh food retailers strengthen their supervision over the quality efforts of fresh food producers. By conveying this information to community consumers through appropriate means, such as technological platforms, the level of food safety trust among consumers is enhanced. From this perspective, overall social welfare is also increased. Community fresh food retailers achieve profit growth while ensuring a certain level of investment costs. Therefore, a virtuous cycle is established among consumers, community fresh food retailers, and fresh food producers, leading to local Pareto improvements.
(3) This study provides management recommendations for the development of certain community fresh food e-commerce models and has a significant promoting effect on the development of community fresh food e-commerce in relatively underdeveloped areas.

More specific and advance management recommendations are also available. First, when selecting the location of the store, the community fresh retailers should try their best to choose the community dominated by expectant consumers to obtain the best profits. Second, community fresh retailers should try their best to increase the FQT and provide consumers with an increasingly better fresh shopping experience, which can improve consumers' fresh utility price. Third, community fresh retailers should control fresh procurement costs after increasing FQT and related services. If the fresh price caused by fresh procurement costs exceeds the utility price of fresh consumers in the community, the profit of the community fresh retailer will be lower or even lose money compared to the case in which FQT is not taken into account. In the future, some research should consider the factors that affect the profits of community fresh retailers, including the changes in freshness, the factors related to FQT, and the type proportion of community fresh consumers. In future, the impact on fresh food producers should be considered, with specific aspect of the community fresh food e-commerce supply chain together. The coordination and optimization of the entire supply chain are not fully explored, which could be directions for future research.

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