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# Effects of online shopping channel and price discount on near-expiry food sales

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## Abstract

Consumers have an aversion to purchasing near-expiry food products, which leads to enormous food waste and economic loss. Given the importance of this issue, past research has studied the effect of impending expiration date on product sales, but its focus has been limited to perishable food products. Since the expiration dates of non-perishable food products are treated as less important than those of perishable food products, we expect that the resulting effect on sales largely varies by shopping environment. With the growing importance of online shopping in food sales, we examine how the effect of impending expiration date differs between mobile and PC shopping environments. By analyzing a unique data set from an online salvage store, we find that consumer aversion toward near-expiry products is more salient in the PC shopping environment than in the mobile shopping environment. However, when there is a deeper price promotion, the between-channel difference is reduced as the sensitivity of an impending expiration date on sales increases in the mobile shopping environment. These findings not only represent novel contributions to the literature but also provide managerial implications for practitioners.

## Keywords

expiration date, non-perishable foods, mobile and PC channels, price promotion

## Introduction

An expiration date is defined as the last day on which a food item will still have its best quality (USDA, 2019). That is, expiration dates are simply related to optimal food quality, not safety (FDA, 2022),

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meaning most foods are edible even after their expiration date; when appropriately stored, even milk should be drinkable up to 2 weeks past its expiration date. However, consumers tend to have a belief that a food item continuously deteriorates on the shelf as it approaches its expiration date. As a result, consumers avoid purchasing food items near their expiration date (NRDC, 2017). Various reports and articles have stated that such misunderstandings about expiration dates and the reflexive aversion toward near-expiry food products cause 229 million tons of food wastes and 450 billion dollars of economic loss (ReFED, 2022). According to ReFED report (2022), it generates greenhouse gas emissions of more than 1.1 million MTCO2e, equivalent of driving 169,000 cars for a year, to produce those foods that are later discarded. It also has a water footprint of 104 billion gallons, the amount of water used in New York City for a hundred days, to produce those wasted food. To reduce this social harm and save the environment, it is crucial for both marketing researchers and practitioners to find a way to alleviate consumer avoidance of purchasing near-expiry food items.

Given the importance of this issue, various studies have investigated consumers' reflexive avoidance of near-expiry food items (Choi et al., 2022; Konuk 2018; Mandal et al., 2021; Sen and Block 2009; Theotokis et al., 2012). For example, Tsiros and Heilman (2005) surveyed grocery shoppers and found that consumers avoid purchasing near-expiry perishable food products (i.e., food products that easily spoil, decay, and become unsafe if not stored appropriately) including milk, meat, and vegetables because they perceive such food products to be of higher risk. In another study, Neff et al. (2019) reported that half of American consumers discard near-expiry food products. According to the results of their online survey, consumers worry about the safety of near-expiry foods while ignoring the true meaning of the expiration dates that appear on the labels of food products, such as "best before" or "sell by". Given customers' avoidance of near-expiry food items, literature has documented decreased sales of near-expiry perishable food as it approaches the expiration date (Choi et al., 2022; Mandal et al., 2021).

Although there is a vast body of literature on expiration dates, there are several limitations to this literature. First, past research has mostly focused on the effects of impending expiration dates on perishable food products (Sen and Block 2009; Theotokis et al., 2012; Tsiros and Heilman 2005). However, the majority of food items sold in grocery stores are non-perishable food products (i.e., food products that are processed and packaged to prolong their storage), such as canned food, frozen food, processed food, snacks, and drinks (Poti et al., 2015). Because non-perishable food products have longer shelf lives and maintain a more stable quality than perishable food products (USDA, 2019), consumers do not treat the expiration dates of non-perishable food products as important as they treat those of perishable food products (Choi et al., 2022). Therefore, there could be unique and nuanced effects of expiration dates among non-perishable food products, which have thus far gone underexamined.

Second, the development of e-commerce, including shipping and delivery services in particular, has rapidly expanded the online channel in the food market. The COVID-19 pandemic set the stage for a particularly dramatic increase; the share of online sales in total grocery sales has grown from 4.3% to 10% (Trainer, 2020) and reached $58.52 billion in the United States in 2020 (eMarketer 2020). However, past research has lacked a comprehensive investigation of the effect of impending expiration date on food sales in an online shopping environment. The two most popular channels in online shopping are PC and mobile (Statista 2021), with each providing a unique and distinct shopping environment. Notably, the small display size in the mobile shopping environment means consumers have to expend more effort to process product information details (Min Kim et al., 2020; Naegelein, Spann, and Molitor 2019; Xu et al., 2017). Thus, consumers tend to process less information when making a purchase in a mobile shopping environment than in a PC shopping environment (Seeger et al., 2019). If this were the case, it would lead to some interesting research questions. For example, is the effect of impending expiration date on sales the same between mobile and PC channels? If not, how do they differ?

Third, while prior research has documented price promotion (i.e., price discount) as a strategy used by firms to sell near-expiry food items (e.g., Choi et al., 2022; Theotokis et al., 2012; van Donselaar et al., 2006), it is less understood how price promotions can affect consumers' avoidance of near-expiry food items. Consumers often infer product quality from price, so a price promotion may increase their apprehensions toward the product quality (Cao et al., 2021; Wu et al., 2021; Zheng et al., 2022). To dispel doubts and concerns about the quality of the product under price promotion, consumers seek information that helps them better judge its quality (Bougie et al., 2003; Bradley and Spark 2002; Lallement et al., 2020). This heightened attention toward product information may cause consumers to pay more attention to the expiration date when making purchase decisions. This leads to another set of questions for further research. For example, will price promotions moderate the effect of impending expiration date on sales? How will the moderating effect of price promotions differ between mobile and PC channels?

This paper attempts to fill these gaps in the literature by comparing the avoidance shown toward near-expiry non-perishable food products in mobile and PC shopping environments. We examine the differences in not only the sensitivity toward the expiration date in general, but also the impact of price promotions on the aversion toward near-expiry products. We address our research questions by investigating the actual PC and mobile sales data of non-perishable food products from an online salvage store in South Korea.

This research makes several theoretical contributions. First, it enriches the understanding about how expiration date affects the sales of non-perishable food products. Second, this study contributes to a stream of research that compares shopping behaviors under PC and mobile environments (Luceri, Bijmolt and Bellini 2022; Naegelein, Spann, and Molitor 2019; Seeger et al., 2019; Wan et al., 2022; Wang et al., 2020). To our knowledge, this research is the first to contrast the effect of impending expiration date between PC and mobile shopping environments. Third, we further uncover the nuanced nature of consumer avoidance of near-expiry products. We document the novel finding that price promotion determines the level of expiration date-based avoidance under certain circumstances.

Our research also offers a managerial implication to online food stores. First, practitioners can better determine an online channel which better sells near-expiry foods between PC and mobile. For instance, online stores can consider asymmetric execution of product assortment, direct marketing or even price promotion between channels. Second, the effect of price promotion is not the same between the PC and mobile channel in selling near-expiry food products. Thus, a marketer should be cautious in implementing expiration date-based pricing across different online channels.

In the following sections, we develop our hypotheses while building upon prior literature. Next, we describe our research setting, data, empirical analyses, and findings. The paper then concludes with the implications and limitations of our research.

## Theoretical development

### *Expiration dates of non-perishable food products*

Prior literature has indicated that sales of a food item decrease as its expiration date approaches because consumers avoid purchasing food items near expiry (Choi et al., 2022; Konuk 2018; Mandal et al., 2021; Sen and Block 2009; Tsiros and Heilman 2005). However, depending on product perishability, consumers may pay differing levels of attention to the expiration dates of products. For instance, most consumers carefully check the expiration date of fresh milk, but not necessarily that of canned tuna.

Generally speaking, consumers regard the expiration date as a core attribute of perishable food products that are easily spoiled, decayed, or unsafe (USDA, 2019). Thus, when shopping for perishable food products such as fruits, vegetables, dairy, fish, and meats, consumers scrutinize expiration dates regardless of the context or the environment (Axtman, 2006; Hall-Phillips & Shah, 2017). As a result, past studies across different research settings have consistently found that the sales of perishable food products decrease with an impending expiration date (Gregory et al., 1996; Péneau et al., 2006; Sen and Block 2009; Theotokis et al., 2012; Tsiros and Heilman 2005).

By contrast, non-perishable food products are defined as food products that have a long shelf-life, often maintaining their quality for years. For instance, canned vegetables and fruits have shelf lives around 2 years, and they are safe to eat over a year after their expiration dates. As non-perishable food products are perceived to have relatively more stable quality and a longer time until expiration, consumers often treat the expiration date as a peripheral—rather than core—attribute of non-perishable food products.[1]

While consumers mostly consider the core attributes of products when purchasing, they may or may not consider peripheral attributes depending on their individual cognitive capacity (Petty and Cacioppo 1981; Sanbonmatsu and Kardes 1988; Hollender et al., 2010; Jacoby, 1984; Simon, 1978). In this regard, we believe that the avoidance of near-expiry foods can largely vary by context (Choi et al., 2022): When consumers have sufficient cognitive resources, they might consider the expiration date of non-perishable products in their purchase decisions. Thus, avoidance of the near-expiry would be salient. However, when consumers have insufficient cognitive resources, they might be less likely to consider the expiration date of non-perishable products in their purchase decisions. Thus, avoidance of the near-expiry would be less salient.

### *Online shopping channel: Mobile versus PC*

Consumers often use either mobile devices (e.g., smart phones and tablets) or PCs (e.g., desktops and laptops) for online shopping (Seeger et al., 2019; Wang et al., 2015). Thus, we compare the effects of these two online shopping channels—mobile and PC—on consumers' cognitive resources.

According to the literature, the mobile shopping environment depletes consumers' cognitive resources more than the PC shopping environment (Min Kim et al., 2020; Naegelein, Spann, and Molitor 2019; Xu et al., 2017). Since mobile devices have smaller screens than PCs, all the images and texts presented on a mobile screen are smaller. Thus, consumers need to expend greater cognitive efforts to intake the product information on their mobile devices (Ghose et al., 2013; Park et al., 2020). Further, the touch interface in a mobile shopping environment reduces both accuracy and the number of available functions compared to clicking and scrolling in the PC shopping environment. The greater potential for error and functional restrictions force consumers to exert greater cognitive efforts in the purchasing process (Seeger et al., 2019).

Since consumers have less cognitive resources in mobile than PC shopping environments, they are likely to pay less attention to peripheral attributes like the expiration date of non-perishable food products in mobile than PC shopping channels. Such asymmetric attention toward the expiration date between the channels is expected to be reflected in the sales of non-perishable food products as follows:

> *H1:* Impending expiration date decreases the sales of non-perishable food products more in the PC channel than in the mobile channel.

### Moderating effect of price promotion

Price promotions are incentives that entice consumers to purchase products (Grewal et al., 1998; Lattin and Bucklin 1989). However, price promotions do not always stimulate the sales of a product, as they can negatively influence consumer perceptions about its quality (Cao et al., 2021; Wu et al., 2021; Zheng et al., 2022); this is because consumers often treat price as a signal of quality. When a price promotion triggers apprehensions about a product's quality, consumers seek information to help them better judge the quality (Bougie et al., 2003; Bradley, and Spark 2002; Lallement et al., 2020). As a result, a price promotion can heighten the consumers' attention toward the peripheral attributes of products that otherwise might not have been recognized, and thus evoke awareness about the expiration date of non-perishable food products.

Such heightened attention toward the peripheral attributes of products may differ under the mobile and PC shopping environments. In mobile shopping channels, consumers tend to pay limited attention to available information by default, based on the cognitive reasoning described above. By contrast, as consumers by default have relatively sufficient cognitive resources in PC shopping, they may have already accounted for the expiration date of non-perishable food products. This would leave little room for a price promotion to enhance attention toward the expiration date in the PC shopping channel, meaning that the impact of price promotion on the sales of near-expiry non-perishable food products would be limited in the PC shopping channel. Consequently, we hypothesize the following:

> *H2:* Under a price promotion, the decrease in sales of perishable food products over the impending expiration date will (a) become more salient in mobile shopping but (b) remain unchanged in PC shopping.

## Research setting

To examine our hypothesis, we collected sales data from an online salvage store in South Korea; we have omitted its identity per request. The online salvage store acquires near-expiry food from manufacturers at give-away prices and resells them online at competitive prices (on average, 80% off). The online salvage store sells a variety of non-perishable food products such as snacks, canned foods, frozen foods, and beverages, the shelf lives of which vary. Due to its product variety and low prices, the online salvage store is growing rapidly; its sales have grown by 80% per year on average from 2015 to 2019. As of 2019, it had more than 290,000 enrolled users and its sales reached eight million dollars. The online salvage store offers an ideal setting to address our research questions for the following reasons.

First, due to its unique business model, the online salvage store clearly presents expiration dates—along with other key attributes such as product name, category, price, and discount rate—on its interface. On a platform that does not show the expiration date information so prominently, an approaching expiration date would hardly affect sales, and our research questions could not be adequately addressed. Figure 1 shows the information presented on the product page on the online salvage store for both channels (i.e., Panel A for the PC shopping channel and Panel B for the mobile shopping channel), where it can be seen that the expiration date is clearly presented in both interfaces.[2] Therefore, this research setting satisfies the necessary conditions for expiration date to affect sales.

Second, consumers can access the online salvage store via both PC and mobile devices. Since the online salvage store sells identical products on both channels and keeps track of PC and mobile sales

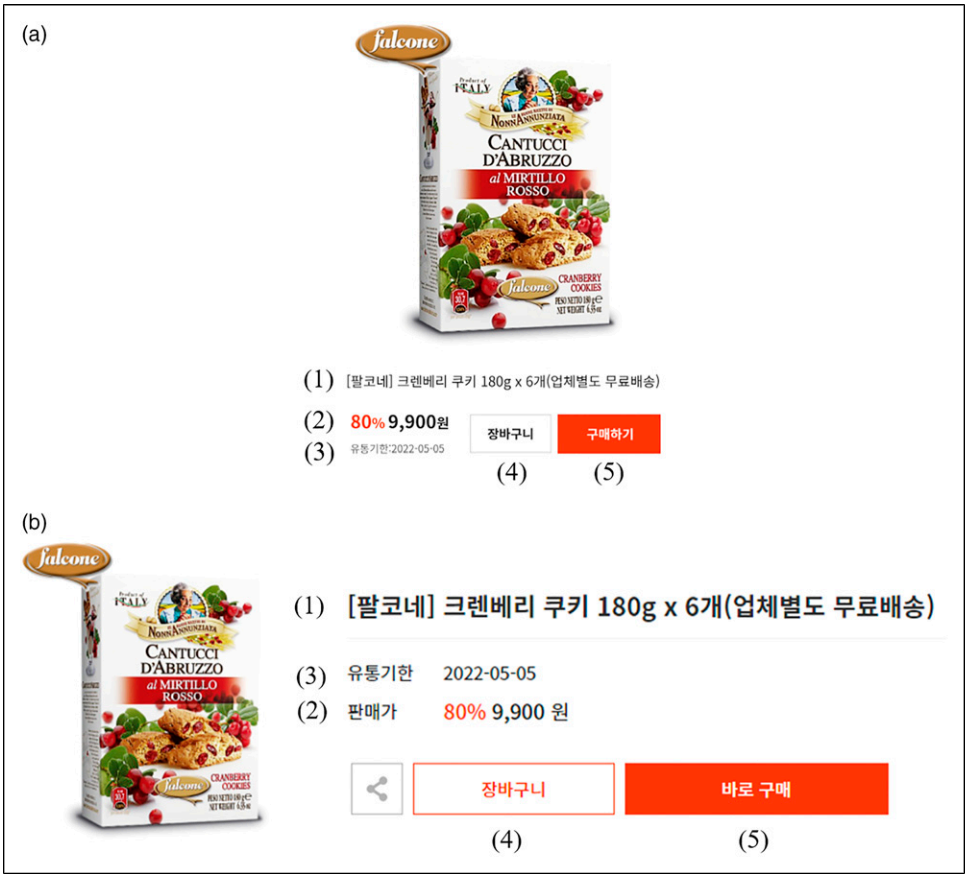


**Figure 1.** Screenshots of online salvage store product page. (a) Mobile (b) PC.

separately, we can conveniently compare the daily sales of every product sold between the two channels. Further, there is no substantial difference in the sales conditions between the two channels; both channels provide identical information and prices. That is, although there are minor differences in layouts and designs between the channels (See Figure 1), there are no unique features specific to either channel. Therefore, we can contrast the impending expiration effect between PC and mobile without being confounded by differences in sales conditions between the two channels.

Third, the pricing practice of the online salvage store is similar to that of other regular food stores so empirical findings in our research setting would be generalizable. Due to avoidance of near-expiry foods, price tends to go down over time on average. However, it does not mean that the price of an individual item gradually goes down over time. In fact, there is no regular pattern in price change of an individual item; there is no price change at all for some products, but price fluctuates due to temporary price promotions for other products. Thus, consumers can hardly predict an individual item's price a priori, and the pricing practice of the online salvage store is similar to other stores.

Finally, the dataset contains rich information about pricing. As mentioned above, retailers in perishable product markets frequently provide price discounts on near-expiry products

(Theotokis et al., 2012). Due to the correlation between sales prices (i.e., the price at which the consumers buy the product) and time left to expiration, daily changes in sales prices will confound the impact of an impending expiration date on sales. Thus, for stringent testing of our hypotheses, it is important to control for daily sales prices. Moreover, retailer's pricing decisions are often based on their predictions about future sales, which creates endogeneity in sales prices. If we have internal information not disclosed to customers such as the supply price (i.e., the price paid by the online retailer to the producer), we can handle the endogeneity issue using the instrumental variable (IV) approach (Petrin and Train 2010; Villas-Boas and Zhao 2005). The fact that the data from the online salvage store includes daily changes in supply prices as well as selling prices also allows us to effectively address endogeneity concerns.

## Data and variables

### Data

Our data consist of three parts: product sales, characteristics, and pricing data. The sales data includes daily sales of 897 non-perishable food products sold on the online salvage store in South Korea for the year 2015. As noted earlier, the store separately records mobile and PC sales. Product characteristics include time-invariant information about each product, such as product name, product category, expiration date, and manufacturer's suggested retail price (MSRP).[3] The same product characteristics are always presented in the PC and mobile shopping channels. Lastly, pricing data contains information about daily changes in the sales price and the supply price of each product. The sales price and the supply price are also identical between the two channels.

The following procedures were implemented to form the sample. First, we eliminated observations of products that were not available for sale; a product may not be sold because it has been sold out or has reached its expiration date.[4] In these cases, the sales of a product are zero regardless of the latent demand for the product. To rigorously test our hypotheses, we distinguished zero sales observations from not-on-sale observations, then excluded the not-on-sale observations. Second, we eliminated daily observations of products with expiration dates that were over a month (i.e., 30 days) away. For products that were registered on the online salvage store with more than 30 days left until expiration, we only included daily observations from days for which there were 30 days or fewer left until the sold-out or expiration date. For products that were registered on the online salvage store with less than 30 days left until expiration, we included all daily observations from the registration date until the sold-out or expiration date. This was done to focus our analysis on focal periods in which the effect of impending expiration date on sales is expected to be the most salient. The shelf lives of most non-perishable food products are longer than a year, so we test our hypotheses among a data set with products that have passed 90% of their shelf lives.

As a result, our sample includes daily observations of 512 non-perishable food products that ultimately account for 7370 observations. Out of these 512 products, 234 were registered on the online salvage store with less than 30 days left until expiration. Further, 488 products were sold out before they expired. Therefore, the number of observations is less than 15,360 (which would be a full 30 days of observations for each of the 512 foods).

### Variables

To empirically test our hypotheses, we construct the following variables: First, we define the daily product sales on each channel as dependent variables; $sales^{P}_{it}$ denotes log-transformed product $i$'s unit sales on calendar day $t$ on the PC channel (upper index P) whereas ${sales^{M}}_{it}$ is the corresponding log-transformed unit sales on the mobile channel (upper index M).[5] We took log-transformation because the units sold on each channel are highly right-skewed.[6] As discussed earlier, the online salvage store offers the same products at the same prices on both channels. Thus, the sales variables (${sales^{P}}_{it}$ and ${sales^{M}}_{it}$) are the only variables that differ between the two channels; no other variables in our analyses differ between the channels.

Next, $remain_{it}$ denotes log-transformed time (i.e., the number of days) left until product $i$'s expiration on day $t$. Since this variable captures the temporal distance to the expiration date, it is the focal independent variable used to test our hypotheses. We log-transformed the time because the effect of the expiration date is expected to be stronger as the expiration date approaches. Thus, $remain_{it}$ ranges between zero (i.e., log (0 + 1) = 0 at the expiration date) and log (31) (i.e., log (30 + 1) = log (31), when a product has 30 days left until the expiration date).

Daily change in sales price is another key variable in this analysis. We define $dc_{it}$ as the percentage of discount for product $i$ on day $t$. Specifically, the percentage is acquired by taking the difference between the sales price and the MSRP and dividing this difference by the MSRP. Further, as we are also interested in the moderating role of price promotion in the effect of impending expiration date on sales, we define $remain\_dc_{it}$ as the interaction term between $remain_{it}$ and $dc_{it}$.

Meanwhile, $dc_{it}$ potentially suffers from an endogeneity problem. This is because sellers often strategically determine the price of a product by considering various unobservable factors that may affect sales (Kim and Petrin 2015; Petrin and Train 2010). To address this issue, we introduce two IVs, $sales_{it-1}$ and $profit_{it-1}$. We define $sales_{it-1}$ as the log-transformed total units of product $i$ sold on day $t-1$ in both channels. Similarly, we define $profit_{it-1}$ as the log-transformed profit from selling product $i$ on the previous day, where profit is calculated as the number of units sold multiplied by the unit profit margin (i.e., the sales price minus the supply price) of product $i$ on day $t-1$. Although consumers are not made aware of the recent sales and profits of a product, the online salvage store may have considered these factors when deciding which products to put in a price promotion and by how much (Petrin and Train 2010; Villas-Boas and Zhao 2005). As both $sales_{it-1}$ and $profit_{it-1}$ satisfy the exclusion restriction condition, we believe it is appropriate to use the two variables as IVs to handle endogeneity issues.

Finally, we introduce dummy variables to control for the temporal effect on day $t$. We include six dummy variables to control the weekday effect and 11 dummy variables to control the month effect. Table 1 summarizes the descriptive statistics of the continuous variables.

## Empirical analyses

### *Model specification*

To flexibly accommodate differences across channels, we specify separate equations for each of the mobile and PC shopping channels. We also have a separate set of parameters for each equation, which allows all independent variables to differently influence sales in the mobile and PC channels. Specifically, we set the equation as follows.

$$sales^{M}_{it} = \beta^{M}_{0i} + \beta^{M}_{1} remain_{it} + \beta^{M}_{2} dc_{it} + \beta^{M}_{3} remain_{\_dcit} + X_{it}\beta^{M}_{4} + \varepsilon^{M}_{it}. \quad (1)$$

In equation (1), ${\beta^{M}}_{0i}$ denotes the product-specific fixed effects (512 dummies), which thoroughly controls for the sales differences across products on the mobile channel. That is, we rule out the idea that potential sales differences across products may distort the effect of impending expiration date.

**Table 1.** Descriptive statistics.

| | Variables | Mean | SD | Min | Max | Correlation (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | $sales^{P}_{it}$ | .35 | .46 | .00 | 1.86 | .59 | −.14 | .27 | .11 | .61 | .48 |
| (2) | $sales^{M}_{it}$ | .37 | .71 | .00 | 4.47 | | −.07 | .27 | .16 | .60 | .41 |
| (3) | $remain_{it}$ | 2.77 | .57 | .00 | 3.43 | | | −.17 | .59 | −.10 | −.07 |
| (4) | $dc_{it}$ | 64.45 | 15.55 | 11.0 | 97.22 | | | | .68 | .30 | .22 |
| (5) | $remain\_dc_{it}$ | 176.98 | 53.81 | .00 | 309.63 | | | | | .16 | .12 |
| (6) | $sales_{it}$ | .73 | 1.01 | .00 | 5.63 | | | | | | .84 |
| (7) | $profits_{it}$ | 3.97 | 4.26 | .00 | 11.84 | | | | | | |

$\beta^{M}{}_{1}$ captures the effect of $remain_{it}$ on sales in the mobile channel. If the sales of non-perishable food products decrease over the impending expiration date in the mobile channel, then $\beta^{M}{}_{1}$ will be positive (i.e., sales 'decrease' when there is 'less' time left to a product's expiration in the mobile channel). The effects of price promotions on mobile sales are captured by $\beta^{M}{}_{2}$. If heavier discounts increase the sales in the mobile channel, then $\beta^{M}{}_{2}$ will be positive. The moderating effect of price promotions on the effect of impending expiration date in the mobile channel will be captured by $\beta^{M}{}_{3}$. If price promotion increases the sensitivity toward the impending expiration date in the mobile channel, as we hypothesized in H2a, then $\beta^{M}{}_{3}$ will be positive (i.e., under deeper price promotions, sales further 'decrease' when there is 'less' time left to a product's expiration in the mobile channel). $X_{it}$ is a vector of dummy variables on weekdays (six dummies) and months (11 dummies) and $\beta^{M}{}_{4}$ is the corresponding vector of parameters.

Next, we specify the equation of PC sales as follows:

$$sales^{P}_{it} = \beta^{P}_{0i} + \beta^{P}_{1} remain_{it} + \beta^{P}_{2} dc_{it} + \beta^{P}_{3} remain_{\_dcit} + X_{it}\beta^{P}_{4} + \varepsilon^{P}_{it}. \tag{2}$$

The interpretation of equation (2) is analogous to that of equation (1). For instance, if the sales decrease over the impending expiration date in the PC channel, then $\beta^{P}{}_{1}$ will be positive. Meanwhile, if a price promotion does not affect the sensitivity toward the impending expiration date in the PC channel, as we hypothesized in H2b, then $\beta^{P}{}_{3}$ will be zero.

In the equations above, there are two variables that potentially suffer from endogeneity issues: $dc_{it}$ and $remain\_dc_{it}$. As discussed earlier, $dc_{it}$ suffers from the endogeneity issue if price promotion decisions are made based on the online retailers' internal predictions about sales. Consequently, $remain\_dc_{it}$—which is an interaction term between $remain_{it}$ (an exogenous variable) and $dc_{it}$ (an endogenous variable)—potentially suffers from the endogeneity issue as well. To resolve the endogeneity issues, we introduce the IV equation for each endogenous variable. We first specify the following IV equation for $dc_{it}$:

$$dc_{it} = \gamma^{D}_{0i} + \gamma^{D}_{1} Z_{it} + \gamma^{D}_{2} sales_{it-1} + \gamma^{D}_{3} profit_{it-1} + \eta^{D}_{it}. \tag{3}$$

In equation (3), superscript $D$ denotes that the coefficient is related to IV equation for $dc_{it}$. The equation follows the standard specification of IV equations in econometrics (Greene, 2012; Wooldridge, 2015). The equation consists of product-specific fixed effects ($\gamma^{D}{}_{0i}$), a vector of all the covariates included in Equations (1) and (2) except for the two endogenous variables ($Z_{it}$), and two IVs ($sales_{it-1}$ and $profit_{it-1}$). $\gamma^{D}{}_{1}$ is a vector of parameters corresponding to $Z_{it}$. The effect of $sales_{it-1}$ on $dc_{it}$ is captured by $\gamma^{D}{}_{2}$; if there are deeper discounts on products that have sold better, then $\gamma^D{}_2$ will be positive. The effect of $profits_{it-1}$ on $dc_{it}$ is captured by $\gamma^D{}_3$; if there are deeper discounts on products with better profits, then $\gamma^D{}_3$ will be positive. Finally, $\eta^D{}_{it}$ is a random component in $dc_{it}$.

Next, we specify IV equation for $remain\_dc_{it}$ as follows:

$$remain\_dc_{it} = \gamma^R_{0i} + \gamma^R_1 Z_{it} + \gamma^R_2 sales_{it-1} + \gamma^R_3 profit_{it-1} + \gamma^R_4 remain_{it} \times sales_{it-1} + \gamma^R_5 remain_{it} \times profit_{it-1} + \eta^R_{it}. \quad (4)$$

In equation (4), superscript $R$ denotes that the coefficient is related to the IV equation for $remain\_dc_{it}$. The specification of the equation is analogous to equation (3), but we added the interaction terms between the IVs in equation (3) and $remain_{it}$ (i.e., $remain_{it} \times sales_{it-1}$ and $remain_{it} \times profit_{it-1}$). This is because $remain\_dc_{it}$ is an interaction term between $dc_{it}$ and $remain_{it}$, so the effects of the IVs used in equation (3) may vary by $remain_{it}$. The parameters in equation (4) are not directly interpretable because $remain\_dc_{it}$ is an interactive term; we include equation (4) in the model to control for endogeneity, not for interpretation. This allows us to at least see the direction of the relationship between $remain\_dc_{it}$ and the independent variables in the equation. For instance, positive $\gamma^R{}_4$ indicates that the association between $sales_{it-1}$ and $remain\_dc_{it}$ is more positive when there is more time left until the expiration date (i.e., greater $remain_{it}$).

The four equations above are intercorrelated via random components. The error terms of the four equations ($\varepsilon^M{}_{it}$, $\varepsilon^P{}_{it}$, $\eta^D{}_{it}$, and $\eta^R{}_{it}$) are assumed to follow a multivariate normal distribution. There could be unobserved common factors that drive product sales on both channels and price discounts; our correlation structure across the error terms flexibly accounts for this possibility (Avery et al., 2012; Berry et al., 2010; Osinga et al., 2019). Consequently, our primary model is a Simultaneous Equation Model that consists of four equations: two equations for Seemingly Unrelated Regression (SUR) and two equations for the IV equations. We estimated all four equations simultaneously using Three-Stage Least Square (3SLS) estimation (Greene, 2012; Wooldridge, 2015).

## Estimation results

Table 2 summarizes the obtained estimation results. In the table, the first and second columns show the estimation results for the mobile and the PC equations, respectively. The third and fourth columns show the results of the first stage IV estimation results of $dc_{it}$ and $remain\_dc_{it}$, respectively.

It can be seen that the sales of non-perishable food products decline with an impending expiration date. That is, there is a positive effect of $remain_{it}$ on sales (i.e., sales 'decrease' when there is less time left until the expiration date) in both the mobile channel ($\widehat{\beta}^M{}_1 = .470$, $p < .001$) and the PC channel ($\widehat{\beta}^P{}_1 = .602$, $p < .001$). These results are consistent with those of previous studies that have documented the evidence of avoidance of near-expiry foods (Sen and Block 2009; Theotokis et al., 2012; Tsiros and Heilman 2005). Next, we tested if there was a significant between-channel difference in the aversion to near-expiry foods. The estimated between-channel difference is $\widehat{\beta}^P{}_1 - \widehat{\beta}^M{}_1$, and the standard error for this estimate is acquired using delta methods (Greene 2005). We found that the sensitivity toward an impending expiration date is significantly greater in the PC shopping channel than in the mobile shopping channel ($\widehat{\beta}^P{}_1 - \widehat{\beta}^M{}_1 = .132$, $SE = .063$, $p < .05$). This finding is consistent with H1.

The between-channel difference implied by our model estimates are not only statistically significant but also economically significant. In the mobile shopping environment, sales of a product with a week (i.e., 7 days) left until the expiration date are 52.9% of those with a month (i.e., 30 days) left until the expiration date [ = exp (.470 × ($log$ (7 + 1) – $log$ (30 + 1)))]. Meanwhile, in the PC

**Table 2.** Estimation results.

| | Main equations | | IV equations | |
|---|---|---|---|---|
| | Mobile | PC | $dc_{it}$ | $remain\_dc_{it}$ |
| $remain_{it}$ | .470*** (.039) | .602*** (.049) | −3.737*** (.102) | 5.891*** (.214) |
| $dc_{it}$ | .144*** (.010) | .190*** (.012) | | |
| $remain\_dc_{it}$ | .010*** (.003) | .004 (.003) | | |
| $sales_{it}$ | | | 2.193*** (.120) | 2.852*** (.364) |
| $profits_{it}$ | | | −.200*** (.019) | −.321*** (.075) |
| $remain_{it}$ × $sales_{it}$ | | | | 6.147*** (.304) |
| $remain_{it}$ × $profits_{it}$ | | | | −.540***(.077) |

*$p \le .05$, **$p \le .01$, ***$p \le .001$. Standard errors in parentheses. The model includes several additional covariates: Product-specific fixed effects (512 dummies), weekday dummies (six dummies) and month dummies (11 dummies). These estimates are not reported to avoid clutter.

shopping environment, sales of a product with a week left until the expiration date are 44.2% of those with a month left until the expiration date [ = exp (.602 × (*log* (7 + 1) – *log* (30 + 1)))]. Therefore, PC sales decline about 9% more than mobile sales during the period between a month before and a week before the expiration date.

Then, does price promotion moderate the effect of impending expiration date as expected? In the mobile equation, the coefficient on $remain\_dc_{it}$ is significantly positive ($\widehat{\beta}^M{}_3 = .010, p < .001$). This result indicates that the aversion to near-expiry non-perishable food products increases with deeper price promotion in mobile shopping. This finding is consistent with H2a. However, in the PC equation, the coefficient on $remain\_dc_{it}$ is not significantly different from zero ($\widehat{\beta}^P{}_3 = .004, p > .05$). That is, the aversion to near-expiry non-perishable food products is not affected by price promotion in PC shopping. This finding is consistent with H2b. Our results imply that the between-channel difference in the avoidance of near-expiry non-perishable food products is reduced with deeper price promotions. According to our model estimate, the sensitivity of sales to an impending expiration date becomes equal between mobile and PC when the discount rate is 22% [= (.602 − .470)/(.004–.010)] higher than the current discount rate.

Further, price promotion increases sales in both the mobile channel ($\widehat{\beta}^M{}_2 = .144, p < .001$) and the PC channel ($\widehat{\beta}^P{}_2 = .190, p < .001$). The finding is congruent with our intuitions. In the estimates of the IV equations, all the IVs turn out to be significant, suggesting that our results do not suffer from weak IV problems. According to the IV equation for $dc_{it}$, there are greater price promotions ($\widehat{\gamma}^D{}_1 = -3.737, p < .001$), greater sales ($\widehat{\gamma}^D{}_2 = 2.193, p < .001$), and less profits ($\widehat{\gamma}^D{}_3 = -.200, p < .001$) for products with an impending expiration date. According to the IV equation for $remain\_dc_{it}$, $remain\_dc_{it}$ has a positive association with $remain_{it}$ ($\widehat{\gamma}^R{}_1 = 5.891, p < .001$). Further, $remain\_dc_{it}$ has a positive association with $sales_{it\text{-}1}$ ($\widehat{\gamma}^R{}_2 = 2.852, p < .001$), and this relationship is stronger when $remain_{it}$ is greater ($\widehat{\gamma}^R{}_4 = 6.147, p < .001$). The association between $remain\_dc_{it}$ and $profit_{it\text{-}1}$ is negative ($\widehat{\gamma}^R{}_1 = -0.321, p < .001$), and the relationship is stronger when $remain_{it}$ is greater ($\widehat{\gamma}^R{}_4 = -.540, p < .001$).

Altogether, we find that the impending expiration date decreases the sales of non-perishable food products more in the PC channel than in the mobile channel; further, under a price promotion, the decrease in sales over the impending expiration date becomes more salient in mobile shopping but remains unchanged in PC shopping.

## Robustness checks

In this section, we show the robustness of our findings in different model specifications.

*Symmetric customer panel between channels.* In our main analysis, sales in each channel have been generated by a different group of customers. In our customer panel, 38% have used PC only, 42% have used mobile only, and 20% have used both channels since registration. If there are substantial differences between PC-only and mobile-only customers, our focal results might have been driven by the difference in customers, not the difference in cognitive resources between shopping channels. To rule out this spurious effect, we exclude all observations from either PC- or mobile-only customers, and analyze the sales from customers who have used both channels. In this analysis, PC and mobile sales are generated from the same panel, so can alleviate the channel-selection issue.

The results of the focal parameters are presented in Panel A of Table 3. Consistent with the focal findings, the sensitivity toward the impending expiration date is significantly greater in the PC channel than in the mobile channel ($\widehat{\beta}^P{}_1 - \widehat{\beta}^M{}_1 = .051\ -.038 = .125$, $SE = .021$, $p < .05$). Furthermore, the aversion to near-expiry non-perishable food products increases under deeper price promotion in mobile shopping ($\widehat{\beta}^M{}_3 = .0009, p < .001$) but not in PC shopping ($\widehat{\beta}^P{}_3 = .0002, p > .05$). Consistency of the results with our main model further supports our theoretical claims that our focal results are not simply driven by the differences in customers between the channels, but driven by the differences in shopping environment between the channels.

*Different sensitivity to near-expiry product by product category.* In our model, we rigorously controlled for differences in baseline sales across different non-perishable food products. However, the effect of impending expiration date is assumed to be the same across all products. If consumers' avoidance of near-expiry products and the level of price promotion on the online salvage store both differ by product category, then our findings may not necessarily indicate a moderating role of price promotion.

To rule out this alternative explanation, we allow for the sensitivity of the expiration date on sales to vary by product category. The online salvage store classifies non-perishable food products into five categories: The first category includes 54 products such as snacks, bread, nuts, and cereal. The second category includes 73 beverage products such as water, soft drinks, and juice. The third category includes 51 products such as jam, sauce, and dressings. The fourth category includes 45 instant and frozen foods. The fifth category includes 15 products of canned meats, fishes, fruits, and vegetables. In this analysis, we introduce a dummy variable for each category and include an

**Table 3.** Robustness checks.

| | (A) symmetric panel | (B) category effects | (C) 15 days | (D) 60 days | (E) linear effect |
|---|---|---|---|---|---|
| Mobile: $remain_{it}$ | .384*** (.033) | .485*** (.049) | .422*** (.054) | .457*** (.024) | .034*** (.003) |
| Mobile: $dc_{it}$ | .119*** (.008) | .147*** (.010) | .107***(.015) | .106*** (.006) | .150*** (.012) |
| Mobile: $remain\_dc_{it}$ | .009*** (.002) | .010*** (.005) | .008* (.004) | .005* (.002) | .0008*** (.0002) |
| PC: $remain_{it}$ | .509*** (.043) | .644*** (.061) | .606*** (.072) | .657*** (.031) | .043*** (.004) |
| PC: $dc_{it}$ | .161*** (.011) | .193*** (.013) | .176*** (.020) | .171*** (.008) | .019*** (.014) |
| PC: $remain\_dc_{it}$ | .002 (.003) | .003 (.003) | .006 (.004) | .002 (.003) | .0002 (.0003) |

*p ≤ .05, **p ≤ .01, ***p ≤ .001. Standard errors in parentheses.

interaction between $remain_{it}$ and each dummy to allow for the avoidance of near-expiry products to vary by category. The first category is set to be the baseline category in the analysis.

The results of the focal parameters are presented in Panel B of Table 3. Consistent with the findings in our primary analyses, the sensitivity toward the impending expiration date is significantly greater in the PC channel than in the mobile channel ($\widehat{\beta}^{P}_{1} - \widehat{\beta}^{M}_{1} = .644 - .485 = .159$, $SE = .078$, $p < .05$). Further, the aversion to near-expiry non-perishable food products increases under deeper price promotion in mobile shopping ($\widehat{\beta}^{M}_{3} = .010$, $p < .001$) but not in PC shopping ($\widehat{\beta}^{P}_{3} = .003$, $p > .05$). That is, price promotion moderates the effect of impending expiration date even when we consider that aversion toward near-expiry non-perishable food products can vary by category. Therefore, our results are robust even when we allow for the sensitivity of the expiration date on sales to vary by product category.

*Different observation periods for analyses.* In our primary sample, we limited the sample to include only daily observations of products with an expiration date within 1 month (i.e., 30 days). To test the robustness of our findings, we analyze the data over different time windows: half a month (15 days) and 2 months (60 days). The empirical model remains identical to our primary models while the sample has been changed.

The sample including daily observations of products with expiration dates within 15 days consists of 2486 observations. The results of the focal parameters using this sample are presented in Panel C of Table 3. Consistent with the findings in our primary analyses, the sensitivity toward an impending expiration date is significantly greater in the PC channel than in the mobile channel ($\widehat{\beta}^{P}_{1} - \widehat{\beta}^{M}_{1} = .606 - .422 = .184$, $SE = .009$, $p < .05$). Further, the aversion to near-expiry non-perishable food products increases with deeper price promotion in mobile shopping ($\widehat{\beta}^{M}_{3} = .008$, $p < .05$) but not in PC shopping ($\widehat{\beta}^{P}_{3} = .006$, $p > .05$).

The sample including daily observations of products with expiration dates within 60 days consists of 12,534 observations. The results of the focal parameters using this sample are presented in Panel D of Table 3. Consistent with the findings in our primary analyses, the sensitivity toward an impending expiration date is significantly greater in the PC channel than the mobile channel ($\widehat{\beta}^{P}_{1} - \widehat{\beta}^{M}_{1} = .657 - .457 = .200$, $SE = .004$, $p < .001$). Further, the aversion to near-expiry non-perishable food products increases under deeper price promotion in mobile shopping ($\widehat{\beta}^{M}_{3} = .005$, $p < .05$) but not in PC shopping ($\widehat{\beta}^{P}_{3} = .003$, $p > .05$). Therefore, our results are robust to the use of different time windows.

*Linear effect of time left to the expiration.* As noted earlier, we assumed that the effect of an impending expiration date is more salient when there is less time left until expiration. Thus, we defined $remain_{it}$ as the log-transformed days left until the expiration date. How would the results change if we did not make such an assumption and tested the linear effect of days left until the expiration date? The results of the focal parameters are presented in Panel E of Table 3. Consistent with the focal findings, the sensitivity toward the impending expiration date is greater in the PC channel than in the mobile channel, and the difference is marginally significant ($\widehat{\beta}^{P}_{1} - \widehat{\beta}^{M}_{1} = .043 - .034 = .008$, $SE = .005$, $p < .1$). Further, the aversion to near-expiry non-perishable food products increases under deeper price promotion in mobile shopping ($\widehat{\beta}^{M}_{3} = .0008$, $p < .001$) but not in PC shopping ($\widehat{\beta}^{P}_{3} = .0002$, $p > .05$). Therefore, our results are robust when we relax the assumption that the effect of impending expiration date is more salient when there is less time left until expiration.

## Discussion

Consumers' avoidance of near-expiry food products is associated with enormous food waste and economic loss (NRDC, 2017; ReFED, 2022). Given the importance of this issue, past research has investigated the effect of impending expiration date on product sales, but the focus of such work has been limited to perishable food products (Konuk 2018; Sen and Block 2009; Theotokis et al., 2012; Tsiros and Heilman 2005). Since the expiration date of non-perishable food products is often treated as a peripheral attribute (Choi et al., 2022), it has a nuanced effect on sales that largely varies by shopping environment. By analyzing a unique data set from an online salvage store in South Korea, we found that aversion toward near-expiry products is more salient in a PC shopping environment than a mobile shopping environment. However, when there is a deeper price promotion, this between-channel difference is reduced as the sensitivity to impending expiration date increases in the mobile shopping environment while remaining unchanged in the PC environment. These findings are robust across different empirical approaches.

### *Theoretical contribution*

This research contributes to the literature in the following ways: First, we extend prior research on the effect of expiration dates. Past research on expiration dates has mostly focused on their effect on the sales of perishable food products, for which the expiration date is considered as a focal attribute (Sen and Block 2009; Theotokis et al., 2012; Tsiros and Heilman 2005). In this research, we instead investigate the effect of an impending expiration date for non-perishable food products, for which the expiration date is considered as a peripheral attribute (Choi et al., 2022). Because consumers' attention toward the expiration date of non-perishable food products is contingent on the shopping environment, we found that it had a nuanced effect in the domain of non-perishable food products. We hope that future studies can further uncover the novel and sophisticated nature of avoidance of near-expiry non-perishable food products.

Second, this research identifies an interesting dimension of food shopping behavior that largely differs when purchases are made in mobile and PC shopping environments. A stream of research on online shopping has compared PC and mobile shopping behaviors such as impulse purchasing (Seeger et al., 2019) and search behavior (Ghose et al., 2013; Naegelein, Spann, and Molitor 2019; Wang et al., 2020). However, no research has compared the effect of food expiration dates between mobile and PC shopping environments. As online food sales are rapidly increasing these days, this research sheds light on the different roles of impending expiration dates across different online shopping channels. Thus, we contribute to the literature on online shopping by documenting a novel difference in online shopping behaviors between mobile and PC environments.

Third, we examine how the level of avoidance of near-expiry non-perishable food products is moderated by price promotions. Past research has studied pricing as a tool to facilitate the sales of near-expiry food products (Nijs et al., 2001; Theotokis et al., 2012; Tsiros and Heilman 2005). However, there has been a lack of research into the more fundamental question, i.e., whether consumers' sensitivity toward the expiration date increases or decreases with a price promotion. Our knowledge about the role of the expiration date would be further enriched by future research examining specific pricing tactics (e.g., buy-one-get-one promotions vs. percentage discounts) that could potentially moderate the attention toward the peripheral attributes or the avoidance of near-expiry food products.

From a methodological perspective, we also use a novel data set to examine the effect of the impending expiration date. Extant research has mostly relied on self-reported surveys to investigate the effects of expiration date (Tsiros and Heilman 2005; Wansink and Wright 2006). Although a myriad of questions can be asked via survey, respondents often suffer from self-reporting bias in a hypothetical setting. To analyze product sales over an impending expiration date, we use data from an online salvage store, where the information about the expiration date is upfront. Our empirical approach will be of interest to researchers who aim to rigorously investigate the effects of expiration dates.

### Managerial implication

Our findings have actionable insights for practitioners. First, if an online retailer has access to both mobile and PC channels, it may want to consider selling more near-expiry products in the mobile channel. Otherwise, an online retailer may want to list products in differing orders between the two channels; for example, products could be listed in the order of the latest in stock in the PC channel, while another order could be used for the mobile channel. Even when it is too costly for an online store to administer different marketing mixes between channels, a marketer can still induce consumers to use their mobile device to purchase near-expiry non-perishable food products by sending mobile push alarms or mobile-only coupons. With the growing interest in salvage stores as a new type of retail platform, the number of such stores has increased by 17.6% in the U.S. from 2011 to 2016. This research has a simple message to those who aim to launch an online salvage store: “Use mobile as your main channel.”

Second, online retailers need to be cautious in offering price promotions on near-expiry products. As noted by past research (Theotokis et al., 2012), the effects of price promotions on near-expiry products are highly context-dependent. The results of this research indicate that price promotions on near-expiry non-perishable food products can increase the avoidance of those products. In particular, such effects of price promotions are more salient in the mobile shopping environment, where consumers are less sensitive to the expiration date by default. As outlined in the previous paragraph, practitioners may be better off exploiting the between-channel difference rather than possibly harming their profits with excessive price promotions on near-expiry non-perishable food products.

### Limitations and future research

Despite its significant contributions, our research has several limitations. First, we addressed our research questions at a specific time in the past, i.e., using data from year 2015. To this day, consumers have less cognitive resources in mobile shopping, where they face smaller screens, than PC shopping. However, consumers get used to new devices and technologies. Then, when shopping on mobile, will today’s consumers experience the same amount of cognitive depletion as consumers in the past? If not, how have behavioral differences between PC and mobile changed over time? We believe that a longitudinal study from past to present would help better project online shopping behavior in the future.

Second, our research has not considered omni-channel consumer, who alternately use different channels to shop for an item. In our data set, we were not able to track in what channel a customer browses and searches; we only observe in what channel the customer makes a purchase. Intuitively, alternate usage of multiple channels would obscure behavioral differences across the channels. Therefore, if we could observe and control interchanged uses of multiple channels, channel differences would be greater than the current estimates. Future research can examine beyond avoidance of near-expiry food products, and potentially investigate what shopping behaviors converge across the channels the most and the least by alternate use of multiple channels.

Third, our findings are applicable to specific channels and categories. According to our theoretical framework, our results would be applicable to products that have longer shelf lives and maintain stable quality such as non-perishable foods, cosmetics, and medicines. For perishable foods, for which expiration date is a focal attribute, we do not expect that the results would be replicated. Then, how different will the results be across various categories? In addition, we compared PC and mobile as the most popular online channels. Then, how will the focal effect differ in offline channel? Future study can provide more comprehensive understanding about avoidance of near-expiry products across various categories and more channels.

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## Notes

1. To verify our conjecture, we surveyed 204 participants in South Korea. We listed eight food items including perishable (e.g., lettuce, milk, chicken, and beef) and non-perishable food products (e.g., dried pasta, Spam, chocolate bars, Coke). Participants were asked to reveal whether or not they cared about the expiration date in purchasing each product. For perishable food products, 97% of the respondents replied that they care about the expiration date, while only 49% of the respondents replied that they cared about the expiration date for non-perishable food products. We find this to be a statistically significant difference ($\chi^2 = 53.41, p < .01$).
2. For the anonymity of the online salvage store, we changed the font style and the color of the icons in the figure; the figure otherwise shows identical information and an identical layout to a product page on the online salvage store. (1) denotes product title, (2) denotes the discount rate and sales price, (3) denotes expiration date, (4) denotes add to cart, and (4) denotes buy now.
3. In our data set, while sales price and supply price both change, MSRP remains constant over the observation periods. Thus, we group MSRP with other product characteristics that do not change over time instead of with other time-variant price variables.
4. In South Korea, it is illegal to sell products that have expired.
5. For each product, $t$ equals 1 for the first observation at which the product appears on the data set.
6. For all our logarithmic transformation variables hereafter, we performed the transformation after adding one to the variable, as some observations have zero values.

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