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An Empirical Analysis of Shopping Behavior Across Online and Offline Channels for Grocery Products: The Moderating Effects of Household and Product Characteristics

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Abstract

We study the moderating effects of household (e.g., shopping frequency) and product (e.g., sensory nature) characteristics on household brand loyalty, size loyalty and price sensitivity across online and offline channels for grocery products. We analyze the shopping behavior of the same households that shop interchangeably in the online and offline stores of the same grocery chain in 93 categories of food, non-food, sensory and non-sensory products. We find that households are more brand loyal, more size loyal but less price sensitive in the online channel than in the offline channel. Brand loyalty, size loyalty and price sensitivity are closely related to household and product characteristics. Light online shoppers exhibit the highest brand and size loyalties, but the lowest price sensitivity in the online channel. Heavy online shoppers display the lowest brand and size loyalties, but the highest price sensitivity in the online channel. Moderate online shoppers exhibit the highest price sensitivity in the offline channel. The online–offline differences in brand loyalty and price sensitivity are largest for light online shoppers and smallest for heavy online shoppers. The online–offline differences in brand loyalty, size loyalty and price sensitivity are larger for food products and for sensory products.
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Introduction

Since the early 1990s, many manufacturers and retailers have incorporated the Internet into their multichannel strategy and devoted considerable resources to building the online channel. Meanwhile, an increasing number of consumers consider the Internet to be an important shopping venue. In 2009, U.S. online retail sales grew 11%, while all retail sales only grew 2.5% and about 154 million people or 67% of the online population shopped online, contributing to online retail sales of $155 billion, or 6% of total retail sales (Sehgal 2010a). Forrester Research forecasts that U.S. online sales will keep growing at a 10% compound annual rate through 2014 to $250 billion (Sehgal 2010a). In Western Europe, online retail sales are expected to grow at 11% per year, going from €68 billion in 2009 to €114.5 billion in 2014 (Sehgal 2010b).

The Internet and conventional brick-and-mortar stores each have unique features. The Internet substantially reduces search costs, grants easy access to product and price information and facilitates product comparison. Online shopping involves no travel, product carrying or restrictions on shopping hours, offering greater accessibility, convenience and time saving. But online shopping does not permit physical examination of the products (feel, touch, sample and trial), interpersonal communication or instant gratification, and often incurs shipping and handling costs. In contrast, offline shopping allows physical

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examination of the products, interpersonal communication and instant gratification, but involves high travel costs and search costs, and often has restrictions on shopping hours, especially in countries with strong labor laws (Grewal, Iyer, and Levy 2004). Consumers may use the two channels differently. Some consumers may use physical stores as the primary shopping channel and the Internet as a supplementary channel, whereas others may follow the reverse pattern. Consequently, the same consumers may exhibit different behaviors when shopping across online and offline channels. Therefore, it is important to understand how the same consumers behave at the two channels.

Several researchers have studied consumer behavior across online and offline channels in different contexts (see Table 1 for a comparison and the literature review section for details), but they often use two separate samples for online and offline shopping. As pointed out by Shankar, Smith, and Rangaswamy (2003), such "between-subject" comparisons cannot eliminate the self-selection explanation for the behavioral differences observed across the two channels, and cannot isolate the effect of the shopping medium on behavior differences. In this paper, we use a unique household panel dataset to study how the *same* household's brand loyalty, size loyalty and price sensitivity vary across online and offline channels in grocery shopping, and how these behaviors vary with household and product characteristics. Since we observe the same households that shop across online and offline stores, we are able to conduct a "within-subject" comparison, which allows us to isolate the effect of the Internet on consumer behavior from consumer-specific effects (Shankar, Rangaswamy, and Pusateri 2001; Shankar, Smith, and Rangaswamy 2003). Further, as we observe the entire shopping basket of both packaged goods and perishables, we are able to investigate a large number of vastly different product categories so as to study the effects of product characteristics on channel-specific behavioral differences. As panel households differ substantially in their online shopping frequency, it allows us to examine how online shopping frequency affects online and offline shopping behavior. Additionally, we show how our data enable us to avoid potential endogeneity issues.

Our descriptive study of household shopping behavior involves 93 categories of food, non-food, sensory and non-sensory items (defined below). Consistent with the literature (e.g. Chu, Chintagunta, and Cebollada 2008), we find the same households are more brand loyal, more size loyal, but less price sensitive in the online channel than in the offline channel. Brand loyalty, size loyalty and price sensitivity are related to household and product characteristics. Light online shoppers exhibit the highest brand and size loyalties, but the *lowest* price sensitivity in the online channel. Heavy online shoppers display the lowest brand and size loyalties, but the *highest* price sensitivity in the online channel. Moderate online shoppers exhibit the highest price sensitivity in the *offline* channel. The online–offline differences in brand loyalty and price sensitivity are the largest for light online shoppers and smallest for heavy online shoppers. The online–offline differences in brand and size loyalties and price sensitivity are larger for food products than non-food products, and larger for sensory products than non-sensory products. These findings should help retailers make better decisions on product offerings, pricing and targeted promotions in the online and offline stores.

Categories such as books, CDs, PCs and holiday gifts that are typical of online shopping are more ideally suited to a comparison of consumer behavior across online and offline channels. However, given the infrequent purchases of these categories, it is difficult to collect consumer panel data on the purchases of these categories across the two channels. Although online revenues only account for a small fraction of the supermarket industry, many conventional supermarkets do have online operations (e.g., Safeway's www.safeway.com). In the UK, a report by TNS shows that online grocery sales at Tesco and other main retailers surged 35% in 2008 over the previous year (The Daily Telegraph 2009). The fact that online giant Amazon is now in the grocery business indicates the increasing importance of online grocery shopping. Therefore, using grocery data, while limited to some extent, can still shed light on the channel-specific behavioral differences.

The rest of the paper proceeds as follows. We first review the relevant literature, develop a conceptual framework and derive the various hypotheses. We then describe the data and present the methodology. Next, we report the results and discuss their managerial implications. We conclude the paper with summary of the findings, limitations and directions for future research.

Literature Review

Researchers have studied consumer behavior across online and offline channels in various contexts, either analytically or using experimental, survey or market data. The general conclusion is that consumers are more brand loyal and more size loyal in the online channel, but their price sensitivity seems to depend on product categories (Table 1).

Bakos (1997) theorizes that price sensitivity would be lower online than offline when quality-related attributes are important to consumers. Lal and Sarvary (1999) analyze the online and offline media and find that the Internet may lead to monopoly pricing under some circumstances. Lynch and Ariely (2000) use experiments to study how search costs affect online and offline competition and find that lower search costs for quality information reduce price sensitivity, while lower search costs for price information increase price sensitivity. Brynjolfsson and Smith (2000) find consumers are *more* price sensitive when shopping books and CDs online than offline. Degeratu, Rangaswamy, and Wu (2000) and Andrews and Currim (2004) find online consumers are *less* price sensitive when shopping groceries online than offline. Both studies find households have less brand switching and size switching online than offline, implying higher brand loyalty and size loyalty online. Danaher, Wilson, and Davis (2003) find high market share brands enjoy a loyalty advantage in the online store, while low market share brands enjoy greater brand loyalty in the offline stores.

Table 1
Selected studies on brand loyalty, size loyalty and price sensitivity across online and offline channels.

Authors	Context/ categories	Main research questions	Data	Method	Key findings
Lal and Sarvary 1999	Analytical	Analytically study when and how the Internet is likely to decrease price competition	Analytical	Analytical	Internet may lead to monopoly pricing when (1) the proportion of Internet users is high enough, (2) nondigital attributes are relevant but not overwhelming, (3) consumers have a more favorable prior on the brand currently used, and (4) purchase situation is destination shopping.
Lynch and Ariely 2000	Wine	How search costs affect competition on price, quality and distribution across online and offline channels	Experimental data	ANOVA	Lower search costs for quality info reduce price sensitivity and increase consumer welfare; lower search costs for price info of identical products increase price sensitivity.
Brynjolfsson and Smith 2000	Books and CDs	Compare pricing behavior between Internet and conventional retail outlets	Online and offline retail outlets	Frequency and t-tests	Online prices are lower, and online price adjustments are smaller than offline Online price dispersions are smaller than offline, reflecting lower friction and stronger competition online than offline
Degeratu, Rangaswamy, and Wu 2000	Grocery	How brand name, price and other search attributes affect	Two separate samples of panel households for the online and offline channels	A two-stage model of channel choice (binary probit) and brand choice (multi-nomial logit model)	Brand names are more valuable when information on fewer attributes is available online; Sensory search attributes have lower impact on choices online, and factual information have higher impact on choices online; Price sensitivity is lower online.
Danaher, Wilson, and Davis 2003		Compare consumer brand loyalty in online and traditional shopping environments		Segmented Dirichlet model	High-share brands enjoy greater brand loyalty in the online store than small-share brands
Andrews and Currim 2004		Study the behavioral differences between online customers and offline customers		Logit brand choice model	Online consumers are less price sensitive, prefer larger sizes to smaller sizes, have stronger size loyalty, do more screening on the basis of brand names but less screening on the basis of sizes, and have stronger choice set effects.
Shankar, Rangaswamy, and Pusateri 2001	Travel/ lodging	Study the main and moderating effects of the online medium on price sensitivity	Separate samples of both online and offline customers; A sample of customers who used both online and offline media	Regression	The online medium does not have a main effect on price importance, but it does increase price search.
Shankar, Smith, and Rangaswamy 2003	Travel/ lodging	Study the effects of the online medium on customer satisfaction, loyalty, and their relationship.		Simultaneous equation model	Loyalty to the service provider is higher when the service is chosen online than offline
Chu, Chintagunta, and Cebollada 2008	Grocery	Compare the same household's price sensitivity across online and offline channels	Same panel of households who shop at both online and offline channels	Logit model of purchase incidence and brand choice	The same households are less price sensitive when shopping online than offline.
Pozzi 2008	Grocery	Study the differences in product exploration across online and offline channels		Logit model of channel and brand choice	The same households explore products less and are less price sensitive when shopping online than offline.
This study	Grocery	Study moderating effects of household and product characteristics on the household's brand & size loyalties and price sensitivity across online and offline channels		Logit model of purchase incidence and brand choice	The differences in brand loyalty, size loyalty and price sensitivity between online and offline channels depend on household and product characteristics.

In all these studies, the online and offline customers come from two separate samples; therefore, the observed differences in shopping behavior may not be caused by the shopping media, but by differences across consumers i.e., the between-subject design could suffer from the selection problem. Shankar, Rangaswamy, and Pusateri (2001) use survey data from the hospitality industry to study the main and moderating effects of the online medium on price sensitivity and find that the online medium does not have a main effect on price importance, but it does increase price search behavior. Shankar, Smith, and Rangaswamy (2003) compare customer satisfaction and loyalty in online and offline environments in the lodging service industry and find that consumers exhibit higher loyalty to the service provider when the service is chosen online than offline. Both studies compare online consumers with offline consumers as well as the same consumers' online and offline behavior, thus they are able to rule out the self-selection bias in the findings. Our study is also based on a within-subject comparison, but it uses household panel data of actual purchases and focuses on the moderating effects of household and product characteristics.

Chu, Chintagunta, and Cebollada (2008) compare the same households' price sensitivity across online and offline channels for grocery products and find the same households are less price sensitive in the online channel. Pozzi (2008) investigates the same household's differences in product exploration of grocery items across online and offline stores and finds product exploration is systematically more prevalent in the physical stores than it is online, which implies the same consumers may be more inertial in the online channel and thus may show higher brand and size loyalty and less price sensitivity. But these two studies do not directly compare a household's brand loyalty and size loyalty across online and offline channels. Further, all existing studies are limited to a small number of product categories, and thus are not able to systematically investigate the effects of household and product characteristics on the differences in channel-specific shopping behavior.

In sum, existing literature provides us with a good foundation for comparing online and offline shopping behaviors for grocery products. However, not much is known about the moderating effects of household and product characteristics on the behavioral differences across the online and offline channels. Our paper intends to address this issue.

Conceptual Framework and Hypotheses

The same households are found to be more brand loyal, more size loyal and less price sensitive when shopping grocery products in the online channel than in the offline channel (Chu, Chintagunta, and Cebollada 2008; Pozzi 2008). How are their brand and size loyalties and price sensitivity affected by their online shopping frequency? How do these behaviors differ across product categories? In this section, we develop hypotheses on the effects of household and product characteristics on the shopping behavior differences across the two channels.

The Moderating Roles of Household Characteristics in Within-channel Brand and Size Loyalties and Price Sensitivity

Households are found to be more brand loyal, more size loyal and less price sensitive in the online store than in the offline stores. If it is Internet, the shopping medium *per se* that makes consumers more brand loyal, more size loyal and less price sensitive, a logical conclusion will be that the more a household shops online, the more brand loyal and size loyal and the less price sensitive it will be in the online store. However, it is the *combination* of the particular circumstances (e.g. time pressure), the household's particular needs (e.g. convenience and time saving), and the web design (personal shopping lists) that makes the household more brand loyal, more size loyal and less price sensitive (Chu, Chintagunta, and Cebollada 2008; Pozzi 2008). We believe the particular circumstances and the particular needs are the primary factors and web design is only a facilitator. If a household is not subject to time pressure, or not seeking convenience or time saving, a rational response will be to do more in-store search to get better deals. Putrevu and Ratchford (1997) find that time pressure is negatively related to search. Therefore households that use the Internet sparingly or selectively for their grocery shopping are more likely to show strong brand loyalty, size loyalty and weak price sensitivity in the online store because the infrequent visits to the online store are more likely to occur during special circumstances.

Households may use the online and offline stores differently for grocery shopping, i.e. they have different levels of involvement with the online channel and the offline channel. Some households may view the physical stores as the primary shopping channel and the online store as the supplementary channel, so they have low-involvement with the Internet channel (light online shoppers). Some households may view the online store as the primary channel and the physical stores as the supplementary channel, so they have high-involvement with the online channel (heavy online shoppers). Some households may treat the two roughly equally and shop in the more "economical" outlet, so they have moderate-involvement with the online channel (moderate online shoppers). Studies have shown that purchase involvement influences brand commitment, loyalty and price sensitivity (e.g. Beatty, Homer, and Kahle 1988; Morrison 1979; Taylor 1984; Warrington and Shim 2000). Cheema and Papatla (2010) find Internet experience affects the relative importance of online and offline information and purchase behavior. Light online shoppers may visit the online store only in some special circumstances such as under extreme time pressure. In such circumstances, they will be least likely to do in-store search, most likely to use the customized lists, and most willing to pay a price premium for the convenience and time saving (Putrevu and Ratchford 1997). Since they do not shop much in the online store, they have little incentive to search because they do not benefit much from intensive search. Therefore, they will be more brand loyal, more size loyal and less price sensitive in the online store. Because light online shoppers primarily shop offline, they benefit more from search in offline stores, and thus show higher price sensitivity in offline stores.

On the other hand, heavy online shoppers are highly involved with the Internet channel. They view the Internet as the primary channel and the physical stores as the supplementary channel. They shop at the Internet store regularly, but only visit the physical stores on special circumstances such as when they run out of certain categories. Depending on the particular shopping occasion, they may search within the store, or simply use the shopping lists. But since these households primarily shop online, more in-store search will help them save more in the online store. Moreover, these households are experienced online shoppers and know the online store layout very well. Studies have found familiarity with the store facilitates search behavior (Park, Iyer, and Smith 1989). Thus, heavy online shoppers can easily find out better deals in the online store. The various online features may still make them less price sensitive in the online store than in the offline stores, but they may be more price sensitive in the online store than light online shoppers. Since they do not visit the physical stores regularly, they do not benefit much from intensive search there; or they only visit the physical stores on special circumstances and are not able to search around. Therefore, they will be less price sensitive in the offline stores than light online shoppers.

Moderate online shoppers may consider these two channels as close substitutes and go to whatever store that has a better deal. Even though their online behavior is somewhat constrained by the limited number of online grocers and by the web design, their offline shopping behavior can exhibit more latitude in terms of search and comparison. Therefore, they may show the highest price sensitivity in the offline stores. Consequently, we expect the light online shoppers to be the least price sensitive and the heavy online shoppers to be the most price sensitive in the online store, and the moderate online shoppers to be the most price sensitive and the heavy online shoppers the least price sensitive in the offline stores. Therefore we hypothesize:

H1. Light online shoppers are more brand loyal than heavy online shoppers in the online store.

H2. Light online shoppers are more size loyal than heavy online shoppers in the online store.

H3a. Light online shoppers are the least price sensitive in the online store.

H3b. Heavy online shoppers are the most price sensitive in the online store.

H3c. Moderate online shoppers are the most price sensitive in the offline stores.

H3d. Heavy online shoppers are the least price sensitive in the offline stores.

Moderating Roles of Household Characteristics in Online–offline (Between-channel) Behavioral Differences

The panel households are all mixed shoppers who shop in both channels. They differ in observed demographics, but the differences are not dramatic. Thus, brand loyalty and size loyalty between adjacent groups such as between light and moderate online shoppers, or between moderate and heavy online shoppers may not differ substantially. Since light and heavy online shoppers are expected to exhibit very different behavior in the two channels, from H1 to H3 we deduce that:

H4. Differences in online and offline brand loyalty are largest for light online shoppers and smallest for heavy online shoppers.

H5. Differences in online and offline size loyalty are largest for light online shoppers and smallest for heavy online shoppers.

H6. Differences in online and offline price sensitivity are largest for light online shoppers and smallest for heavy online shoppers.

Moderating Roles of Product Characteristics in Online–offline Behavioral Differences

Product characteristics such as food versus non-food, sensory versus non-sensory may affect consumer shopping behavior differently in the online store from the offline stores. Food products, particularly perishables, have higher quality uncertainty than non-food items. The purchase of food products involves an additional risk over non-food products — the health risk. To reduce quality uncertainty and avoid health risk, consumers may resort to brand names (Png and Reitman 1995; Wernerfelt 1988). This is particularly true for online shopping because (1) they cannot physically examine the products before purchase, and (2) it might be difficult to find some important information such as the "sell-by-date," which might be missing or put at the corner of the pack. When shopping for food items in a physical store, consumers can carefully examine the sell-by date and compare quality (Tsiros and Heilman 2005), thus there is less need to rely on the brand for quality assurance. Kacen, Hess, and Chiang (2002) find consumers perceive the quality of food products to be better in physical stores than in online stores and are less uncertain about getting the right product when shopping offline. Consequently, households may show stronger brand and size loyalties but lower price sensitivity for food items in the online store than in the offline stores. Thus we have:

H7. Online–offline differences in brand loyalty, size loyalty and price sensitivity are greater for food products than for non-food products.

Degeratu, Rangaswamy and Wu (2000) divide a product's search characteristics into four groups: brand name, price, sensory and non-sensory characteristics. Sensory characteristics are those that can only be verified by senses, particularly by touch and smell, while non-sensory characteristics are those that can be easily expressed verbally. For example, the scent of perfumes and the texture of paper towels are sensory characteristics, whereas the fat content of margarine is a non-sensory characteristic. It is easy to uncover search attributes such as brand names and prices, both online and offline, but it is

difficult, sometimes even impossible, to convey a product's sensory features in the online store. When sensory features are important factors in the purchase decision (sensory products) and when such features cannot be verified prior to purchase, households may rely on brand names, or buy the familiar brands. Alternatively, they may simply repeat the brands purchased on the previous occasions to reduce risk (Campbell and Goodstein 2001). Thus, consumers are likely to show stronger brand and size loyalty and lower price sensitivity in the online store than in the offline stores when buying sensory products than non-sensory products. We therefore hypothesize:

H8. Online–offline differences in brand loyalty, size loyalty and price sensitivity are greater for sensory products than for non-sensory products.

Data

The Grocery Retailer

Our data come from one of the five leading grocery chains in Spain. This grocery chain has a prominent presence throughout Spain. It started online operations in 2001 and has been one of the most successful online grocers in Spain. The data are for one metro area, where the retailer has about 200 physical stores. The online store is the retailer's largest store by revenue. It partners with 17 of the chain's physical stores for grocery supply. After placing an order online, a household has two options: it can either go to one of these partner stores to pick up the order for no charge or have the basket delivered home with delivery charges (€4.5 delivery fee for orders under €90, or free otherwise). An important feature of grocery stores in the metro area is that they do not always have parking lots, so consumers usually walk or take public transport to do grocery shopping. About 60% physical stores in this chain also provide home delivery service. The delivery charge for offline shopping is €3.5 for orders below €90 and free otherwise.

The retailer has a Hi-Lo chain-wide promotion policy. Price cuts apply to all stores in the chain, both online and offline. The retailer also practices zone pricing for offline stores (a practice that was subsequently abandoned). There are two offline price zones. Roughly, stores in the low-income area belong to the low-price zone, and those in the high-income area belong to the high-price zone. Average prices across *all* categories in the high-price zone are about 3% higher. When this retailer started the online business, it applied the prices in the high-price offline zone to the online store.

Household Panel Data

We obtained online household panel data on 2,733 households from this retailer. To be included in the panel, a household needs to have made at least one online purchase at the retailer's online store prior to the data collection period. So, all panel households are online shoppers, although some of them did not make any online trips during the data period. We observe all trips both to the online and offline stores in this chain during 12/2002–11/2003. For each trip, we observe the entire basket of both consumer packaged goods and perishables. For each item, we have prices, quantity bought, and a detailed description. We have detailed demographics for these households, including household size, numbers of children, adults and elders, and distance to the closest offline stores. As we want to compare the same households' shopping behavior across the online and offline channels, we focus on the 2,432 mixed shoppers that shop across both channels in the data period. The households on average made 43.3 shopping trips during the one-year period, of which 27.9% occurred to stores in the low-price offline zone, 55.5% to stores in the high-price offline zone, and 16.6% to the online store. When shopping offline, households primarily visit stores in the price zone where they reside. Interestingly, households residing in the low-price zone are more likely to shop online than those in the high-price zone, even though they have a cheaper option nearby and shopping online implies higher monetary costs to them. Households in the low-price zone made 18.89% shopping trips to the online store and spent 43.69% grocery expenditure online, while households in the high-price zone made 15.27% shopping trips to the online store and spent 37.90% grocery expenditure online (see Table 2). Thus, it does not seem that the online store only attracts households who primarily shop at the high-price zone, and there is no associated selection bias.

Choice of Categories

We use three criteria to select the categories. (1) The category should have at least two brands and two sizes for households to choose from, or there would be no variation in

Table 2
Distribution of shopping trips and grocery expenditure by price zone and channel.

	% Trips to stores in				% Grocery spending in				Per capita basket size (€)			
	Low-price zone	High-price zone	Online	Total	Low-price zone	High-price zone	Online	Total	Low-price zone	High-price zone	Online	Total
Households in low-price zone	66.48	14.63	18.89	100	42.17	14.14	43.69	100	10.64	16.21	38.81	16.78
Households in high-price zone	5.48	79.25	15.27	100	3z.82	61.25	34.93	100	11.57	12.82	37.95	16.59
Total	27.85	55.55	16.60	100	16.78	45.32	37.90	100	10.11	13.69	38.31	16.78

brand choice or size choice. (2) There should be enough number of households buying the category both online and offline. This is to ensure the statistical power of the analysis. (3) There should be enough numbers of food and non-food categories, as well as sensory and non-sensory categories. This is to ensure the statistical power of the hypothesis tests. All together, we choose 93 categories, of which 66 are food products and 43 are sensory products. We summarize these categories in Table 3. For each category, we only use those households that made at least one online and one offline purchase in that category.

A product category is defined as a sensory category when transparent or semi-transparent packaging allows shoppers to judge the real appearance of the product prior to purchase in a physical store. A product category is defined as non-sensory when opaque packaging makes it impossible for shoppers to examine its appearance either online or offline. We adopted this classification because it is easy to implement (we only need to check the characteristics of the category packages) and appropriate for grocery products where packaging plays an important role. We checked our sensory/ non-sensory classification using a convenience sample by mall intercept and found it provides an accurate representation of the sensory nature of the product categories considered.

Methodology

Our testing of the hypotheses consists of two steps. We first estimate a demand model of purchase incidence and brand choice to get coefficients on brand loyalty, size loyalty and price for the online and offline channels. Importantly, we use a household's store visits and purchases in both channels and estimate the online and offline coefficients *jointly* in the *same* demand model. We then compute elasticities for brand loyalty, size loyalty and price sensitivity. Next, we regress the online and offline elasticities on household and product characteristics to see whether there exist systematic differences across households and products.

Model of Purchase Incidence and Brand Choice

We follow the standard random utility approach for the demand model. We assume that on a given shopping trip, a household either chooses an alternative that yields the highest utility in a particular category, or chooses not to purchase in the category. The specification of the demand model is similar to Chu, Chintagunta, and Cebollada (2008), but differs in that we assume a discrete distribution of observed household heterogeneity in brand and size loyalties and price sensitivity. This is to facilitate the hypothesis tests in the second step. A discrete specification is also more useful for the retailer's segmentation and targeting strategies. Further, due to the large number of categories involved, we do not account for unobserved household heterogeneity, but run analysis on a smaller subset of categories to check the robustness of our conclusions (see the subsection on robustness checks). On a shopping trip in week t, the indirect utility of household h of Type i (explained below) from choosing alternative ω of brand b of size z (in category c) from store s is:

$$\begin{aligned} U_{h(i)\omega st} = {} & \alpha_b + \alpha_z + D_h\gamma + D_h BL_{h\omega t}\left(I_{st}^{on}\theta_D^{on} + I_{st}^{off}\theta_D^{off}\right) \\ & + D_h SL_{h\omega t}\left(I_{st}^{on}\lambda_D^{on} + I_{st}^{off}\lambda_D^{off}\right) \\ & + D_h P_{\omega st}\left(I_{st}^{on}\beta_D^{on} + I_{st}^{off}\beta_D^{off}\right) \\ & + \left\{\left(I_{st}^{on}\theta_i^{on} + I_{st}^{off}\theta_i^{off}\right)BL_{h\omega t} + \left(I_{st}^{on}\lambda_i^{on} + I_{st}^{off}\lambda_i^{off}\right)SL_{h\omega t}\right. \\ & \left. + \left(I_{st}^{on}\beta_i^{on} + I_{st}^{off}\beta_i^{off}\right)P_{\omega st}\right\} I_{hi} + \varepsilon_{h\omega st} \end{aligned} \quad (1)$$

α_b is the intrinsic brand preference and α_z the intrinsic size preference, D_h includes family size, numbers of preschool children and elders, and distance to the closest offline store, and γ is the effect of demographics on category purchase. $BL_{h\omega t}$ is brand loyalty, I_{st}^{on} and I_{st}^{off} are online and offline indicators, θ_D^{on} and θ_D^{off} are the effects of demographics on online and offline brand loyalties. $SL_{h\omega t}$ is size loyalty, and λ_D^{on} and λ_D^{off} are the effects of demographics on online and offline size loyalties. $P_{\omega st}$ is retail price, and β_D^{on} and β_D^{off} are the effects of demographics on online and offline price sensitivities. I_{hi} is household type indicator, and $\theta_i^{on}, \theta_i^{off} \lambda_i^{on}, \lambda_i^{off}, \beta_i^{on}$ and β_i^{off} are respectively online and offline parameters for brand loyalty, size loyalty and price sensitivity for households of Type i. $\varepsilon_{h\omega st}$ is household h's idiosyncratic utility.

We define brand and size loyalties as exponentially weighted averages of past purchases as in Guadagni and Little (1983). Guadagni and Little estimated the smoothing constant as .875 for brand loyalty and .812 for size loyalty. However, Ortmeyer (1985) and Gupta (1988) demonstrated their model's fit and parameter estimates are very robust to small changes (+/− .1) in the smoothing constant. Hence, instead of estimating, we pre-specify the constants as .8 as in Gupta (1988). A sensitivity analysis with smoothing constants as .7 and .9 for four categories corroborates Ortmeyer's and Gupta's findings. Brand and size loyalties are initialized as suggested by Guadagni and Little (1983). For example, for the 1st purchase occasion of household h, $BL_{h\omega t}$ is set to the smoothing constant value of .8 if the brand (size) of alternative ω was bought, otherwise .2/(number of brands (sizes) — 1). This step ensures that the sum of loyalties across brand names (sizes) always equals 1 for a household.

$$\begin{aligned} BL_{h\omega t} &= 0.8BL_{h\omega t-1} + 0.2\begin{cases} 1 \text{ if Household } h \text{ bought the brand of alternative } \omega \\ \quad \text{at purchase occasion } t-1 \\ 0 \text{ otherwise} \end{cases} \\ SL_{h\omega t} &= 0.8SL_{h\omega t-1} + 0.2\begin{cases} 1 \text{ if Household } h \text{ bought the size of alternative } \omega \\ \quad \text{at purchase occasion } t-1 \\ 0 \text{ otherwise} \end{cases} \end{aligned} \quad (2)$$

We use two ways to capture household heterogeneity. (1) We allow demographics to affect the overall category purchase probability (γ) and online and offline brand loyalties (θ_D^{on} and θ_D^{off}), size loyalties (λ_D^{on} and λ_D^{off}), and price sensitivities (β_D^{on} and β_D^{off}). (2) We group households into three types — "light online shoppers", "moderate online shoppers" and "heavy online

Table 3
Summary statistics of the 93 categories.

Category	# of items	# of brands	# of sizes	Food	Sensory	# of HH	# Trips		# Purchases	
							Online	Offline	Online	Offline
Aluminum	8	2	5	0	0	211	1838	7202	724	1430
Asparagus	22	7	11	1	1	363	2226	13,660	948	1431
Beer	33	18	5	1	1	1173	8246	44,922	5829	9644
Bleach	28	7	6	0	0	930	6357	36,711	3748	4765
Body wash	34	20	6	0	0	806	5692	29,463	2551	2871
Brandy	5	5	2	1	1	117	942	4332	369	630
Broth powder	15	5	8	1	0	203	1559	6948	471	572
Butter	18	7	3	1	0	676	4799	24,348	2083	3241
Cereal	53	12	5	1	0	1026	9870	41,020	7162	12,007
Packed cheese	17	10	7	1	1	211	1838	7202	724	1430
Liquid cleaner	43	19	6	0	0	1054	8377	41,028	4763	5722
Cleaning towel	15	7	5	0	0	382	2879	13,396	847	938
Cocoa spread	17	8	10	1	0	792	6161	29,211	3157	4092
Coffee	50	6	8	1	0	1273	9442	49,471	6087	9365
Conditioner	11	6	4	0	0	147	1010	4420	354	428
Cream	15	8	4	1	0	633	4605	23,324	2198	3524
Dairy dessert	40	7	15	1	1	855	8831	34,915	6259	12,961
Deodorant	33	15	5	0	0	522	3922	19,786	1668	1746
Dessert powder	6	2	4	1	0	97	673	3724	206	280
Liquid detergent	26	18	9	0	0	887	6271	35,436	3902	4926
Powder detergent	28	27	21	0	0	678	4384	26,379	2577	3293
Diaper	30	13	22	0	0	632	6031	24,954	4041	6019
Liquid dish detergent	18	6	7	0	1	892	6112	34,530	2589	3051
Drinking water	45	18	15	1	0	1692	14,852	71,019	13,541	23,752
Dry pasta	93	9	4	1	1	1504	17,047	65,556	13,317	18,214
Dry fruit	7	2	5	1	1	323	2707	12,423	1098	1271
Liquid fabric softener	35	14	6	0	0	801	5012	31,513	2772	3571
Face cosmetic	7	5	4	0	0	238	1744	8714	622	775
Fillet	5	4	3	1	1	76	543	2594	240	189
Flour	15	8	7	1	0	700	5587	26,447	2342	3079
Liquid formula	7	5	4	1	0	83	532	3030	331	584
Powder formula	32	3	4	1	0	320	3683	13,821	2621	4223
Fresh cheese	25	14	8	1	1	695	5818	23,766	3059	6181
Fruit candy	31	6	9	1	1	373	2909	13,661	1524	1744
Fruit syrup	10	5	7	1	0	174	1303	6826	573	684
Glass cleaner	23	14	6	0	1	495	3565	18,570	1475	1834
Packed ham	4	2	3	1	1	97	672	3379	229	417
Ice cream	20	5	12	1	0	213	1764	6522	776	941
International meal	7	3	5	1	1	120	963	3228	279	447
Legume	26	8	7	1	1	828	6949	33,451	4320	5492
Mashed potato	8	2	5	1	0	293	1989	10,577	733	757
Mayonnaise	10	6	4	1	1	408	2805	15,049	1201	1494
Milk	53	12	5	1	0	1983	16,123	82,597	14,663	28,715
Fresh mushroom	5	3	4	1	1	73	371	2735	185	229
Napkin	11	2	4	0	1	579	3872	22,417	2139	2888
Nonalcoholic beer	8	4	2	1	1	238	1461	8169	873	1219
Nuts	51	7	11	1	1	685	6176	26,034	3087	4937
Oil	38	13	6	1	1	1386	9817	58,464	7132	11,124
Olive	39	11	15	1	1	1173	8860	44,500	5680	8662
Palm fresh	4	3	4	1	1	55	335	1685	161	198
Paper towel	9	4	5	0	1	1246	7751	48,676	4802	5904
Pate	18	5	8	1	0	301	2215	11,085	1142	1352
Peas fresh	4	2	4	1	1	108	760	3182	308	304
Pepper	5	2	5	1	1	134	868	5180	322	338
Pickle	4	4	2	1	1	84	435	2973	195	234
Pineapple juice	15	9	3	1	0	427	2911	15,712	1740	2790
Pizza	25	4	9	1	0	515	4958	18,795	3040	4718
Plastic bag	19	3	8	0	1	1170	8521	45,179	4706	5644
Razor	8	2	4	0	0	153	1090	5879	327	337
Rice	25	9	4	1	1	1133	7678	44,520	4298	5720
RTE meal	12	4	8	1	1	119	768	4190	408	510
Vegetable salad	6	5	4	1	1	190	1379	6330	528	1412

Table 3 (*continued*)

Category	# of items	# of brands	# of sizes	Food	Sensory	# of HH	# Trips		# Purchases	
							Online	Offline	Online	Offline
Salt	10	2	4	1	0	546	3673	21,132	1183	1409
Sanitary napkin	41	8	10	0	1	848	7654	33,398	4164	5112
Liquid sauce	13	8	7	1	0	239	1759	8927	618	758
Powder sauce	25	15	18	1	0	239	1734	8211	736	1001
Sausage	12	8	9	1	1	103	878	3163	208	374
Packed sausage	22	7	15	1	1	392	3126	13,151	1482	2102
Shampoo	42	14	5	0	0	720	5456	26,225	2352	2927
Shave cream	9	7	3	0	0	128	832	4475	227	228
Smoked fish	7	2	3	1	1	102	876	3698	248	412
Snack	39	8	16	1	1	970	9017	37,465	5909	11,375
Soft drink	95	20	10	1	0	376	4062	16,640	3581	6642
Soup	10	4	7	1	0	122	794	3996	304	338
Spinach	8	4	2	1	1	261	1742	10,703	754	1036
Sweet candy	10	7	5	1	1	114	960	3126	303	321
Tea	20	4	6	1	0	208	1529	7056	581	778
Toilet paper	12	3	6	0	1	1539	9692	60,521	6540	8827
Tomato juice	4	3	2	1	0	94	534	2829	223	255
Packed tomato	32	12	17	1	1	1216	9153	48,732	6002	8940
Toothpaste	46	22	6	0	0	732	5529	27,440	2553	3172
Vinegar	16	9	5	1	1	401	2645	15,064	832	1200
WC hygiene	13	7	3	0	0	288	1883	10,390	775	965
Female shave	3	3	3	0	1	108	663	3156	183	183
Stain remover	4	3	3	0	0	119	614	4438	205	278
Paper handkerchief	8	4	4	0	1	600	4342	23,385	2084	2653
Canned saltine	9	6	2	1	0	119	719	4232	345	355
Canned tuna	26	8	8	1	0	1140	7843	43,617	4955	6831
Canned anchovy fillet	6	6	3	1	0	112	872	3724	241	360
Canned bonito	12	5	10	1	0	196	1307	6932	770	1058
Canned cockle	15	8	7	1	0	301	2075	9622	813	962
Canned clams	7	4	4	1	0	79	628	1917	243	196
Canned mussel	9	4	5	1	0	81	524	2529	209	209

shoppers", based on the proportions of their total grocery expenditure spent at the online store, and estimate type-specific loyalty and price coefficients. "Light online shoppers" (44.76%) are households with online expenditure < 25%, "moderate online shoppers" (28.85%) are households with online expenditure between 25% and 60%, and "heavy online shoppers" (26.40%) are households with online expenditure > 60% of total grocery expenditures recorded at that chain. The no-purchase utility is:

$$U_{h0st} = X_{ht}\left(I_{st}^{on}\theta_{on} + I_{st}^{off}\theta_{off}\right) + \varepsilon_{h0st} = V_{h0st} + \varepsilon_{h0st} \quad (3)$$

Where, X_{ht} includes (1) weather dummy, (2) weekday dummy, (3) purchase quantity on the last trip divided by household size, and (4) a lagged purchase indicator that takes the value 1 if the household purchased the category on the most recent trip (to capture inventory effects but mitigating the endogeneity problem associated with using inventory or time since last purchase). Assuming $\varepsilon_{h\omega st}$ follows an extreme value distribution yields the logit probability of item choice:

$$S_{h(i)\omega st} = \frac{exp\{\alpha_b + \alpha_z + D_h\gamma + V_{D\omega st} + V_{h\omega st}\}}{exp(V_{h0st}) + \sum_{\omega'=1}^{\Omega} exp\{\alpha_b + \alpha_z + D_h\gamma + V_{D\omega' st} + V_{h\omega' st}\}} \quad (4)$$

Where $V_{D\omega st} \equiv D_h BL_{h\omega t}(I_{st}^{on}\theta_D^{on} + I_{st}^{off}\theta_D^{off}) + D_h SL_{h\omega t}(I_{st}^{on}\lambda_D^{on} + I_{st}^{off}\lambda_D^{off}) + D_h P_{\omega st}(I_{st}^{on}\beta_D^{on} + I_{st}^{off}\beta_D^{off})$ and $V_{h\omega st} \equiv \{(I_{st}^{on}\theta_i^{on} + I_{st}^{off}\theta_i^{off}) BL_{h\omega t} + (I_{st}^{on}\lambda_i^{on} + I_{st}^{off}\lambda_i^{off}) SL_{h\omega t} + (I_{st}^{on}\beta_i^{on} + I_{st}^{off}\beta_i^{off}) P_{\omega st}\} I_{hi}$ and Ω is the set of alternatives available to households.

Methods for Hypothesis Testing

After obtaining the online and offline coefficients for brand loyalty, size loyalty and price sensitivity, we compute elasticities for brand loyalty, size loyalty and price elasticity (we recognize that it is somewhat unusual to compute "loyalty elasticities" but do this largely to facilitate comparisons across households and categories). We then use regression and t-tests to test the various hypotheses. Note that since the dependent variables here are estimated quantities, we need to account for the sampling error associated with their estimation in this stage of the analysis. We therefore use the estimated covariance matrix computed from the estimates of the logit model in a generalized least-squares regression.[1] Specifically, we do the following:

(1) We compute the ratios of online/offline elasticities for brand loyalty, size loyalty and price elasticities and test whether

[1] In addition to using generalized least squares, we also tried a bootstrapping approach to adjust for the standard errors. This does not change our conclusions.

the ratios are significantly different from 1. This is to check whether households are more brand loyal, more size loyal and less price sensitive in the online channel than in the offline channel.

(2) We stack together the online (offline) brand loyalty, size loyalty or price sensitivity of all three household types and regress them on category dummies, household type dummies and household demographics. This is to check the within-channel relationships in brand loyalty, size loyalty and price sensitivity across households of different online shopping frequency. Take price elasticities as an example. We have:

$$\begin{aligned}\varepsilon_{c,i}^{on} &= \kappa_{c,on} I_c + \kappa_{light,on} I_{light} + \kappa_{moderate,on} I_{moderate} + \kappa_{D,on} D_{c,i} + e_{c,i}^{on} \\ \varepsilon_{c,i}^{off} &= \kappa_{c,off} I_c + \kappa_{light,off} I_{light} + \kappa_{moderate,off} I_{moderate} + \kappa_{D,off} D_{c,i} + e_{c,i}^{off}\end{aligned} \quad (5)$$

Where $\varepsilon_{c,i}^{on}$ ($\varepsilon_{c,i}^{off}$) is household Type i's online (offline) price elasticity for category c, I_c is category indicator, and I_{light} and $I_{moderate}$ are indicators for light and moderate online shoppers. $D_{c,i}$ is the mean demographics of household Type i that makes purchases in category c, including number of preschool children, number of elders, family size and distance to the closest physical stores. We include demographics in this regression because the elasticities may reflect the effects of demographics (see Eq. (1)). We are interested in coefficients $\kappa_{light,on}$ ($\kappa_{light,off}$) and $\kappa_{moderate,on}$ ($\kappa_{moderate,off}$). If $\kappa_{light,on} > 0$, it means light online shoppers are less price sensitive in the online store than heavy online shoppers (whose coefficient is normalized to 0). If $\kappa_{moderate,on} > 0$, it means moderate online shoppers are less price sensitive in the online store than heavy online shoppers. If $\kappa_{light,on} > \kappa_{moderate,on} > 0$, it means light online shoppers are the least and heavy online shoppers are the most price sensitive in the online store.

(3) We stack together online and offline brand loyalty, size loyalty and price elasticities for all three household types and regress them on category dummies, the interactions between online indicator with indicators for food, sensory, light online shoppers and moderate online shoppers, and household demographics. This is to check whether household and product characteristics moderate online and offline differences in brand loyalty, size loyalty and price sensitivity. Take price elasticities as an example. We have:

$$\begin{aligned}\varepsilon_{c,i} = {} & \rho_c I_c + \rho_{food} Food_c * I_{on} + \rho_{sensory} Sensory_c * I_{on} \\ & + \rho_{light,on} I_{light} * I_{on} + \rho_{moderate,on} I_{moderate} * I_{on} + \rho_D D_{c,i} + e_{c,i}\end{aligned} \quad (6)$$

Where $\varepsilon_{c,i} \equiv \{\varepsilon_{c,i}^{on}, \varepsilon_{c,i}^{off}\}$ is the vector of household Type i's online and offline price elasticities in category c, and I_{on} is online indicator. ρ_{food} is online–offline difference in price sensitivity for food products (the difference for non-food products is normalized to 0). $\rho_{sensory}$ is online–offline difference in price sensitivity for sensory products (the difference for non-sensory products is normalized to 0). $\rho_{light,on}$ and $\rho_{moderate,on}$ are respectively online–offline differences in price sensitivity for light online shoppers and moderate online shoppers (the difference for heavy online shoppers is normalized to 0). If $\rho_{food} > 0$, it means online–offline price elasticity difference for food products is greater than for non-food products. If $\rho_{sensory} > 0$, it means online–offline price elasticity difference for sensory products is greater than for non-sensory products. If $\rho_{light,\ on} > \rho_{moderate,\ on} > 0$, it means online–offline difference in price sensitivity is largest for light online shoppers and smallest for heavy online shoppers. Note the logit model coefficients are estimated up to a scale factor, so elasticities of different models (different categories here) are *not* directly comparable if the scale effect is not controlled for (Swait and Louviere 1993). This is resolved in our model by including category fixed effects.[2]

Robustness Checks

We conducted a series of robustness checks on model specification, classification of household types and self-selection bias, and found our conclusions remain the same.

Potential Endogeneity Bias Due to Omitted Variables

Our model does not account for retailer promotion efforts such as features and displays due to data unavailability. If these variables are correlated with the included price variable, the estimated price effects can suffer from an endogeneity bias. Chu, Chintagunta, and Cebollada (2008) show that accounting for price endogeneity does not change the directional relationship between online and offline price sensitivity. We tried to address price endogeneity using the same approach as in Chu, Chintagunta, and Cebollada (2008) with the four categories in Table 4 and found that our conclusions remain unchanged.

Unobserved Household Heterogeneity

One caveat of our study is that we do not account for unobserved household heterogeneity due to the large number of categories involved. To assess how this will affect our findings, we estimated a random coefficients logit model for 33 categories, assuming normal distributions for brand loyalty, size loyalty and price sensitivity coefficients for all three household types and re-ran the hypothesis tests. The results are in the Appendix. We obtain qualitatively similar results, though the significance of some coefficients is compromised due to a smaller number of categories.

[2] Elasticity estimates from the same logit model are comparable because they have the same logit scale factor. Elasticity estimates from different logit models are not comparable because they have different scale factors. Since we model each category separately, each category has its own logit model and scale factor. Thus, elasticities for light, moderate and heavy online shoppers for the *same* category are comparable, but elasticities for different categories are not comparable because they come from different logit models and have different scale factors. When we include category fixed effects, the common scale factor for each category will be absorbed by category fixed effects, making elasticities from different models comparable.

Table 4
Major parameter estimates of the demand model.

	Packed tomatoes		Flour		Liquid detergent		Paper towel	
	est	se	Est	se	Est	se	Est	se
Light online shoppers								
Brand loyalty: online	2.810	.046	3.406	.022	4.813	.019	2.734	.072
Brand loyalty: offline	1.402	.050	2.397	.077	3.879	.019	1.720	.071
Size loyalty: online	3.078	.043	2.687	.015	3.054	.015	2.428	.085
Size loyalty: offline	2.124	.039	1.934	.019	2.398	.012	1.698	.059
Price: online	−2.842	.024	−6.163	.048	−0.576	.014	−2.285	.051
Price: offline	−2.977	.033	−6.805	.052	−3.788	.029	−3.714	.048
Moderate online shoppers								
Brand loyalty: online	2.400	.039	3.165	.014	4.579	.014	2.544	.065
Brand loyalty: offline	1.210	.050	2.352	.069	3.806	.019	1.499	.073
Size loyalty: online	3.035	.038	2.256	.034	2.845	.007	2.449	.077
Size loyalty: offline	2.005	.042	1.798	.036	1.866	.026	1.509	.059
Price: online	−3.107	.019	−6.961	.026	−1.467	.006	−2.648	.044
Price: offline	−3.203	.033	−7.264	.065	−4.045	.022	−3.900	.044
Heavy online shoppers								
Brand loyalty: online	2.444	.040	3.168	.010	4.536	.010	2.440	.064
Brand loyalty: offline	1.009	.060	2.080	.085	3.377	.006	1.081	.081
Size loyalty: online	3.156	.039	2.104	.028	2.565	.006	2.527	.078
Size loyalty: offline	1.667	.051	1.949	.040	1.844	.010	1.168	.065
Price: online	−3.269	.019	−6.584	.030	−1.086	.008	−2.613	.046
Price: offline	−3.100	.056	−7.083	.027	−3.016	.037	−3.550	.071
*Demographics*brand loyalty*								
Children*online	.043	.010	.099	.049	−0.026	.024	−.024	.022
Elders*online	.153	.009	.289	.078	0.143	.024	−.067	.011
Family size*online	.287	.013	−.016	.013	0.102	.020	.163	.017
Distance*online	.273	.029	−.116	.034	−0.373	.057	.405	.035
Children*offline	−.012	.008	−.033	.037	0.025	.020	.011	.028
Elders*offline	.139	.008	.131	.028	0.002	.019	.014	.011
Family size*offline	.300	.011	.071	.019	−0.103	.017	.184	.017
Distance*offline	.749	.025	.090	.032	0.388	.056	.403	.048
*Demographics*size loyalty*								
Children*online	−.083	.014	−.203	.051	0.088	.023	−.018	.009
Elders*online	.362	.013	−.408	.098	0.242	.035	.125	.012
Family size*online	.284	.013	.109	.024	−0.110	.019	.198	.018
Distance*online	.097	.024	−.136	.034	0.376	.066	.471	.042
Children*offline	−.111	.013	−.023	.048	0.046	.017	−.111	.035
Elders*offline	−.015	.011	−.188	.048	0.061	.022	−.094	.019
Family size*offline	.234	.010	.021	.017	0.054	.013	.118	.013
Distance*offline	.526	.018	−.057	.033	−0.248	.042	.544	.044
*Demographics*price*								
Children*online	.055	.008	.055	.009	0.116	.030	−.026	.014
Elders*online	−.294	.008	−.549	.018	1.244	.011	−.653	.012
Family size*online	.282	.005	−.146	.045	−0.559	.015	.251	.011
Distance*online	.850	.014	1.258	.027	−1.042	.023	.556	.021
Children*offline	.047	.010	−.236	.016	−0.174	.014	−.077	.031
Elders*offline	−.038	.011	−.531	.023	1.259	.016	−.620	.012
Family size*offline	.220	.006	.026	.046	−0.407	.016	.367	.010
Distance*offline	.792	.022	.184	.134	−0.853	.009	.893	.028

The Possibility of Self-selection Bias

The households reside either in the high-price zone or in the low-price zone, while the prices in the online store are the same as in the high-price zone. In the data section, we showed that the online store does not only attract households in the high-price zone. Actually, it is slightly more attractive to households in the low-price zone. To further check whether there exists a self-selection bias, we divide households into three groups by their offline shopping behavior — those who only shop in the high-price zone, those who only shop in the low-price zone and those who shop across both price zones, and estimate the models separately for each group of households

with the four categories in Table 4. We obtained similar results for all three groups of households, though the significance of the coefficient estimates is somewhat reduced due to a smaller sample in each model.

Continuous Versus Discrete Operationalization of Household Types for Online Grocery Expenditure

Instead of using a continuous measure and interacting it with brand loyalty, size loyalty and price in the demand model, we bin households into three types according to their percentages of online grocery expenditure in the total grocery expenditure incurred in the chain. This is because findings based on the discrete operationalization can be easily applied by the retailer for market segmentation and targeting purposes. We compared the stability of a household's online expenditure over time, and find it is very stable and thus can be treated as a household characteristic. This is consistent with the finding in Chintagunta, Chu, and Cebollada (2010) that online shopping is more regular both in terms of trip interval and basket size.

Results

In this section, we first report demand parameter estimates and loyalty and price elasticities for 4 categories — one sensory food product (packed tomatoes), one non-sensory food product (flour), one non-sensory non-food product (liquid laundry detergent), and one non-food sensory product (paper towel). Results of other categories are available from the authors. We then report the results of the hypothesis tests.

Demand Parameter Estimates

In Table 4, we report key demand parameter estimates and in Table 5, we report online and offline loyalty elasticities and price elasticities for light, moderate and heavy online shoppers for packed tomatoes, flour, liquid laundry detergent and paper towels. Across all four categories, irrespective of online shopping frequency, households demonstrate strong brand and size loyalties. Consistent with the literature, for all three types of households, online brand loyalty is greater than offline brand loyalty, online size loyalty is greater than offline size loyalty, and online price sensitivity is smaller than offline price sensitivity. The differences are significant at the 99% level.

The majority of the coefficients of the interactions between demographics and brand loyalty, demographics and size loyalty, and demographics and price are significant, implying that demographics play an important role in determining online and offline brand loyalty, size loyalty, and price sensitivity. But the signs of the interaction coefficients are not the same across categories.

In Table 6, we summarize the directional relationships in online and offline brand loyalty, size loyalty and price elasticities for the three types of households. For light online shoppers, 89% categories have larger online brand loyalty and size loyalty elasticities than offline, and all categories have smaller (in magnitude) online price elasticity. For moderate online shoppers, 85% have larger online brand loyalty elasticity, 88% have larger online size loyalty elasticity, and 90% have larger online price elasticity. For heavy online shoppers, the figures are respectively

Table 5
Online and Offline Elasticities.

	Packed tomatoes		Flour		Liquid detergent		Paper towel	
	est	se	Est	se	Est	se	Est	se
Light online shoppers								
Brand loyalty: online	.590	.018	.412	.017	.288	.009	.867	.042
Brand loyalty: offline	.475	.017	.385	.028	.271	.010	.774	.054
Size loyalty: online	.510	.014	.496	.031	.674	.035	.804	.044
Size loyalty: offline	.436	.013	.354	.027	.572	.025	.665	.044
Price: online	−1.537	.083	−1.473	.065	−.911	.030	−1.471	.170
Price: offline	−2.092	.110	−1.706	.088	−1.662	.029	−2.711	.189
Moderate online shoppers								
Brand loyalty: online	.533	.017	.369	.016	.275	.009	.845	.041
Brand loyalty: offline	.429	.017	.356	.026	.263	.009	.710	.054
Size loyalty: online	.487	.013	.435	.036	.631	.033	.840	.043
Size loyalty: offline	.411	.013	.339	.031	.463	.028	.626	.045
Price: online	−1.968	.075	−1.685	.060	−1.165	.028	−2.012	.160
Price: offline	−2.504	.108	−1.823	.090	−1.741	.026	−3.093	.183
Heavy online shoppers								
Brand loyalty: online	.558	.017	.379	.017	.270	.008	.847	.042
Brand loyalty: offline	.420	.020	.328	.029	.241	.009	.619	.060
Size loyalty: online	.502	.013	.399	.036	.538	.031	.860	.043
Size loyalty: offline	.348	.013	.363	.032	.426	.023	.549	.048
Price: online	−2.201	.076	−1.613	.063	−1.054	.029	−1.975	.161
Price: offline	−2.311	.142	−1.786	.080	−1.474	.032	−2.543	.223

86%, 88% and 70%. From the elasticities, we can see that households are more brand loyal, more size loyal but less price sensitive in the online channel than in the offline channel.

In Table 7, we show how the same households' online and offline brand loyalty, size loyalty and price elasticities are correlated. For all three household types, online brand loyalty is positively correlated with offline brand loyalty, online size loyalty is positively correlated with offline size loyalty, and online price sensitivity is positively correlated with offline price sensitivity, indicating some consistency in a household's shopping behavior across the two channels. Brand loyalty, size loyalty and price sensitivity are also positively correlated, but the correlation coefficients are either small, or not significant.

Comparison of Online and Offline Brand Loyalties, Size Loyalties and Price Sensitivities

We compute the ratios of online/offline brand loyalty, size loyalty and price elasticities, and test whether the ratios are significantly different from 1, respectively for all households together and for each type of households (Table 8). We find that, consistent with the literature, all types of households exhibit stronger brand loyalty and size loyalty in the online store than in the offline stores, but lower price sensitivity in the online store than in the offline stores.

Comparison of Within-channel Brand Loyalty, Size Loyalty and Price Sensitivity by Household Characteristics

To test whether online and offline behaviors differ by online shopping frequency, we regress online and offline brand loyalties, size loyalties and price elasticities respectively on category dummies, household type dummies and household demographics (Eq. (5)). The results are in Table 9. Light online shoppers are more brand loyal than heavy online shoppers both in the online and offline channels. There is no significant difference in brand loyalty between light and moderate online shoppers, as well as between moderate and heavy online shoppers. This supports H1. Similarly, light online shoppers are more size loyal than heavy online shoppers both in the online and offline channels. There is no significant difference between light and moderate and between moderate and heavy online shoppers in size loyalty. This supports H2.

In the online channel, light online shoppers are significantly less price sensitive than moderate and heavy online shoppers, and moderate online shoppers are slightly less price sensitive than heavy online shoppers. This supports H3a and H3b. In the offline channel, light online shoppers are less price sensitive than moderate online shoppers, but more price sensitive than heavy online shoppers, and moderate online shoppers are also more price sensitive than heavy online shoppers. In other words, the moderate online shoppers show the highest price sensitivity and the heavy online shoppers show the lowest price sensitivity in the offline channel. This supports H3c and H3d.

In sum, we find support for H1, H2 and H3a–H3d, confirming that in the online store light online shoppers are more brand loyal and less price sensitive than heavy online shoppers, while in offline stores they are more price sensitive than heavy online shoppers, but less price sensitive than moderate online shoppers.

Online–offline Differences in Brand Loyalty, Size Loyalty and Price Sensitivity by Household and Product Characteristics

To test how online–offline behavioral differences are affected by household and product characteristics, we stack online and offline brand loyalties, size loyalties and price elasticities and regress them on the interactions between online

Table 6
Summary of Brand Loyalty, Size Loyalty and Price Elasticities.

	>0	<0	Online > offline		Online <offline	
			#	%	#	%
Light online shoppers						
Brand loyalty: online	93	0	83	89.24	10	10.76
Brand loyalty: offline	93	0				
Size loyalty: online	93	0	83	89.24	10	10.76
Size loyalty: offline	93	0				
Price elasticity	0	93	93	100.00	0	0.00
Moderate online shoppers						
Brand loyalty: online	93	0	79	84.95	14	15.05
Brand loyalty: offline	93	0				
Size loyalty: online	93	0	82	88.17	11	11.83
Size loyalty: offline	93	0				
Price elasticity	0	93	84	90.32	10	9.68
Heavy online shoppers						
Brand loyalty: online	93	0	80	86.02	13	13.98
Brand loyalty: offline	93	0				
Size loyalty: online	93	0	82	88.17	11	11.83
Size loyalty: offline	93	0				
Price elasticity	0	93	65	69.89	28	31.11

Table 7
Correlation between Online and Offline Brand Loyalty, Size Loyalty & Price Sensitivity.

	Online Brand Loyalty	Offline Brand Loyalty	Online Size Loyalty	Offline Size Loyalty	|Online Price Sensitivity|	|Offline Price Sensitivity|
Light online shoppers						
Online brand loyalty	1					
Offline brand loyalty	.919***	1				
Online size loyalty	.100	.231**	1			
Offline size loyalty	.204**	.298***	.914***	1		
|Online price sensitivity|	.217**	.222**	.269***	.239**	1	
|Offline price sensitivity|	.187*	.200*	.283***	.281***	.974***	1
Moderate online shoppers						
Online brand loyalty	1					
Offline brand loyalty	.947***	1				
Online size loyalty	.247**	.308***	1			
Offline size loyalty	.284***	.322***	.867***	1		
|Online price sensitivity|	.169	.112	.251**	.234**	1	
|Offline price sensitivity|	.188*	.149	.290***	.328***	.971***	1
Heavy online shoppers						
Online brand loyalty	1					
Offline brand loyalty	.934***	1				
Online size loyalty	.215**	.236**	1			
Offline size loyalty	.255**	.226**	.823***	1		
|Online price sensitivity|	.166	.126	.171	.194*	1	
|Offline price sensitivity|	.156	.126	.118	.140	.981***	1
All households						
Online brand loyalty	1					
Offline brand loyalty	.923***	1				
Online size loyalty	.180***	.254***	1			
Offline size loyalty	.247***	.279***	.867***	1		
|Online price sensitivity|	.182***	.149**	.223***	.215***	1	
|Offline price sensitivity|	.177***	.156***	.231***	.257**	.970***	1

indicator and dummies for household and product characteristics and demographics (Eq. (6)). The results are in Table 10. For brand loyalty, the online–offline difference is largest for light online shoppers and smallest for heavy online shoppers. This supports H4. For size loyalty, the online–offline difference is larger for light and moderate online shoppers than for heavy online shoppers, and there is no significant difference between light and moderate online shoppers. This supports H5. For price sensitivity, the difference is largest for light online shoppers and second largest for moderate online shoppers, supporting H6.

The online–offline difference in brand loyalty is significantly larger for food products than for non-food products. The online–offline difference in size loyalty is also significantly larger for food products than for non-food items. The online–offline difference in price sensitivity is significantly larger for food products than for non-food products. This supports H7.

Table 8
T-test of Online and Offline Ratios (test value = 1).

	N	Mean	Sd	Se	t-stat
Brand loyalty ratio (online/offline)					
All shoppers	279	1.318	0.688	0.041	7.714
Light online shoppers	93	1.422	0.993	0.103	4.105
Moderate online shoppers	93	1.209	0.254	0.026	7.939
Heavy online shoppers	93	1.322	0.598	0.062	5.197
Size loyalty ratio (online/offline)					
All shoppers	279	1.364	0.537	0.032	11.330
Light online shoppers	93	1.342	0.503	0.052	6.559
Moderate online shoppers	93	1.364	0.623	0.065	5.636
Heavy online shoppers	93	1.385	0.477	0.050	7.784
Price sensitivity ratio (online/offline)					
All shoppers	279	0.820	0.265	0.016	−11.380
Light online shoppers	93	0.698	0.243	0.025	−12.036
Moderate online shoppers	93	0.823	0.220	0.023	−7.776
Heavy online shoppers	93	0.940	0.274	0.028	−2.120

Table 9
Regression of within-channel Elasticities on Household Characteristics.

	Online		Offline		Online		Offline	
	est	se	est	se	est	se	est	se
Brand loyalty								
Light online shoppers	.049	.030	.046	.024	.073	.034	.050	.027
Moderate online shoppers	.001	.030	−.005	.024	.002	.034	.018	.027
No. of preschool children					.245	.144	−.234	.116
No of elders					.459	.358	−.068	.290
Family size					−.242	.098	.201	.079
Closest distance					−.450	.332	−.051	.268
N	279		279		279		279	
R^2	.981		.978		.982		.980	
Size loyalty								
Light online shoppers	.080	.041	.094	.037	.084	.044	.071	.037
Moderate online shoppers	.029	.041	.059	.037	.023	.044	.090	.037
No. of preschool children					−.727	.190	−.334	.160
No of elders					−.797	.472	.415	.398
Family size					.411	.129	.486	.109
Closest distance					1.398	.437	1.340	.369
N	279		279		279		279	
R^2	.964		.947		.969		.960	
Price elasticity								
Light online shoppers	.456	.055	−.140	.059	.473	.063	−.092	.065
Moderate online shoppers	.052	.055	−.256	.059	.034	.063	−.275	.065
No. of preschool children					−.035	.270	−.190	.279
No of elders					−.925	.672	.112	.694
Family size					.011	.184	−.493	.190
Closest distance					−.380	.623	−1.560	.643
N	279		279		279		279	
R^2	.994		.994		.994		.995	

* Category fixed effects are not reported. Results account for sampling errors in the elasticities.

The online–offline difference in brand loyalty is significantly larger for sensory products than for non-sensory products, the difference in size loyalty is directionally larger for sensory products than for non-sensory products, and the difference in price sensitivity is significantly larger for sensory products. This supports H8.

To summarize, we find empirical support for all our hypotheses. We find that households are more brand loyal, more size loyal and less price sensitive in the online channel than in the offline channel. Households' online shopping frequency affects brand loyalty, size loyalty and price sensitivity. In the online channel, light online shoppers are more brand loyal, more size loyal but less price sensitive than heavy online shoppers, while in the offline channel, heavy online shoppers are the least and moderate online shoppers are the most price sensitive. The online–offline differences in brand loyalty, size loyalty and price sensitivity are largest for light online shoppers and smallest for heavy online shoppers, larger

Table 10
Regression of Loyalty & Price Elasticities on Product & Household Characteristics.

	Brand loyalty			Size loyalty			Price Elasticity		
	est	se	t-stat	est	se	t-stat	est	se	t-stat
Food*online	.094	.033	2.837	.184	.038	4.789	.086	.051	1.680
Sensory*online	.072	.037	1.940	.042	.043	.979	.312	.069	4.535
Light online shoppers*online	.120	.032	3.709	.066	.037	1.759	.556	.060	9.316
Moderate online shoppers*online	.073	.032	2.263	.085	.037	2.275	.112	.060	1.885
No. of preschool children	.033	.114	.292	−.511	.132	−3.868	−.026	.211	−.125
No of elders	.221	.287	.770	−.213	.332	−.640	−.137	.530	−.259
Family size	−.012	.078	−.152	.442	.091	4.859	−.153	.145	−1.054
Closest distance	−.393	.246	−1.595	1.294	.286	4.529	−1.535	.456	−3.367
N	558			558			558		
R^2	.963			.948			.991		

* Category fixed effects are not reported.

Table 11
Summary of Findings and Implications.

Findings	Implications
The same households are more brand loyal, more size loyal, but less price sensitive in the online store than in the offline stores.	The retailer can fine tune its pricing policies for the two channels and charge price premiums in the online store.
Light online shoppers are least price sensitive and heavy online shoppers are most price sensitive in the online store. Moderate online shoppers are most price sensitive in the offline stores.	The retailer can adopt differential and targeted promotions for different types of households: • Deeper online coupon drops for heavy online shoppers • Deeper offline coupon drops for moderate online shoppers • Promote the online store to light online shoppers and non-online shoppers
Online and offline differences in brand loyalty and price sensitivity are larger for food products than for non-food products and larger for sensory products than for non-sensory products.	• Offer more non-food products and non-sensory products in the online store • Offer more food products and more sensory products in the offline stores • Charge price premiums for food products and sensory products in the online store

for food products than for non-food products, and larger for sensory products than for non-sensory products.

Managerial Implications, Limitations and Conclusions

Our findings have important implications for Internet retail practice as shown in Table 11. One implication concerns retailer pricing policy. The findings suggest specific pricing actions for the retailer in question — a well-established grocery chain in Spain. This retailer used to practice zone pricing in the offline stores. The offline stores were partitioned into a high-price zone and a low-price zone. When this retailer started the online arm, it did not change its pricing policy for the offline stores. Nor did it develop online prices different from its offline zone prices. Rather, it decided to use the prices in the high-price offline zone for the online store (Now the retailer practices uniform pricing across both online and offline stores). We find that regardless of online shopping frequency, the same households exhibit lower price sensitivity in the online store than in the offline stores. This finding suggests that the retailer can be better off if it can fine tune its pricing policies for the two channels so that the online prices can be better matched to household online price sensitivity. The retailer can estimate average online and offline price sensitivities across households shopping in each channel and set online and offline prices accordingly. The lower online price sensitivities mean the retailer can charge price premiums in the online store.

A second implication concerns the differential price sensitivities across households of different online shopping frequency and the possibility of market segmentation and targeting. Given the popularity of the loyalty card program, it is not difficult for the retailer to find out which households are heavy online shoppers and which households are light online shoppers. Given that light online shoppers are least price sensitive and heavy online shoppers are most price sensitive in the online store, the retailer may consider using different promotional policies such as targeted coupon drops and email promotions to different types of households. For example, they can send deeper online promotion coupons to heavy online shoppers, and send deeper offline promotion coupons to moderate online shoppers.

A third implication is about different product offerings in the online and offline channels. Given that online and offline differences in brand loyalty and price sensitivity are larger for food products than for non-food products and larger for sensory products than for non-sensory products, the retailer may consider offering different products in different channels. Instead of offering the same products across the two channels, it may want to offer more non-food products and non-sensory products in the online store, and offer more food products and more sensory products in the offline stores. Although this implication is intuitive, our results provide a strong empirical basis for such a recommendation.

The finding that product characteristics influence consumer behavior in the online store differently from the offline stores should help manufacturers and retailers tailor their marketing strategies to different channels. For example, the larger online–offline difference in price sensitivity for sensory products than for non-sensory products implies that the retailer can extract higher margins for sensory products in the online store than in the offline stores. It can encourage consumers to buy sensory products in the online store, or even set higher prices for sensory products in the online store. This is to extract more consumer surplus from those households that do buy sensory products in the online store. In terms of sales volume, the retailer may have lower sales of sensory products in the online store, but in terms of unit margin, the retailer can get a higher margin from selling sensory products in the online store.

Our research confirms the complementary nature of the online store to offline stores. For many households, the online store is an extension of the physical stores that has more flexible shopping hours and alleviates the burden of grocery shopping. These households are least price sensitive in the online store but are most price sensitive in the offline stores. The retailer should promote its online store to its customers who have not adopted its online store. This is because when these households adopt

the online store, they will likely use the Internet as a supplementary channel and be less price sensitive in that channel, allowing the retailer to charge a price premium.

Our paper has several limitations that should be addressed by future research. First, our demand model does not account for retailer promotion efforts such as features and displays due to data unavailability. Even though we show that this omission will not likely affect our conclusions, including these variables will enhance the managerial value of the findings. Second, there are additional product characteristics such as competitive intensity and deal elasticity that may moderate a household's brand and size loyalties and price sensitivity. Again, due to lack of data, we do not address them in this paper. Third, we model a household's purchase incidence and brand choice decisions conditional on its channel choice decision. We recognize the limitation of treating channel choice as exogenous, but a single category may not be adequate to drive a household's channel choice decisions (Chintagunta and Chu 2010; Chintagunta, Chu, and Cebollada 2010). Formulating and estimating a store/channel choice model with as many categories as we have would be a challenging task. We leave it to future research to model channel choice, purchase incidence and brand choice simultaneously. Fourth, we compare online and offline purchase behaviors related to grocery products, which are not the typical products sold online. Future studies can compare the results with those obtained with non-grocery products such as books, CDs and PCs.

In conclusion, we analyzed households' channel-specific brand loyalty, size loyalty and price sensitivity in 93 categories of food, non-food, sensory and non-sensory grocery products and test whether these behaviors differ by household characteristics (online shopping frequency) and product characteristics (food versus non-food, sensory versus non-sensory). Consistent with the literature, we find the same households are more brand loyal, more size loyal and less price sensitive in the online store than in the offline stores. Importantly, our results show that the online and offline behavioral differences are moderated by household and product characteristics.

Given the potential of the Internet and its increasing importance throughout the world, many retailers now have online operations. Our study reveals that consumer behavior in the online store does not simply mimic that in the conventional channel. Firms need to tailor their marketing strategies so as to better cater to consumer's online behavior.

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Appendix. Results of Random Coefficients Logit

Table A1
T-test of Online and Offline Ratios (test value = 1): Random Coefficients Logit.

	N	Mean	Sd	Se	t-stat
Brand loyalty ratio (online/offline)					
All shoppers	99	1.437	1.087	.109	4.005
Light online shoppers	33	1.645	1.613	.281	2.295
Moderate online shoppers	33	1.266	.698	.122	2.188
Heavy online shoppers	33	1.401	.671	.117	3.437
Size loyalty ratio (online/offline)					
All shoppers	99	1.271	.495	.050	5.451
Light online shoppers	33	1.262	.486	.085	3.091
Moderate online shoppers	33	1.201	.297	.052	3.884
Heavy online shoppers	33	1.350	.643	.112	3.128
Price sensitivity ratio (online/offline)					
All shoppers	99	0.746	0.245	0.025	−10.337
Light online shoppers	33	0.652	0.265	0.046	−7.535
Moderate online shoppers	33	0.778	0.196	0.034	−6.510
Heavy online shoppers	33	0.807	0.246	0.043	−4.513

Table A2
Regression of within-channel Elasticities on Household Characteristics.

	Online		Offline		Online		Offline	
	est	se	est	se	est	se	est	se
Brand loyalty								
Light online shoppers	.222	.127	.157	.088	.040	.068	.136	.077
Moderate online shoppers	.213	.127	.044	.089	.136	.069	.050	.079
No. of preschool children					.250	.215	.069	.245
No of elders					.475	.570	.699	.650
Family size					−.328	.158	−.420	.180
Closest distance					.444	.507	−.228	.578
N	99		99		99		99	
R^2	.975		.946		.977		.951	
Size loyalty								
Light online shoppers	.233	.110	.195	.120	.110	.099	.101	.062
Moderate online shoppers	.200	.110	.169	.120	.058	.101	.053	.063
No. of preschool children					−.286	.315	.022	.196
No of elders					.090	.833	1.051	.521
Family size					.144	.231	.030	.144
Closest distance					−.129	.741	−.004	.463
N	99		99		99		99	
R^2	.945		.964		.947		.969	
Price elasticity								
Light online shoppers	.711	.181	−.130	.242	.636	.200	.029	.184
Moderate online shoppers	.209	.181	−.441	.242	.132	.205	−.330	.189
No. of preschool children					−1.175	.637	−.606	.586
No of elders					−1.452	1.687	−.240	1.553
Family size					.099	.467	−.655	.430
Closest distance					.082	1.501	.323	1.381
N	99		99		99		99	
R^2	.986		.990		.987		.991	

* Category fixed effects are not reported.

Table A3
Regression of Loyalty & Price Elasticities on Product & Household Characteristics.

	Brand loyalty			Size loyalty			Price Elasticity		
	est	se	t-stat	est	se	t-stat	est	se	t-stat
Food*online	.142	.077	1.847	.148	.075	1.983	.262	.189	1.387
Sensory*online	.057	.064	.888	.081	.082	.993	.640	.206	3.108
Light online shoppers*online	.092	.051	1.793	.054	.049	1.100	.625	.174	3.582
Moderate online shoppers*online	.004	.052	.076	.018	.050	.365	.106	.176	.603
No. of preschool children	.205	.184	1.115	−.132	.179	−.737	−.905	.451	−2.006
No of elders	.643	.491	1.308	.588	.477	1.232	−.689	1.203	−.573
Family size	−.345	.135	−2.548	.092	.132	.702	−.234	.332	−.706
Closest distance	−.204	.411	−.496	−.099	.399	−.248	−.004	1.006	−.004
N	198			198			198		
R^2	.974			.983			.984		

* Category fixed effects are not reported.

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