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A laboratory exploration for multi-period perishable food pricing

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Abstract

Purpose – The purpose of this paper is to put forward a multi-period dynamic pricing strategy for perishable food considering consumers’ price fairness perception. The impacts of the multi-period retail price, food freshness and inventory shortage risk on consumers’ heterogeneous willingness to pay (WTP) and their strategic purchasing behaviours are studied.

Design/methodology/approach – The authors present a price optimization model for perishable food, and conduct a laboratory experiment to justify the theoretical model. The data collected are analysed by correlation analysis and nonparametric test.

Findings – The results obtained reveal, first, food freshness and inventory shortage risk have effect on consumers’ heterogeneous WTP. Second, different retail prices lead to consumers’ strategically purchasing behaviours. Finally, consumers’ intertemporal price fairness perception and the food retailer’s long-term utility maximization can be achieved by developing multi-period dynamic pricing strategy.

Practical implications – This study suggests the perishable food retailer to apply a step-by-step price markdown strategy. It aims at eliminating price unfairness perceptions caused by loss of freshness and high shortage risk of the perishable food in the subsequent selling periods within the shelf life. Some valuable managerial insights towards perishable pricing for food retailers are discussed.

Originality/value – This study serves as the first step to utilize a laboratory experiment to dig out consumers’ intertemporal WTP towards perishable food. It also presents a novel way for describing consumers’ intertemporal price fairness perception by equalizing consumers’ average utilities considering consumer surplus, food freshness and shortage risk at different selling periods. The line of research on dynamic pricing concerning consumers’ price fairness perception is quite new in academic research, and has arisen due to its importance for food retailers of maximizing their long-term revenues and also of constructing mutual benefit and lasting connections with the consumers.

Keywords Consumer behaviour, Empirical study, Consumer perceptions, Food, Pricing strategy

Paper type Research paper

1. Introduction

Perishable food refers to items whose quality and freshness deteriorate over time such as meat, fruit and vegetables, etc. (Ferguson and Koenigsberg, 2004). The limited shelf life induces consumers’ risk perceptions on food safety, quality and inventory shortages. Consumers choose the best timing to purchase perishable food concerning
the monetary factor and other risk-related factors. The salvage value of the unsold and decayed food is negligible, but the disposal of these items is always the responsibility of the food retailer. Hence, many retailers are engaged in developing appropriate pricing strategies for perishable food and making their best to improve the operational performance and avoid food wastage. In practice, the most used pricing strategy for perishable food is the end-of-period sales, which is used to attract more consumers to purchase before food deterioration. Regarding the different levels of food freshness and inventory shortage risk, consumers perceive heterogeneous valuations at different selling periods and generate heterogeneous willingness to pay (WTP) for perishable food (Huang et al., 2011; Herbon, 2013). The line of research on perishable pricing has received a lot of attentions in academic (Dasu and Tong, 2010; Jerath et al., 2010; Ovchinnikov and Milner, 2012; Li and Tang, 2012; Avinadav et al., 2013; Chung and Li, 2013; Beneke and Carter, 2015). Besides the end-of-period sales pricing tactic adopted by most practical perishable food retailers, researchers have proposed other solutions for perishable pricing. For example, some use time-based price discrimination models for perishable food by maximizing retailer’s revenue via exploiting consumer heterogeneity in their WTP throughout different selling periods (Huang et al., 2011; Li and Tang, 2012; Chung and Li, 2013; Herbon, 2013; Herbon et al., 2014; Qin et al., 2014). Some put forward version-based price discrimination methods, which means that the food retailers develop several versions of the perishable food, and charge different prices towards different segmented consumers (Boatto et al., 2011; Tempesta and Vecchiato, 2013; Marian et al., 2014).

However, it is well known that price discrimination of revenue management leads to consumers’ price fairness perception (Xia et al., 2004; Garbarino and Maxwell, 2010; Ashworth and McShane, 2012; Wu et al., 2012; Nguyen and Klaus, 2013). Fairness is a critical criterion that significantly affects consumers’ purchasing decisions. As a concept, price fairness perception is rooted in the theory of dual entitlement, which contends that perceptions of fairness are governed by the principle that firms are entitled to a reference profit and consumers are entitled to a reference price. Consumers believe that the value to the firms should be equal to the value for themselves (Kahneman et al., 1986; Thaler, 2008). If the relationship becomes unbalanced, increased value for the firm or decreased value for the consumer, the consumer may perceive subsequent transactions to be unfair, which plays an important role in consumer satisfaction and subsequent behaviours (Oliver and Swan, 1989; Bei and Chiao, 2001; Heo and Lee, 2011; Heo et al., 2013). Although the importance of multi-period pricing strategies for perishable items is recognized by many researchers, its implications on consumers’ intertemporal price fairness perception have not been widely studied. With regard to the estimation of consumers’ valuation and WTP, four alternative methods have been mostly adopted in empirical studies: hedonic price, contingent valuation, conjoint analysis and experimental auction (Grunert et al., 2009). In the context of perishable food pricing, the former three methods evaluate consumer’s WTP in terms of food retailers’ provided information, and rough ranges of consumers’ WTP are obtained through the options given by questionnaires. However, it is more accurate to obtain individual’s WTP in experimental auctions, which avoids overestimating the valuation of the perishable food compared to the other methods. In addition, there are many complicated influential factors for perishable pricing, and it is feasible and effective to analyse the interplay effects of these factors individually in the laboratory experiment (Lee and Hatcher, 2001; Lusk and Hudson, 2004; Akaichi et al., 2012).
Based on the above considerations, in this paper, we propose a laboratory exploration method with the aim of proposing a dynamic multi-period pricing model for perishable food with consumers’ price fairness perception, and two research questions are investigated. In the first place, as mentioned in Tversky’s (1972) work that the individual’s choices demonstrate high uncertainties, and the retailer’s goal of pricing fairly does not mean a one price policy for everyone. Thus, it is better to set up a series of discriminatory prices for different segmented consumers. Consumers within the same segment are assumed to have homogeneous attitudes towards the perishable food. A key question is how to make price differences more acceptable and less likely to evoke price unfairness perceptions among different segmented consumers, who purchase the perishable food at different time points. In the second place, to the best of our knowledge, many researchers proposed pricing models for perishable food from a theoretical perspective, such as Dasu and Tong (2010), Jerath et al. (2010), Ovchinnikov and Milner (2012), Li and Tang (2012), Ali et al. (2013), Avinadav et al. (2013), Herbon et al. (2014) and Qin et al. (2014), etc. While few empirical studies have researched the perishable pricing models and put forward concrete pricing path for perishable food. Furthermore, in both theoretical and empirical studies, perishable dynamic pricing with consumers’ price fairness perception is very rare. As stated by Corbett and Wassenhove (1993) that the empirical research investigating the success of operations research techniques can be very valuable. Therefore, how to conduct the empirical research driven by both practice and theory in the context of perishable food pricing with consumers’ price fairness perception and strategic purchasing behaviour is put forward as the second research question of this paper.

The remainder of this paper is laid out in the following way. In Section 2, we briefly review the related literature and identify the contributions of our work. Then, we put forward the research hypotheses in Section 3. In Section 4, we introduce the theoretical model and the design of the experiment. Section 5 displays the experiment results, and Section 6 concludes the paper with a brief summary and suggestions for further research.

2. Related works
There is extensive literature on revenue management and behavioural operations management in the field of perishable pricing. For an overview of revenue management, readers may refer to Talluri and van Ryzin (2004). Here, we briefly review some related works about food pricing and consumers’ WTP for perishable food, and dynamic pricing with consumer behaviour as well.

2.1 Food pricing and consumers’ WTP for perishable food
For perishable food pricing with consumer behaviour in empirical studies, few studies concentrate on pricing strategy development except for Chung and Li (2013). They compare the impact of multi-period pricing and end-of-period pricing on consumers’ satisfaction and WTP for perishable food. They suggest that food retailers can enhance consumer satisfaction by offering an earlier but lower discount, and increasing it as perishable food items approach their expiry date, rather than a higher discount when the expiry date is imminent. However, they did not specify the detailed pricing path of the dynamic pricing strategy. The majority of empirical studies on food pricing is concerned with the consumers’ WTP for food and yields many valuable results. WTP is defined as “the maximum price a buyer is willing to pay for a given
quantity of a good” (Wertenbrock and Skiera, 2002). Dasu and Tong (2010) pointed out that the frequency of price changes, the number of units for sale, market size, consumers’ valuation distribution, inventory information disclosure and scarcity level, etc., were main influential factors that have effects on consumers’ purchasing decisions. Levin et al. (2010) proved that initial capacity could be used to effectively reduce the impact of strategic consumer behaviour. Steur et al. (2012) utilized experimental auctions to analyse consumers’ WTP for GM rice, and results revealed that consumers’ GM food acceptance and objective knowledge were main determinants for WTP. Piramuthu and Zhou (2013) studied perishable inventory management with demand which was directly dependent on the amount of shelf-space allocated to the item of interest as well as its instantaneous quality. Avinadav et al. (2013) pointed out that the demand rate of perishable items was positively affected by the remaining shelf life, since higher time-to-expiry indicated better freshness and higher quality. Bett et al. (2013) adopted contingent valuation experiment and two-step Heckman selection model to understand how consumers would respond to a price increase and estimate the amount they are willing to pay for indigenous chicken products. Socioeconomic factors like age, income, education and family size significantly determined consumers’ WTP. Other factors about the food characteristics and consumers’ preferences were also studied. Lee and Yun (2015) investigated an S-O-R model to examine how consumers perceive organic food attributes (S) that lead to consumers’ attitudes (O) and behavioural intentions to buy organic food (R). The findings indicated that consumers’ intentions to purchase were determined by the utilitarian attitudes established by the favourable perceptions of the nutritional content and ecological welfare attributes, in addition to the hedonic attitudes formed by the perceptions of the nutritional content, ecological welfare and sensory appeal attributes. Beneke and Carter (2015) hypothesized that consumers’ WTP for private label branded breakfast cereal was influenced by the perceived product value, quality, relative price and risk, in addition to store image, in-store extrinsic cues, familiarity with private label brands and loyalty towards existing national brands, etc. They introduced partial least squares path analysis to test the causal relationships within the hypotheses and the conceptual model. Results were found to be statistically significant with all hypotheses related to influential criteria towards consumers’ WTP.

2.2 Dynamic pricing with consumer behaviour

Dynamic pricing becomes a common practice adopted by retailers that sell a limited inventory of perishable or seasonal products within a finite horizon. The fundamental principle of dynamic pricing is that retailers adjust their prices based on the inventory level and the time remaining in the selling period. Different prices trigger different perceptions about price fairness and different consumer behaviours towards purchasing the items. In recent years, the research on dynamic pricing with consumer behaviour has been emphasized. Chen and Zhang (2009) investigated the implications of the dynamic interactions between strategic consumers and firms, and developed dynamic targeted pricing based on consumer purchase history. Dasu and Tong (2010) studied dynamic pricing policies for a monopolist selling perishable products over a finite time horizon to strategic buyers. They find that when buyers are strategic and shortages are perceived, dynamic pricing is better than static pricing even if demand is deterministic. Strategic buyers purchase a product only if their valuations exceed a threshold. This threshold is higher than the prevailing price and depends on the perceived level of scarcity. Zhao et al. (2012) studied consumers’ behaviour of purchase
delay in a general dynamic pricing context. They explicitly modelled the consumer dynamic choice process using the classical multinomial logit model, in which they specified the probability of purchasing one unit of product as a function of inertia. They find that the optimal pricing policy depends on the inventory scarcity and also the level of consumer inertia in two dimensions: depth of inertia (i.e. extent of inertia) and breadth of inertia (i.e. probability that a customer is affected by inertia). Wu et al. (2014) developed their study on the online retail selling of durable products over an infinite horizon. They studied the randomized pricing strategy by switching the price between regular level and low level, and assumed that the price of the retailer followed a Markov process. The reneging behaviour of strategic consumers was also included. The effects of consumers’ patience and discount factor on optimal prices and promotion probability were studied. Liang et al. (2014) considered a seller that offered a product in the form of group buying (priced low but uncertain) and spot purchasing (priced high but guaranteed) from a dynamic perspective. Customers were assumed to be strategic with a time-dependent utility and they characterized the customer behaviour within a rational expectations framework. The retailers tried to balance the tradeoff between a large customer base incorporating as many group-buying customers as possible and a relatively high margin by pushing high-end customers into the spot-buying option.

3. Hypotheses development

In our paper, we extend the consumer behaviour theory and utility theory, to hypothesize that a multi-period pricing strategy will realize consumers’ price fairness perception and the food retailer’s long-term revenue maximization. This strategy makes trade-offs among retail price, food freshness and shortage risk. Here below are the hypotheses developed in three aspects.

From the perspective of the factors that influence food pricing and consumers’ WTP for perishable food, we have reviewed some recent research in Section 2.1. So far, most research mentions that the deterioration state and quantity in stock are key factors that determine perishable pricing. Other factors such as the market size, consumers’ valuation distribution, information disclosure, familiar with the product and socioeconomic factors like age, income, education and family size, etc. are common factors that influence the pricing strategies of both perishable and durable items. Since the objective of our study lies in perishable pricing, based on the previous studies, the following hypothesis is put forward:

\[ H1 \]. The deterioration state and the quantity in stock of the perishable food have significant effects on consumer’s WTP.

From the perspective of the factors that influence the consumers’ purchasing determinations of perishable food, consumers’ strategic behaviours are widely studied. The study of consumers’ strategic behaviour was first researched in durable pricing. A classic work is that Ronald Coase (1972) pointed out that if consumers strategically wait for price reductions, even a monopolist would be forced to price at marginal cost and earn zero profits. Lately, as for perishable pricing, Levin et al. (2010) demonstrated that firms should attach great importance to strategic consumers while selling perishable items; otherwise, the firm will receive much lower total revenues. In the viewpoint of consumers, Cachon and Swinney (2009) assumed that strategic consumers are aware of the retailer’s markdowns at some given time during the selling horizon, and they would like to strategically choose when to make their purchase. Additionally, Su and Zhang (2009) addressed the existence of consumers’ strategic behaviour.
If consumers do not perform strategically, they may face up with increased decision-making cost, increased transaction cost as well as other inconveniences such as having to choose a substitute, going to another store to purchase the item, etc. Since the extant researches are mostly theory-driven pricing models considering the strategic behaviour of consumers, in our study, we would like to justify $H2$ posited as below from an empirical point of view. Given that consumers are aware of price reductions, we hypothesize that:

$H2$. Consumers purchase the perishable food strategically, considering different retail price, food freshness and inventory shortage risk at different selling periods.

Many researchers and practitioners mention that firms would like to adopt price discrimination strategy for perishable. For example, Bakker et al. (2012) surveyed the research of inventory control of perishable items and addressed that it was usual to offer the deteriorated items at a discount price in practice. For example, in many supermarkets, items near their expiration date are marked down by a fixed percentage to influence the consumer’s buying behaviour. Policies such as price discount when the items reach a predetermined age are mostly used. However, Jerath et al. (2010) pointed out that although the use of last-minute sales to dispose the unsold capacity might generate incremental revenues in the short term, the long-term consequences of such a strategy were not immediately obvious. The reason is that if more and more consumers were inclined to anticipate the discount and would not purchase the item at regular or premium price, they might potentially reduce revenues for the firms in the long run. Therefore, the multi-period pricing strategy is more acceptable with its more long-term utility, since an appropriate discount in addition to the desirable freshness may incite consumers to purchase at an early time before the due date.

On account of the multi-period pricing strategy, consumers always purchase perishable at different retail prices at different time points. It is very common to see consumers comparing their purchasing experiences with others who bought the same items at different selling periods, as well as comparing the current deal with their previous purchases. Giampaolo and Graziano (2014) researched the effect of past reference price and social comparison on consumers’ current WTP. Price unfairness perceptions would be generated if consumers receive less utility from the current transaction. Cachon and Swinney (2009) analysed two reasons for consumers’ price unfairness perception from waiting for potential deal of the perishable item. One is that the strategic consumers evaluate purchasing the item less at the end of the season than at the start of the season due to the decayed state of the perishable; the other is that items may be unavailable at the end of the shelf life and consumers have to confront shortage risk. Therefore, due to different levels of deterioration state and shortage risk, consumers generate different WTP and receive different utilities at different selling periods. Levin et al.’s (2009) work demonstrated the idea of price fairness concerns in dynamic pricing. They modelled the pricing strategy for selling differentiated perishable items to multiple segments of strategic consumers. The segments were stochastically homogeneous in the sense that all consumers within a segment had the same distributional and parametric characteristics. In other words, they were trying to ensure the distributions of consumers’ utilities to be homogeneous in different segments. Based on the above discussions, the third hypothesis is presented:

$H3$. A multi-period pricing strategy leads to consumers’ intertemporal price fairness perceptions for perishable foods.
4. Theoretical model and design of the laboratory experiment

4.1 Theoretical model

We assume that a monopolist retailer sells a kind of perishable food to potential consumers in a region using a dynamic multi-period pricing strategy. We consider the shelf life of the perishable food is $T$, and $T$ is divided into several selling periods and each is indexed by $t \ (1 \leq t \leq T)$. At the $t$th selling period, the retail price is denoted as $p_t$; the potential market demand of the perishable food is denoted as $N_t$; the actual amount of consumers who succeed in purchasing the food is denoted as $\lambda(p_t, t)$, which is calculated in Equation (1); the consumers’ WTP is denoted as $v_t$ and the probability density function of the consumers’ WTP is denoted as $f(v_t)$:

$$\lambda(p_t, t) = N_t \times \int_{p_t}^{+\infty} f(v_t)dv_t$$

(1)

In addition, the total surplus of consumers who purchase the perishable food at the $t$th selling period is denoted as $I_t$, which is calculated by Equation (2). It is under the assumption that an individual’s surplus is based on the difference between the individual’s WTP and the retail price. If the consumer’s WTP is higher than the retail price, he or she succeeds in the transactions with the retailer; otherwise, the consumer fails in purchasing the items and his surplus is deemed as zero:

$$I_t = N_t \times \int_{p_t}^{+\infty} \max(v_t - p_t, 0) \times f(v_t)dv_t$$

(2)

We also assume that the inventory of the perishable food cannot be replenished within the shelf life and the unsold items at the end of the shelf life have no salvage values. Without loss of generality, both the unit procurement cost and the per-unit holding cost for the perishable food are assumed to be zero. $q_t$ is the amount of perishable foods sold out at the $t$th selling period. $C(t)$ is the amount of available items at the $t$th selling period, which can be calculated according to the following equation:

$$C(t) = C(t-1) - q_{t-1}, (C(0) = C(1), q_0 = 0)$$

(3)

We further assume that consumers are aware of future markdowns and they decide whether to buy one unit of the perishable food, or to wait until a suitable retail price later. Their decisions are based on two external factors, i.e. the freshness factor $\alpha(t)$ given by an exponential decay function in Equation (4) and the inventory availability factor $\beta(t)$ given in Equation (5). In Equation (4), $\theta$ is the deteriorating rate of the perishable food, which varies depending on the characteristics of the particular perishable food and the storage conditions such as temperature or humidity, etc. In this study, both freshness factor $\alpha(t)$ and inventory availability factor $\beta(t)$ are monotonically decreasing with parameter $t$:

$$\alpha(t) = e^{-\theta(t-1)}$$

(4)

$$\beta(t) = C(t)/C(1)$$

(5)

According to Equation (4), we further express the deterioration state of the perishable food as $1-\alpha(t)$.

The average utility of consumers who purchase the perishable food at the $t$th selling period is denoted as $\bar{U}_t$, which can be calculated by Equation (6). It is under the
assumption that consumers' utility is determined by consumers' surplus, food freshness and perceived risk of inventory shortage:

\[ U_t = \frac{\alpha(t) \times \beta(t) \times I_t}{\lambda(p_t, t)} \]  

(6)

The retailer's total revenue within the perishable's shelf life is denoted as \( R \), given in the following equation:

\[ R = \sum_{t=1}^{T} p_t \times \lambda(p_t, t) \]  

(7)

To incorporate consumers' intertemporal price fairness perception within the perishable's shelf life, in addition to maximize the food retailer's long-term utility denoted as \( U \), the theoretical model is described as follows:

\[ \text{Max} \ U = R + \omega I \]  

(8)

s.t. \( U_1 = U_2 = \cdots = U_t \)  

(9)

In Equation (8), \( \omega \) is a constant and \( 0 \leq \omega \leq 1 \). If the food retailer pays more attentions on short-term revenue, the retailer's total revenue equals to its total utility, here \( \omega = 0 \); the higher \( \omega \) is, within \( 0 < \omega < 1 \), it indicates that the retailer pays more attentions on long-term utility. Equation (9) depicts consumers' intertemporal price fairness perception condition, which means that consumers' average utilities at different selling periods are equally controlled.

The solution procedures are attached in the Appendix. In this paper, we assume the consumers' WTP is a uniform distribution \([v_{\text{min}}, v_{\text{max}}]\). Further, we define parameter \( \gamma \) in Equation (10). Thus, the optimal retail price at the \( t \)th selling period is given in Equation (11):

\[ \gamma = \frac{v_{\text{max}} \sum_{t=1}^{T} \frac{N_t}{\alpha(T) \beta(T)}}{(2-\omega) \sum_{t=1}^{T} \frac{N_t \alpha(1) \beta(1)}{\alpha(T) \beta(T)}} \]  

(10)

\[ p_t = \begin{cases} 
  v_{\text{max}} - \frac{v_{\text{max}}}{\alpha(1) \beta(1)} \sum_{t=1}^{T} \frac{N_t}{\alpha(T) \beta(T)}, & \text{if } \gamma > \frac{v_{\text{max}}}{\alpha(1) \beta(1)}(v_{\text{max}} - v_{\text{min}}) \\
  v_{\text{max}} - \frac{v_{\text{max}}}{(2-\omega) \alpha(1) \beta(1)} \left( \sum_{t=1}^{T} \frac{N_t}{\alpha(T) \beta(T)} \right), & \text{if } \gamma \leq \frac{v_{\text{max}}}{\alpha(1) \beta(1)}(v_{\text{max}} - v_{\text{min}}) 
\end{cases} \]  

(11)

4.2 Subject

The experiment was conducted in Northeastern University in Shenyang, China. We recruited 67 graduate students aging from 22 to 28 years old, and seven young teachers aging from 30 to 36 years old, who were majoring in business administration and management science. The subjects were composed of 38 female participants and 36 male participants. They did not have prior knowledge about the objective and conditions of this study. And none of them have ever participated in similar economic experiments before. They volunteered to take part in the experiment for payoff contingent on performance, and a show-up fee was paid to each participant.

During the experiment, the subjects took the role of consumers and the experiment conductor took the role of the food retailer. Two experiment helpers were recruited to collect the subjects' submitted envelops and did necessary counting and calculation at
each selling period. Dam-boards were set up between neighbouring subjects to avoid mutual communication, information disclosure or sharing.

4.3 Experimental treatment
The goal of our study is to analyse how a markdown multi-period pricing strategy realizes consumers’ price fairness perception at different selling periods within the shelf life of a particular perishable food. In this laboratory experiment, we tested the hypotheses as posited in Section 3 on the basis of the theoretical model proposed in Section 4.1. As for the first hypothesis, the consumers are expected to have an increased WTP with the scarcity of the available inventory and have a decreased WTP with the deterioration of the perishable food, taking different levels of food freshness and inventory shortage risk into consideration. As for the second hypothesis, we expect the consumers to purchase the perishable food at different selling periods; especially at the last selling period, we expect the consumers to have the highest utilities and the highest trading volume. As for the third hypothesis, we would like to justify that the multi-period retail price can incite homogeneous consumers’ utility distributions; in other words, the consumers’ intertemporal price fairness perception could be assured by the theoretical model.

In addition to the multi-period retail prices given by the model, two types of information were also provided: one was the reference price of the perishable food at the market, including an upmost price at which the perishable food situated in a most freshest state, and a lowermost price at which the perishable food was near its expire date; the other was the initial capacity of the perishable food and the remained capacity at the beginning of each selling period.

In this experiment, the dependent variables are consumers’ WTP, retail price and available capacity of the perishable food; the independent variables are the frequency of price changes, market size, deteriorating rate and initial capacity. Variables involved are depicted in Table I.

In this experiment, we would like to focus on subjects’ reactions to different levels of food freshness and shortage risk at different selling periods; therefore, the distributions of consumers’ average utilities are compared accordingly. The perishable food used in our experiment is a very common type of banana, which all subjects are able to afford in their daily life. Therefore, we did not consider the demographic characteristics of subjects in this experiment, such as gender, income and education, etc.

4.4 Steps followed in the experiment
The process to collect data in this study consists of three steps. In step 1 and after taking a seat and given a welcome, each participant received an envelope, which contained five RMB as a show-up fee for their participation, his or her identification number and 120 tokens. To make sure that all participants have a full understanding of the experiment procedures, in step 2, participants were given an oral explanation supported by some examples by the experiment conductor. During the explanation, the participants were totally free to ask questions to dissipate any doubts about the experiment. We moved to the next step only after making sure that all participants fully understood how the experiment worked. Before doing the actual biddings, we also performed one unpaid practice for selling a previous silver pout. In this training session, we did not use the material food but only displayed the pictures of a silver pout at different phases within its shelf life, and described the loss of nutritional value to let the participants perceive the
change of food freshness. In step 3, we carried out the experiment using the material Philippines bananas. The session lasted approximately 90 minutes. The detail experimental procedures are displayed in Figure 1 and explained afterwards.

As shown in Figure 1, the experimental procedures are briefly explained as follows: first, the food retailer announced the market price as reference for consumers; second, the retailer displayed the food and announced the amount of items on shelf at the current selling period; third, consumers submitted their WTP as the highest price they could afford for the food at the current selling period; fourth, the retailer announced the retail price; fifth, for consumers whose WTP were higher than the retail price, they succeeded in buying the food. Then, they paid the food retailer the corresponding tokens and gained the items; and sixth, for consumers who failed in the current transaction, they continued to take part in the next selling period, until the consumers and the retailer concluded the transaction at certain retail price within the shelf life; or else the consumer did not make a deal with the retailer at the last selling period; or else the food was sold out.

Throughout the experiment, we used tokens instead of actual money. The market reference price of the chosen type of banana ranged from 120 tokens in the freshest situation to 80 tokens close to its expiration date. We assumed that bananas’ shelf life is ten days and we divided the shelf life into five selling periods equally. The freshness and nutritive value of the bananas at different selling periods were quite different. Since it is a one-time experiment, instead of waiting for bananas’ naturally deteriorating (which

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Description</th>
<th>Valuation basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer’s WTP</td>
<td>The highest price offered by the consumers towards the perishable food</td>
<td>Contingent on food freshness and inventory shortage risk at different selling periods</td>
</tr>
<tr>
<td>Retail price</td>
<td>The retail price offered by the food retailer towards the perishable food</td>
<td>Provided according to the theoretical model and the amount of perishable food sold out at previous selling periods</td>
</tr>
<tr>
<td>Available capacity</td>
<td>The available capacity equals to the initial capacity minors the amount of perishable food sold out at the previous selling periods</td>
<td>Contingent on the amount of perishable food sold out at the previous selling periods</td>
</tr>
<tr>
<td>Frequency of price changes</td>
<td>The frequency of pricing changes of the retailer’s multi-period pricing strategy</td>
<td>Assuming the frequency of pricing changes is 5 in this experiment</td>
</tr>
<tr>
<td>Market size</td>
<td>The number of potential consumers who would like to purchase the perishable food</td>
<td>The number of subjects participating in this experiment is the market size, i.e. the market size is 74 in this experiment</td>
</tr>
<tr>
<td>Deteriorating rate</td>
<td>The rate of perishable food’s decaying or quality changing</td>
<td>Assuming the deteriorating rate of perishable food is 0.5 in this experiment</td>
</tr>
<tr>
<td>Initial capacity</td>
<td>The amount of perishable food to be sold without inventory replenishment</td>
<td>The initial capacity is less than the market size in order to induce consumer’s perceived inventory shortage risk. Assuming the initial capacity is 70 in this experiment; if someone’s WTP was higher than the retail price but food shortage happened, we regard the consumer’s utility equals to zero</td>
</tr>
</tbody>
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| Table I. Variable description and valuation basis |

Multi-period perishable food pricing
requires several days), we prepared enough bananas (more than the amount of the initial capacity) for all selling periods. In doing so, all subjects were able to purchase his or her desirable banana at any selling period unless the predetermined initial capacity was sold out. Moreover, the subjects were told that they might encounter with inventory shortage risk, and not all subjects were able to purchase the bananas. As shown in Table I, the initial capacity is determined as 70, which is four less than the market size 74 in this experiment. The design of capacity rationing was to test subjects’ perceived risk of inventory shortage and their subsequent strategic behaviours.

5. Results
The experimental data are listed in Table II. The retail price is given by Equation (11), the freshness factor is given by Equation (3) and the inventory availability factor is given by Equation (4).

5.1 Correlation analysis result
In this section, we introduce correlation analysis to test \( H1 \). Table III shows the correlation analysis results of consumers’ WTP and the factors of deterioration state and inventory availability.

In the first part of Table III, no variables are controlled. We can see that: first, consumers’ WTP is highly negatively correlated with deterioration state and positively correlated with the scarcity of the available inventory with Pearson correlation values being \(-0.776\) and \(0.801\), respectively; second, deterioration state and the scarcity of the available inventory are highly negatively correlated, and the Pearson correlation value

<table>
<thead>
<tr>
<th>Selling period</th>
<th>Retail price ( p_t )</th>
<th>Deterioration state ( 1-\alpha_t )</th>
<th>The scarcity of available inventory ( 1-\beta_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>119</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>114</td>
<td>0.39</td>
<td>0.17</td>
</tr>
<tr>
<td>3</td>
<td>111</td>
<td>0.63</td>
<td>0.25</td>
</tr>
<tr>
<td>4</td>
<td>94</td>
<td>0.78</td>
<td>0.55</td>
</tr>
<tr>
<td>5</td>
<td>80</td>
<td>0.86</td>
<td>0.79</td>
</tr>
</tbody>
</table>

Table II. Experimental data
is $-0.798$. In the second part of Table III, the scarcity of the available inventory is controlled, and the correlation between consumers’ WTP and deterioration state is studied. The Pearson correlation value is $-0.379$, which indicates that the more decayed the perishable food is, the less likely consumers would like to purchase it. In the third part of Table III, deterioration state is controlled, and the correlation between consumers’ WTP and the scarcity of the available inventory is studied. The Pearson correlation value is 0.478, which indicates that the more the scarcity of the available inventory is, the more likely consumers would like to purchase. In addition, it is sufficient to say that the significance values being less than 0.01 indicate statistically meaningful correlations, and $H1$ holds.

5.2 Descriptive statistics and the Kolmogorov-Smirnov test
In this section, we introduce descriptive statistics analysis and the Kolmogorov-Smirnov test to test $H2$. Table IV shows the descriptive statistics of consumers’ utilities at different selling periods. We can see from means column that consumers’ average utilities was around one throughout the former four selling periods, with relatively low successful transaction volume; while at the fiftth selling period, consumers had relatively higher utilities and almost half consumers purchased at this selling period.

The observed statistics indicate that consumers’ average utilities throughout the former four selling periods were homogeneous, and consumers’ average utilities at the fifth selling period differed slightly. Therefore, we would like to examine whether the observed homo average utilities of the former four selling periods and the departure at the last selling period were not attributed to sampling errors but to reflect genuine

<table>
<thead>
<tr>
<th>Selling period</th>
<th>Means</th>
<th>$n$</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00</td>
<td>8</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>1.06</td>
<td>12</td>
<td>0.65</td>
</tr>
<tr>
<td>3</td>
<td>1.02</td>
<td>6</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td>0.92</td>
<td>12</td>
<td>0.89</td>
</tr>
<tr>
<td>5</td>
<td>1.52</td>
<td>32</td>
<td>1.14</td>
</tr>
<tr>
<td>Total</td>
<td>1.23</td>
<td>70</td>
<td>0.91</td>
</tr>
</tbody>
</table>
homogeneity or heterogeneity themselves. For these purposes, we introduced the Kolmogorov-Smirnov test to assess whether there was significant homogeneity or departure from uniform in the population distribution at different selling periods. The test process comprised two steps. First, we examined whether consumers’ average utilities in all selling periods were uniformly distributed; second, we examined whether consumers’ average utilities of the former four selling periods were uniformly distributed. The null hypothesis for both steps stated that the population distribution was uniform. The test results are shown in Tables V and VI.

As shown in Table V, the minimum of consumers’ average utilities is 0.92 and the maximum of consumers’ average utilities is 1.52. The Kolmogorov-Smirnov $Z$ value is 1.275 with the significant value of 0.078, which is larger than 0.05; therefore we do not reject the null hypothesis. However, the significant value of 0.078 is very close to 0.05, we assume that the null hypothesis in this test is weakly supported. As shown in Table VI, the minimum of consumers’ average utilities is 0.92 and the maximum of consumers’ average utilities is 1.06. The Kolmogorov-Smirnov $Z$ value is 0.606 with the significant value of 0.856, which is too much larger than 0.05; therefore, we do not reject the null hypothesis and assume that the null hypothesis in this test is strongly supported.

On the basis of these statistics, we conclude that consumers’ average utilities of the former four selling periods are homogeneous, but they are heterogeneous from consumers’ average utilities at the fifth selling period. It means that consumers are

<table>
<thead>
<tr>
<th></th>
<th>Consumers’ average utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n$</td>
<td>5</td>
</tr>
<tr>
<td>Uniform parameters $^a,b$</td>
<td>0.92</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.92</td>
</tr>
<tr>
<td>Maximum</td>
<td>1.52</td>
</tr>
<tr>
<td>Most extreme differences</td>
<td>0.57</td>
</tr>
<tr>
<td>Absolute</td>
<td>0.57</td>
</tr>
<tr>
<td>Positive</td>
<td>0.57</td>
</tr>
<tr>
<td>Negative</td>
<td>$-0.20$</td>
</tr>
<tr>
<td>Kolmogorov-Smirnov $Z$</td>
<td>1.275</td>
</tr>
<tr>
<td>Asymp. sig. (2-tailed)</td>
<td>0.078</td>
</tr>
</tbody>
</table>

**Notes:** $^a$Test distribution is uniform; $^b$calculated from data

<table>
<thead>
<tr>
<th></th>
<th>Consumers’ average utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n$</td>
<td>4</td>
</tr>
<tr>
<td>Uniform parameters $^a,b$</td>
<td>0.92</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.92</td>
</tr>
<tr>
<td>Maximum</td>
<td>1.06</td>
</tr>
<tr>
<td>Most extreme differences</td>
<td>0.30</td>
</tr>
<tr>
<td>Absolute</td>
<td>0.30</td>
</tr>
<tr>
<td>Positive</td>
<td>0.25</td>
</tr>
<tr>
<td>Negative</td>
<td>$-0.30$</td>
</tr>
<tr>
<td>Kolmogorov-Smirnov $Z$</td>
<td>0.606</td>
</tr>
<tr>
<td>Asymp. sig. (2-tailed)</td>
<td>0.86</td>
</tr>
</tbody>
</table>

**Notes:** $^a$Test distribution is uniform; $^b$calculated from data
inclined to strategically purchase the banana at a low price, and take food freshness and inventory shortage risk into consideration as well. So far, we have justified H2 that once consumers are aware of markdown in the future, they would behave strategically even the perishable freshness decays over time and inventory shortage risk is increasing.

5.3 Nonparametric test
We assumed that consumers who purchased the bananas of the same quality and faced with the same level of inventory shortage risks belonged to a population. In this experiment, the participants whose WTP were higher than the retail price at the same selling period were deemed as samples of a same population. Owning to different levels of food freshness and consumers’ perceived risk of inventory shortages, consumers’ WTP at different selling periods were independent from each other. Accordingly, we assumed that the five groups or populations were independent from each other.

As for population distribution, we cannot assume them to be normality and homogeneity of variance. Therefore, we primarily used nonparametric methods, i.e. the Kruskal-Wallis test, to test whether the population distributions from the five selling periods were of significant difference. The Kruskal-Wallis test is a nonparametric version of the one-factor independent measures ANOVA, and it does not require a minimum number of samples in each population. The null hypothesis of H3 states consumers’ price fairness perceptions are of no differences among the five groups, i.e. the consumers’ utility distributions at different selling periods are of statistically no differences. The results of the Kruskal-Wallis test are shown in Tables VII and VIII.

Table VII shows the mean ranks of consumers’ utility at different selling periods. These rankings appear quite different but we would like to rely on the statistical test result shown in Table VIII to determine whether the null hypothesis holds. As shown in Table VIII, the Kruskal-Wallis statistic ($\chi^2$) value is equal to 4.058 with a significance value of 0.398, larger than 0.05. Thus, we conclude that the null hypothesis of H3 holds, and the population distributions from five selling periods were of statistically no differences. In this way, we conclude that the offered retail price generated by the theoretical model considering consumers’ surplus, food freshness and shortage risk can realize fair consumer segments and consumers’ price fairness perception at

<table>
<thead>
<tr>
<th>Selling period</th>
<th>$n$</th>
<th>Mean rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer’s surplus</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>32.83</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>43.50</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>26.50</td>
</tr>
<tr>
<td>5</td>
<td>32</td>
<td>38.13</td>
</tr>
<tr>
<td>Total</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>

Table VII. Ranks

<table>
<thead>
<tr>
<th>Consumer’s surplus at different selling periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi^2$</td>
</tr>
<tr>
<td>df</td>
</tr>
<tr>
<td>Asymp. sig</td>
</tr>
</tbody>
</table>

Table VIII. Test statistics

Note: "Kruskal-Wallis test; grouping variable: selling period
different selling periods. That is, those consumers who succeeded in purchasing the perishable food at different selling periods had similar population distribution of consumers’ utilities. Statistically, no plenty of extreme unfairness perception events would happen under the proposed multi-period perishable pricing strategy.

6. Concluding remarks and future work

The line of research on dynamic pricing concerning consumers’ price fairness perception is quite new in academic research, and has arisen due to its importance for food retailers of maximizing its long-term revenues and also of constructing mutual benefit and lasting connections with the consumers. In this paper, we proposed a multi-period perishable pricing strategy considering consumers’ price fairness perception. Three research hypotheses were put forward and a theoretical pricing model was built accordingly. We conducted a laboratory experiment to test consumers’ heterogeneous WTP and their strategic behaviours towards multi-period perishable pricing. The statistical results justified the hypotheses and theoretical model.

This study serves as the first step to utilize a laboratory experiment to dig out consumers’ intertemporal WTP towards perishable food. It puts forward a novel model for describing consumers’ intertemporal price fairness perception by equalizing consumers’ average utilities concerning consumer surplus, food freshness and shortage risk at different selling periods, and justifies the model empirically. The unique contribution of this paper lies in that we introduce the distribution of consumers’ utilities at different selling periods as the criterion to evaluate consumers’ intertemporal price fairness perception. We assumed that once the distributions at different selling periods were of statistically no difference, and we could conclude that consumers who purchased the perishable food at different selling periods had similar distributions of valuations on it, and no plenty of extreme unfairness perception events would be induced.

This paper also sheds light on some valuable managerial insights for dynamic pricing of perishable foods, and we have proposed three suggestions. First, owing to different levels of food freshness and perceived inventory shortage risk, consumers have heterogeneous WTP for perishable food, and most of them would like to purchase strategically. Therefore, the food retailer could adopt multi-period pricing strategy instead of the fixed price or last-minute discount strategy in order to generate as much revenue as possible from a variety of market segments. Second, when the inventory is scarce, i.e. the inventory shortage risk is a bit high; the food retailer could adjust its retail price and prompt the consumers’ forward purchases. At last, to reduce the price unfairness perceptions among consumers who purchase the perishable foods at different selling periods, the food retailer’s pricing strategy should be focused on balancing the perishable’s retail price, food freshness and perceived risk of inventory shortage; therefore, a long-term utility maximization would be likely to be ensured.

However, our analysis was based on some restrictions. First, we tested the effects of freshness and inventory shortage risk of perishable food on consumers’ price fairness perception. To incorporate more factors, extensive data including demographic information should be collected to provide more valuable managerial insights for the food retailers in further studies. Second, we studied a perishable food whose freshness decays continuously. We may explore more perishable foods whose freshness, quality or market demand decay discretely, such as seasonal items or festival foods, etc. Moreover, in this paper, a monopolist retailer’s pricing strategy was studied. Future work is encouraged to probe this further and provide new perspectives with respect to more complicated market environments with the existence of substitutes or...
competitors. Last but not the least important, since it is difficult to practice the multi-period dynamic pricing in reality due to the increased cost and lack of manpower, more suitable managerial suggestions should be investigated.

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References


**Further reading**

Appendix

According to Equations (1-2, 6-9), the model is transformed as below:

\[
\max U = \sum_{t=1}^{T} \rho_t N_t \int_{p_t}^{1} f(v_t) dv_t + \sum_{t=1}^{T} N_t \int_{p_t}^{1} (v_t - p_t)f(v_t) dv_t 
\]

(A1)

\[
U_1 = U_2 = \cdots = U_T
\]

(A2)

\[
U_t = \frac{\alpha(t)\beta(t)N_t \int_{p_t}^{1} (v_t - p_t)f(v_t) dv_t}{N_t \int_{p_t}^{1} f(v_t) dv_t} 
\]

(A3)

Since \(v_t\) satisfies the uniform distribution \([v_{\text{min}}, v_{\text{max}}]\), we have the following equations:

\[
\int_{p_t}^{1} f(v_t) dv_t = \frac{v_{\text{max}} - p_t}{v_{\text{max}} - v_{\text{min}}}
\]

(A4)

\[
\int_{p_t}^{1} (v_t - p_t)f(v_t) dv_t = \frac{(v_{\text{max}} - p_t)^2}{2(v_{\text{max}} - v_{\text{min}})}
\]

(A5)

Then, we transform Equations (A1) and (A3) into the following equations:

\[
\max U = \frac{1}{v_{\text{max}} - v_{\text{min}}} \times \left[ \sum_{t=1}^{T} \rho_t N_t (v_{\text{max}} - p_t) + \sum_{t=1}^{T} \frac{\alpha}{2} N_t (v_{\text{max}} - p_t)^2 \right] 
\]

(A6)

\[
U_t = \frac{\alpha(t)\beta(t)(v_{\text{max}} - p_t)}{2}
\]

(A7)

We assume that \(c_t = v_{\text{max}} - p_t\) and according to Equation (A2), we have \(c_t = (\alpha(1)\beta(1))/(\alpha(t)\beta(t))\). Thus, Equation (A6) is transformed into the following equation:

\[
\max U = \frac{1}{v_{\text{max}} - v_{\text{min}}} \times \left[ \sum_{t=1}^{T} N_t v_{\text{max}} \alpha(1)\beta(1)c_t + \sum_{t=1}^{T} \frac{\alpha}{2} N_t \alpha^2(1)\beta^2(1)c_t^2 \right] 
\]

(A8)

Since \((\alpha)/(2)-1 < 0\) and the axis of symmetry \(\gamma\) satisfies the following equation:

\[
\gamma = \frac{v_{\text{max}} \sum_{t=1}^{T} N_t \alpha(1)\beta(1)c_t}{(2-\alpha) \sum_{t=1}^{T} N_t \alpha^2(1)\beta^2(1)c_t} < \frac{v_{\text{max}}}{(2-\alpha)} < v_{\text{max}} 
\]

(A9)

Since \(v_{\text{min}} \leq p_t \leq v_{\text{max}}\) and \(\alpha(t)\beta(t)\) is monotone decreasing; we have \(0 \leq c_t \leq (\alpha(T)\beta(T))/(\alpha(1)\beta(1))(v_{\text{max}} - v_{\text{min}})\).
If \( \gamma > (z(T)\beta(T))/(z(1)\beta(1))(v_{\text{max}} - v_{\text{min}}) \), the optimal retail price \( p_t \) is given in the following equation:

\[
p_t = v_{\text{max}} - \frac{z(T)\beta(T)}{z(1)\beta(1)}(v_{\text{max}} - v_{\text{min}})
\]

(A10)

If \( \gamma \leq (z(T)\beta(T))/(z(1)\beta(1))(v_{\text{max}} - v_{\text{min}}) \), the optimal retail price is given in the following equation:

\[
p_t = v_{\text{max}} - \frac{v_{\text{max}}}{(2-\omega)z(T)\beta(T)} \left[ \sum_{i=1}^{T} \frac{N_i}{z(1)\beta(1)} \right]
\]

(A11)

Therefore, the optimal retail price is expressed in Equation (11):

\[
p_t = \begin{cases}
  v_{\text{max}} - \frac{z(T)\beta(T)}{z(1)\beta(1)}(v_{\text{max}} - v_{\text{min}}), & \text{if } \gamma > \frac{z(T)\beta(T)}{z(1)\beta(1)}(v_{\text{max}} - v_{\text{min}}) \\
  v_{\text{max}} - \frac{v_{\text{max}}}{(2-\omega)z(T)\beta(T)} \left[ \sum_{i=1}^{T} \frac{N_i}{\min_{t} z(1)\beta(1)} \right], & \text{if } \gamma \leq \frac{z(T)\beta(T)}{z(1)\beta(1)}(v_{\text{max}} - v_{\text{min}})
\end{cases}
\]

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