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# Why is Price Dispersion Higher Online than Offline? The Impact of Retailer Type and Shopping Risk on Price Dispersion

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**Abstract**

When physically similar products, of similar quality, are offered by retailers both online and offline, we often observe that the dispersion in prices of these products online is greater than the price dispersion offline. This observation runs counter to early theories that suggested price dispersion online would be smaller than that offline due to the ease of search and information availability online. This paper investigates and provides an explanation for this puzzling phenomenon by examining the impact of two important drivers of price dispersion: retailer type and consumers' shopping risk. Retailer type refers to whether a retailer is a pure offline, pure online, or dual channel retailer. Shopping risk is defined as the product of consumers' perceived risk of shopping and the transaction uncertainty related to shopping at different types of retailers.

A game-theoretic approach is adopted to model consumers' price search and product purchase, as well as price competition within and across retailer types in online and offline markets. Equilibrium pricing strategies are derived for different retailer types competing for different consumer segments with different levels of perceived shopping risk. The impact of retailer type and shopping risk on online versus offline price dispersion are quantified, and conditions when price dispersion is greater online than offline are identified.

Results indicate that price dispersion is greater online when the number of pure online retailers is sufficiently large and is increasing in the number of pure online retailers. In addition, a reduction in online shopping risk may actually increase online price dispersion. Results further suggest that even without any online sales, dual channel retailers should maintain their online presence for the purpose of information dissemination, which justifies the importance for pure offline retailer to incorporate webrooming strategies, where consumers can search for prices online but purchase offline.


*Keywords:* Online and offline price dispersion; Retailer type; Shopping risk; Consumer search; Pricing strategy; Game theory

## Introduction

Price dispersion refers to the difference in prices set by different sellers of the same product in a given market (Hopkins 2008). Studying the factors influencing price dispersion is of great importance to retailers, as it affects their ability to charge different prices from their competitors. The recent trends towards multi and omni-channel retailing have increased the importance of studying price dispersion and comparing price dispersion between online and offline markets.

Generally, price dispersion is believed to be caused by imperfect information as consumers do not know which seller charges the lowest prices. Therefore, the increased ability to search for price information online was expected to reduce price dispersion among online retailers (Bakos 1997; Smith and Brynjolfsson 2001). However, contrary to expectation some studies reported that significant online price dispersion remains (Brynjolfsson and Smith 2000; Pan, Ratchford, and Shankar 2004), and in some cases price dispersion is even higher online than offline (Clay, Krishnan, and Wolff 2001; Degeratu, Rangaswamy, and Wu 2000). This paper aims to investigate and explain this puzzling phenomenon. In particular, we examine the impact of two important drivers of price dispersion: retailer type and consumers' shopping risk. Retailer type refers to whether a retailer is a pure offline, pure online, or dual channel retailer. Shopping

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risk is defined as the product of consumers' perceived risk of shopping and the transaction uncertainty related to shopping at different types of retailers.

To further motivate the research question, we provide additional and more recent evidence that price dispersion persists and is greater online than offline for a variety of product categories. We collected data over a period of 3 months for several product categories, including batteries, flash drives, Espresso makers, toys, televisions and vacuum cleaners and found that price dispersion was consistently higher online than offline (for identical products, offered by retailers both online and offline). Details about the data and the procedures used to collect and analyze it are provided in Table A1. Further analysis of this data also suggests that price dispersion is different across retailer types.

We adopted a game-theoretic approach to model consumers' price search and product purchase, and price competition within and across retailer types in both online and offline markets. We derive equilibrium pricing strategies for different retailer types competing for different consumer segments with different levels of perceived shopping risk. Equilibrium pricing strategies of different retailer types in online and offline markets are used to derive market level price distributions and compare online versus offline price dispersion. We focus on quantifying the impact of retailer type and shopping risk on online versus offline price dispersion. Price dispersion across retailers of the same type may also exist due to different strategies used (e.g., differentiation based on product quality or service level), though, this is outside the scope of the current research.

Our research makes several contributions to the literature. We address the puzzle of why online price dispersion may be higher than offline price dispersion, even for homogeneous products (physically similar products, of similar quality). In particular, we study the impact of retailer type and consumers' shopping risk on online versus offline price dispersion. This is in contrast to previous analytical models that limited the analysis of price dispersion to a single market (online or offline) or just to two retailer types (pure online and pure offline retailers). Previous research has largely ignored the influence of retailers selling through multiple channels, an important limitation given the recent trends towards multi-channel and omni-channel retailing (Ailawadi and Farris 2017; Cao and Li 2015; Herhausen et al. 2015; Verhoef, Kannan, and Inman 2015; Yurova et al. 2017). These trends have important implications for competitive pricing strategies within and across different retailer types, and as such, on online versus offline price dispersion.

In addition, we focus on the impact of shopping risk on online versus offline price dispersion. Shopping risk plays an important role in consumers' decisions to shop online or offline (Kiang et al. 2011; Shankar, Urban, and Sultan 2002). In particular, concerns about fraud and information privacy are major worries to online consumers (Dai, Forsythe, and Kwon 2014; Nepomuceno, Laroche, and Richard 2014; Zhang et al. 2010). Shopping risk therefore influences retailer pricing, due to consumers' willing to pay for making purchases at more secure retailer types (Al-Matarneh 2016; Dai, Forsythe, and Kwon 2014; Gupta, Su, and Walter 2004). This influence of shopping risk is directly related to the different types of retailers. Buying from pure online retailers is generally perceived to be riskier than purchasing from pure offline retailers. Adding to the previous literature, this paper makes a *unique* contribution by modeling shopping risk (as a product of transaction uncertainty related to shopping at different retailer types and consumers' heterogeneous risk sensitivities) and analyzing its impact on price dispersion in the online versus offline markets.

Finally, we show that our main results, of market conditions with greater online than offline price dispersion, are robust for list and transaction prices, for asymmetrical marginal costs (for retailers of the same type), under conditions of channel-based price differentiation, for different measures of price dispersion (range and variance), and for geographic-based search costs.

Results from our analytical model indicate that retailer type and shopping risk directly influence competing retailers' equilibrium pricing strategies. Shopping risk influences where different consumer segments shop and the price and price premium that different retailer types can charge for a more secure shopping environment. Pure online retailers set the most competitive prices. Their prices are the lowest because they compete for consumers who perceive shopping risk to be low online (i.e., who are **not** willing to pay a premium for the security of an offline store), and due to reduced search cost in the online market, allowing them to search without cost for the lowest price. Pure offline retailers set the highest prices. They compete for consumers who perceive shopping risk to be high online, and who are willing to pay a risk premium for the added security of an offline store. Consumers who purchase offline incur non-negligible search cost to visit different retailers, searching for lower prices. In equilibrium pure offline retailers set prices at the level where consumers in the offline market feel indifferent between purchasing at the current retailer or continuing to search for better prices. Dual channel retailers set prices in between pure online and pure offline retailers. They set prices higher than pure online retailers since they can charge a risk premium to mixed consumers who value the convenience of shopping online yet prefer the safety of the offline presence of dual channel retailers. However, dual channel retailers set prices below those of pure offline retailers since not doing so would result in a loss of sales from both the mixed and offline consumer segments.

We find that these pricing strategies and the number of retailers of each type drive the difference in price dispersion between online and offline markets in our model. We show general market conditions under which price dispersion is greater online than offline. In particular, price dispersion is greater online when the number of pure online retailers is sufficiently large (relative to the number of pure offline or dual channel retailers), and online price dispersion further increases as the number of pure online retailers increases. This finding suggests that contrary to conventional beliefs, retailers may have greater ability to charge different prices in online markets. Our findings further indicate that even without any online sales, dual channel retailers should maintain their online presence for the purpose of information dissemination. This finding also points to the importance of adopting webrooming strategies by pure offline retailer. Webrooming, where consumers can search for prices online but purchase offline where shopping risk is lower, are increasingly used in current retail practice (Orús, Gurrea and Flavián 2016; PricewaterhouseCoopers 2015).[1]

Shopping risk influences online versus offline price dispersion as well due to consumers' risk attitude towards transaction uncertainty related to shopping at different retailer types. Dual channel retailers reduce transaction uncertainty by allowing consumers to search for prices online and buy offline, providing them with a competitive advantage over single channel retailers. Moreover, as the risk of shopping at pure online retailers reduces over time, competition with dual channel retailers will intensify. The best response for dual channel retailers is to focus more on the offline market by charging prices similar to pure offline retailers, causing higher online versus offline price dispersion. Therefore as more consumers gradually accept online shopping, pure online retailers or both invest in technology to reduce online shopping risks (e.g., showrooms), online price dispersion may actually increase, contrary to earlier predictions in the literature.

We also study market entry strategies and find that pure offline retailers can benefit from becoming dual channel retailers. By adding an online presence they can provide price information to consumers at low or no cost, attracting a greater proportion of mixed consumers with high risk sensitivity, who like to search online but prefer the added security of purchasing offline.

Our main model results are derived using a game theoretical model. Like most analytical models, we realize that some key assumptions of the main model may limit the applicability of our results. First, we did not distinguish between list and transaction prices, while previous research has found that transaction prices have lower price dispersion than list prices (Ghose and Yao 2011; Zhao, Zhao, and Deng 2015). Second, we did not incorporate differences in retailers' geographic locations, which will influence travel costs and consumers' likelihood of search, and in turn may influence price dispersion (e.g., Choi and Choi 2014; Forman, Ghose, and Goldfarb 2009). Third, marginal costs of different retailers are assumed to be zero in our main model, while it is likely that different retailers have different wholesale prices and operating costs, due to variations in retailer locations, assortment, services, and so on. Different costs for online and offline retailers may therefore increase the difference in price dispersion. Fourth, we assume that dual channel retailers charge identical price in their online and offline stores, which restricts the ability for dual channel retailers to implement channel-based pricing.[2] Fifth, we assume that offline consumer price search is finite, under full information, and without recall. This assumption is made for model tractability and may be more applicable for less expensive goods. Lastly, we study a single-period pricing competition which excludes the possibility of consumer learning or retailer loyalty, both of which may influence price dispersion (Haruvy and Popkowski Leszczyc 2010; Narasimhan 1988; Raju, Srinivasan, and Lal 1990). We extend our main model by relaxing the key assumptions related to the first four concerns mentioned above, and show that our main results are robust and do not vary substantially. We discuss the potential implications of learning or retailer loyalty in the conclusion section.

The rest of the paper is organized in the following way. Section "Literature Review" presents a discussion of literature background, Section "Model" introduces the setup of our analytical model, which is solved in Section "Analysis and Solution of Main Model". Section "Extensions" presents the extensions of main model and a discussion and conclusion is provided in the last section.

## Literature Review

This literature review section consists of three parts. First we discuss the previous research that studied different factors that influence price dispersion, and indicate the gaps in the literature and what this paper achieves in closing those gaps. The next two subsections focus on literature related to retailer type and shopping risk, the two major factors whose impact on price dispersion are analyzed in this research.

### *Factors Influencing Price Dispersion*

Researchers have studied different factors that influence price dispersion for homogeneous and heterogeneous products. For heterogeneous products price dispersion has been attributed to brand differentiation (Pan, Ratchford, and Shankar 2002; Smith and Brynjolfsson 2001), consumers' heterogeneity in brand loyalty (Narasimhan 1988; Raju, Srinivasan, and Lal 1990), and inertia in consumer choice (Haruvy and Popkowski Leszczyc 2010). However, since our focus is on price dispersion of homogeneous products, we abstract away from these factors in our analytical model.

Price dispersion for homogeneous products has been primarily attributed to consumer search costs (Stigler 1961; Carlson and McAfee 1983; Burdett and Judd 1983). However, empirical studies reported that price dispersion persists despite "zero" search costs online for a wide range of products, including books and CDs (e.g., Bailey 1998; Brynjolfsson and Smith 2000), airline tickets (e.g., Chellappa, Sin, and Siddarth 2011; Clemons, Hann, and Hitt 2002), and may even be higher in online markets than in offline markets (e.g., Ancarani and Shankar 2004; Bailey 1998; Brynjolfsson and Smith 2000; Chellappa, Sin, and Siddarth 2011; Clay, Krishnan, and Wolff 2001). Therefore, research has tried to identify alternative drivers of price dispersion.

Besides search costs, price dispersion may also be due to the distinction between posted prices and transaction prices. Zhao, Zhao, and Deng (2015) found that online transaction prices have lower price dispersion than list prices for luxury imported handbags sold on Taobao.com. Ghose and Yao (2011) reported that price dispersion is higher offline than online for transaction prices, of U.S. government procurement (B2B market).

[1] Researchers have found that 73% of U.S. consumers searched for information online, after which they purchased the product offline (PricewaterhouseCoopers 2015).

[2] In support of this assumption, a number of studies have reported that dual channel retailers tend to charge identical prices in their online and offline stores (Cavallo 2017; Wolk and Ebling 2010). Cavallo (2017) collected data of 56 dual channel retailers in 10 different countries and reported that 72% priced products similarly online and offline.

Chellappa, Sin, and Siddarth (2011) found that online transaction and list prices for domestic air travel in the U.S. are more dispersed than offline transaction and list prices. Hence, while price dispersion may be lower when using transaction prices, the impact of this measure on the difference between online and offline price dispersion is less clear.

In addition, geographic location may influence price dispersion. Geographic locations of offline retailers have been shown to influence travel cost and price dispersion offline (Choi and Choi 2014), and consumers' choice of purchasing online or offline (Forman, Ghose, and Goldfarb 2009). Location is expected to have a greater influence on offline price dispersion, given that travel costs are positive offline but (almost) zero online.

Hence, although previous research identified different drivers that influence price dispersion, the existing studies do not provide sufficient explanations for the greater online versus offline price dispersion for homogeneous products as documented by empirical studies. This research fills this gap by focusing on investigating and quantifying two important factors that influence price dispersion between online and offline markets: retailer type and shopping risk. The review in the next two sections highlights the unique contributions made by this research.

### *Retailer Type*

Recent trends towards multi-channel and omni-channel retailing have resulted in a more competitive market environment with a greater number of retailers competing both online and offline (e.g., Verhoef, Kannan, Inman, 2015), which directly influences price competition and price dispersion in online and offline markets. Cao and Li (2015) found that cross-channel integration has a positive effect on sales. Yurova et al. (2017) studied the importance of adaptive selling techniques in omni-channel retailing, and Ailawadi and Farris (2017) identified important questions for multi- and omni-channel marketers to address. Finally research has studied the impact of channel expansion (i.e., single channel retailers becoming dual channel retailers) on sales or profitability (Avery et al. 2012; Pauwels and Neslin 2015; Wang and Goldfarb 2016). Therefore, the impact of retailer type on retailer pricing strategies is of great importance for the investigation of market-level price dispersion.

A significant amount of empirical research has identified online versus offline retailer type as an important indicator of price dispersion. Studies have compared price dispersion between pure online retailers and pure offline retailers (e.g., Brynjolfsson and Smith 2000; McDonald and Wren 2017) and between pure online retailers and dual channel retailers (e.g., Pan, Ratchford, and Shankar 2002; Pan, Shankar, and Ratchford 2003; Tang and Xing 2001).

Similarly, analytical models have focused on price dispersion between different retailer types, but those analyses limited their studies to a single market (online or offline), or limited it to just two retailer types (pure online and pure offline retailers) (Baye and Morgan 2001; Iyer and Pazgal 2003). We contribute to this literature by incorporating three different retailer types. This inclusion is important given that our data collection, provided in Appendix A Table A1 shows that price dispersion is different across retailer types online (pure online retailers vs. dual channel retailers) and offline (pure offline retailers vs. dual channel retailers). In addition, we include in our analytical model the potentially different number of retailers within each type, which are expected to influence price competition and price dispersion at the market level. As a result, we provide a more accurate reflection of the competitive retail landscape.

### *Shopping Risk*

Shopping risk has been identified as an important factor causing reduced growth in online shopping (Al-Matarneh 2016; Egeln and Joseph 2012; Eggert 2006). Examples of shopping risk include potential financial risk owing to fraud (e.g., sellers fail to deliver an item after receiving payment, or provide a misleading product description), and privacy and security risks.[3] The general consensus of previous research is that the perceived risk associated with online shopping negatively influences online purchase behavior (Al-Matarneh 2016; Dai, Forsythe, and Kwon 2014; Forsythe and Shi 2003; Lal and Sarvary 1999).

Based on the previous literature we focus on transaction-specific shopping risk (e.g., financial risk due to potential fraud, privacy and security risk), which is expected to vary with retailer types. Purchasing from pure online retailers is generally considered to be riskier (Chatterjee and Kumar 2017; Donthu and Garcia 1999), especially when compared to purchasing from pure offline retailers, as shopping risk is greater online than offline (Bhatnagar and Ghose 2004). Shopping from a dual channel retailer is less risky than purchasing from a pure online retailer, as the offline presence of the dual channel retailer helps to reduce many of the above-mentioned uncertainties. Purchasing from an online store of a dual channel retailer is generally considered to be riskier than purchasing from a pure offline retailer, while the risk is similar when purchasing from an offline store of a dual channel retailer. Although consumers can search at offline stores of dual channel retailers and buy online, this practice does not overcome the transaction-specific shopping risks (e.g., privacy and security concerns).[4]

We incorporate these different risk levels for shopping at different retailer types in our model to analyze and compare online versus offline price dispersion. While previous studies have discussed the importance of shopping risk, they tend to only consider consumers' risk attitude towards online purchasing (e.g. Lal and Sarvary 1999; Loginova 2009). To our best knowledge, there are no prior studies which looked at how between-market price dispersion is driven by consumers' shopping risk.

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[3] A major concern is online theft of personal and credit card information, which has resulted in fraudulent online payments. In 2014, the cost of fraud reached $32 billion, a 38% increase over 2013 (LexisNexis Study 2014). Also, information privacy is a major concern to the majority of American adults (Jesdanun 2008).

[4] Retailers can use different strategies to reduce shopping risk, including, showrooming. While these strategies reduce product-specific shopping risk, they do not eliminate transaction-specific shopping risk, which is the focus of this research.

## Model

We propose a model that includes retailers' pricing decisions and consumers' price search and product purchase. Consumers are assumed to know the price distribution across retailer types (and across online and offline markets) resulting from retailers' equilibrium pricing strategies, but they have to search to determine the price at specific retailers. We first introduce the model setup on the supply (retailers) and the demand (consumers) sides of the marketplace, followed by the sequence of game moves and the information structure.

### *Retailers*

We model a retail market with three retailer types: pure offline, pure online, and dual channel retailers, where the number of retailers within each retailer type is denoted as $N_f$, $N_o$, $N_d$, respectively. As such, the offline market consists of $N_f$ pure offline retailers and offline stores of $N_d$ dual channel retailers, and the online market consists of $N_o$ pure online retailers and online stores of $N_d$ dual channel retailers.

### *Consumers*

The utility function $u$, for a consumer with unit demand for a homogeneous product, can be specified as $U = r - p - \theta\omega^2$, where $r$ is the reservation value of the product, which is the same for all consumers and is sufficiently high such that the entire market is served, $p$ is the price, and the last term represents the shopping risk, which is defined as the product of transaction uncertainty ($\omega^2$) associated with the retailer type where the consumer shops and that consumer's level of risk sensitivity ($\theta$). We denote $\omega_o^2$ as the transaction uncertainty related to shopping at pure online retailers, and $\omega_{d_o}^2$ as that related to shopping at online stores of dual channel retailers. Transaction uncertainty for pure offline retailers and offline stores of dual channel retailers are normalized to zero. Further, we assume that transaction uncertainty is higher for pure online retailers than for online stores of dual channel retailers owing to the presence of dual channel retailers' physical storefronts, that is, $\omega_o^2 > \omega_{d_o}^2$.

Consumers have different preferences or risk sensitivities associated with purchasing at different retailer types. Some consumers prefer the convenience of shopping online, some value the added security of dual channel retailers, and others desire the safety of visiting an offline retailer where they can inspect products.[5] Hence, we classify consumers into three segments according to their shopping preferences. The total mass of consumers in the marketplace is assumed to be one. A fraction $\alpha$ of consumers belongs to the "offline" segment, which perceives online shopping to be highly risky. This segment's risk sensitivity is assumed to be sufficiently large such that they only search and buy from offline retailers. A fraction $\beta$ of consumers belongs to the "online" segment, which searches and buys only via the internet. As the cost for online price search is negligible, online consumers are assumed to search all online retailers before purchase (Kuksov and Lin 2010). As they do not perceive online shopping to be risky, their risk sensitivity is set to 0. The remaining $1 - \alpha - \beta$ consumers belong to the "mixed" segment, which may search and buy either online or offline. They value the advantages of online and offline shopping differently, and have some risk aversion to shopping online. We assume risk sensitivity ($\theta$) for the mixed segment follows a uniform distribution over the range [0,1].

[5] A Nielsen survey reported that 16% of consumers with internet connection never purchased online, one-third of online consumers made most of their online purchases at pure online retailers and 20% preferred dual channel retailers (Nielsen 2010).

### *Pricing Game and Information Structure*

We study a two-period game where all retailer types in online and offline markets simultaneously set prices, followed by consumers' search and purchase decisions. A dual channel retailer is assumed to charge the same price in its online and offline stores in the main model in Section "Analysis and Solution of Main Model" (we relax this assumption in Section "Channel-Based Price Differentiation by Dual Channel Retailers"). The size and composition of consumer segments and retailer types (represented by parameters $\alpha$, $\beta$, $N_o$, $N_f$, $N_d$), are assumed to be common knowledge. So are the distributions of risk sensitivities for three consumer segments and the transaction uncertainties associated with different retailer types. We look for a symmetric Nash equilibrium for prices (the same type of retailers follow the same pricing strategy in equilibrium). In the model extension, we explore possible asymmetric pricing equilibria for the same type of retailers.

## Analysis and Solution of Main Model

We first solve consumers' optimal search and purchase decisions and then derive equilibrium pricing strategies for different retailer types. Finally, we compare online versus offline price dispersions.

Let us denote $F_f(.)$, $F_d(.)$, $F_o(.)$ as the cumulative density functions (CDF) for the equilibrium prices of pure offline, dual channel, and pure online retailers, and $f_f(.)$, $f_d(.)$, $f_o(.)$ *as* their probability density functions (PDF), respectively. Correspondingly, let $F_{on}(.)$, $F_{off}(.)$ be the CDFs for the equilibrium prices of online and offline market, and $f_{on}$, $f_{off}$ be their PDFs, respectively. The major notations in the paper are summarized in Table 1.

### *Consumers' Optimal Search and Purchase Decisions*

In this section we derive optimal search rules and purchase decisions for different consumer segments: online, offline and mixed consumers.

Table 1
Definition of major symbols used in the paper.

| | |
|---|---|
| Consumers | |
| $\alpha$, $\beta$, $1-\alpha-\beta$ | Segment sizes of the offline, online, and mixed consumers, respectively. |
| $c$ | Search cost: the cost of visiting an offline retailers |
| $r$ | Consumers' reservation value of the product |
| $\theta$ | Consumer's level of risk sensitivity |
| $\theta_{d_o d_f}$ | Level of risk sensitivity where mixed consumers are indifferent as to buying at an online or offline store of a dual channel retailer |
| $\theta_{od_o}$ | Level of risk sensitivity where mixed consumers are indifferent as to buying from a pure online retailer or an online store of a dual channel retailer |
| $\theta_{od_f}$ | Level of risk sensitivity where mixed consumers are indifferent as to buying from a pure online retailer or an offline store of a dual channel retailer |
| $U$ | Consumer's utility from product purchase |
| Retailers | |
| $N_f$, $N_o$, $N_d$ | Numbers of pure offline, pure online, and dual channel retailers, respectively |
| $\omega_0^2$,$\omega_{d_o}^2$ | Transaction uncertainties related to purchase at pure online and the online stores of dual channel retailers |
| $D_{st}$, $D_{mk}$ | Retail-type-specific and market-specific transaction uncertainty |
| $k$ | Probability of a pure offline retailer going online |
| $c_e$ | Cost for a pure offline retailer to enter the online market |
| Prices and price distributions | |
| $p*$ | Threshold price for an offline consumer to stop searching. |
| $\underline{p}_{off}$ | Lower bound of equilibrium price distribution in the offline market |
| $\underline{p}_d$,$\underline{p}_o$ | Lowest prices charged by dual channel, and pure online retailers in equilibrium |
| $F_f(.)$, $F_o(.)$, $F_d(.)$ | CDFs for pure offline, pure online and dual channel retailers' equilibrium prices. |
| $f_f(.)$, $f_o(.)$, $f_d(.)$ | PDFs for pure offline, pure online and dual channel retailers' equilibrium prices. |
| $F_{on}$, $F_{off}$ | PDFs for equilibrium price distribution in the online and offline markets |
| $f_{on}$, $f_{off}$ | PDFs for equilibrium price distribution in the online and offline markets |
| $\sigma_{on}^2$, $\sigma_{off}^2$ | Variances of equilibrium price distributions in the online and offline markets |

*Online Consumers*

As there is no cost for online price search, they search all online retailers before buying from the online retailer, which charges the lowest price.

*Offline Consumers*

We assume that an offline consumer's price search is finite, under full information, and without recall.[6] Search is *finite* because the number of retailers is fixed. *Full information* implies that consumers know the price distributions across different retailer types and for online and offline markets before they search. *Search without recall* means that consumers do not recall prices of previously visited retailers. Under these assumptions, the search rule can be described as follows: An offline consumer starts searching by randomly choosing an offline retailer to visit, and after observing the price she determines whether to continue searching. If the utility of further search is not higher than that of no additional search, she will purchase now, otherwise she will continue to search. This trade-off is specified as: $r - c - \int_p^{\overline{p}_{off}} pf_{off}(x)dx - \int_{\underline{p}_{off}}^{p} xf_{off}(x)dx \leq r - p$, where $\underline{p}_{off}$ and $\overline{p}_{off}$ are the lowest and highest equilibrium prices in the offline market, $c$ is the additional search cost and the left side of the inequality is the offline consumer's expected utility of further search. This expression can be restated as the trade-off between the cost of additional search ($c$) and the expected benefit from additional search ($p - \left(\int_p^{\overline{p}_{off}} pf_{off}(x)dx + \int_{\underline{p}_{off}}^{p} xf_{off}(x)dx\right)$). An offline consumer will purchase at the current retailer and pay price $p$ if the price $x$ at the next retailer (plus the cost of search) is higher than the price at the current retailer.[7] Otherwise, the consumer will purchase at the next retailer and pay price $x$ (this is represented by the third term in the above expression of the benefit from search).

Equating the cost to the benefit of additional search yields the **threshold price**, $p*$, which satisfies $c = \int_{\underline{p}_{off}}^{p^*} F_{off}(x)dx$.[8] This

[6] Our search model is based on work by DeGroot 1970, p. 646; Weitzman 1979, pp 331–335, though different from our model they assume search with recall. The threshold price we derived for an offline consumer to be indifferent between buying now and continuing search is similar to the reservation price in Weitzman's paper (after filtering out the discount effect and adjusting for the difference between recall and no recall). Our model is also similar to the classic model by Stahl (1989), but differs as (1) our model is without recall, and (2) we model two markets (online and offline) with three retailer types and three consumer segments, compared to Stahl's model with a single market with $n$ identical firms and two segments.

[7] Because search is sequential and without recall consumers will not consider prices at previously visited retailers. When consumers make the trade-off to search or not, they do consider the possibility of returning to the previous retailer and buy there if the price at the next retailer is higher. That is why $p$ appears in the first integral of the expression representing the expected benefit of additional search.

[8] It should be noted that (1) $p*$ is implicitly defined as a function of search cost and the offline market price distribution with lower bound is $\underline{p}_{off}$; (2) $p*$ is not a function of the number of retailers searched by an offline consumer (though it is related to the total number of retailers in the market through the equilibrium price distribution).

is the price where an offline consumer is indifferent between buying now and continuing to search. We summarize the optimal search rules and purchasing behaviors for the online and offline consumer segments as follows:

**Lemma 1.** *An online consumer searches all retailers in the online market and buys from the retailer that charges the lowest price. An offline consumer searches sequentially in the offline market for a lower price and stops searching and purchases when the price charged at the current retailer is equal to or less than the threshold price $p^*$, which satisfies $c = \int_{p_{off}}^{p^*} F_{off}(x)dx$.*

*Mixed Consumers*

*Mixed consumers* decide whether to search and buy either online or offline at a retailer which provides them the highest utility. Therefore, we first determine the utilities for a mixed consumer to shop at the three different retailer types, and next calculate the point of indifference between the shopping options. These determine the optimal search rule and purchase behavior of mixed consumers.

The utility for a mixed consumer with risk sensitivity ($\theta$) buying from a pure online retailer is $U_o = r - \underline{p}_o - \theta\omega_0^2$, and the utility for buying from the online or offline store of a dual channel retailer is $U_{d_o} = r - \underline{p}_d - \theta\omega_{d_o}^2$ or $U_{d_f} = r - \underline{p}_d - c$, respectively, where $\underline{p}_o$ and $\underline{p}_d$ denote the lowest prices charged by pure online and dual channel retailers. Based on these utility functions, we can specify the following indifference points: $\theta_{d_o d_f} = c/\omega_{d_o}^2$, the risk sensitivity with which mixed consumers are indifferent as to buying at the online or offline store of a dual channel retailer; $\theta_{od_o} = (\underline{p}_d - \underline{p}_o)/(\omega_o^2 - \omega_{d_o}^2)$, the risk sensitivity with which mixed consumers are indifferent as to buying from a pure online retailer or the online store of a dual channel retailer; $\theta_{od_f} = (\underline{p}_d - \underline{p}_o + c)/\omega_o^2$, the risk sensitivity with which mixed consumers are indifferent as to buying from a pure online retailer or the offline store of a dual channel retailer. The relative magnitude of $\theta_{d_o d_f}$ versus $\theta_{od_o}$ can be interpreted as the degree to which the existence of a physical storefront increases consumers' confidence of shopping online. $\theta_{od_o}$ is negatively correlated with the retailer-type-specific risk $D_{st}$, where $D_{st}$ is the difference in transaction uncertainty with or without a physical storefront ($D_{st} = \omega_o^2 - \omega_{d_o}^2$). $\theta_{d_o d_f}$ is negatively correlated with market-specific risk $D_{mk}$, where $D_{mk}$ is the difference in transaction uncertainty between online and offline markets ($D_{mk} = \omega_{d_o}^2$). Lemma 2 summarizes the optimal search and purchase behavior of mixed consumers (see Online Appendix for proof).

**Lemma 2.** *The optimal search and purchase behavior of a mixed consumer is as follows: she first searches online to find the lowest price ($\underline{p}_d$) charged by dual channel retailers.*

1. *If this price is not higher than the threshold price (specified in* Lemma 1*), she purchases online.*

*a) When the existence of a physical storefront (for a dual channel retailer) does not substantially increase a consumer's confidence (i.e.,$\theta_{od_o} > \theta_{d_o d_f}$), a mixed consumer with low risk sensitivity (i.e., in $[0, \theta_{od_f})$) buys from a pure online retailer and a consumer with high risk sensitivity (i.e., in $(\theta_{od_f}, 1]$) buys from the offline store of a dual channel retailer which charges $\underline{p}_d$.*

*b) When the existence of a physical storefront does substantially increase a consumer's confidence (i.e., $\theta_{od_o} \le \theta_{d_o d_f}$), a mixed consumer with low risk sensitivity (i.e., in $[0, \theta_{od_o})$)* buys from a pure online retailer, a consumer with medium risk sensitivity (i.e., in $(\theta_{od_o}, \theta_{d_o d_f}]$) *buys online from a dual channel retailer charging $\underline{p}_d$, and a consumer with high risk sensitivity (i.e., in $(\theta_{d_o d_f}, 1]$) buys from the offline store of a dual channel retailer charging $\underline{p}_d$.*

2. *If this price is higher than the threshold price, she purchases online from a pure online retailers or offline from a pure offline retailer. When buying from pure offline retailers, she searches sequentially for a lower price and purchases when the price at the current retailer is no higher than $p_f*$*, which satisfies $c = \int_{\underline{p}_f}^{p_f^*} F_{off}(x)dx$.

*Equilibrium Pricing Strategies for Different Retailer Types*

The degree of market level price dispersion is directly linked to the prices set by different retailers. In this section we derive the equilibrium pricing strategies for the three different retailer types (summarized in Proposition 1), which allows us to study the key research issue: the price dispersion between online and offline markets.

*Pure Online Retailers*

Consumers, who consider buying from pure online retailers, buy from the one charging the lowest price. This practice implies that pure online retailers are in a Bertrand competition, resulting in an equilibrium in which they charge a price equal to their marginal costs which are assumed to be zero in our main model. Consequently, the CDF for the equilibrium price of pure online retailers can be written as: $F_o(p) = \begin{cases} 1 & p = 0 \\ 0 & p > 0 \end{cases}$.

*Pure Offline Retailers*

We only consider the case where $p_{\text{-}d} \le p^*$, since the scenario described in Part 2 of Lemma 2 does not occur in equilibrium.[9] We prove that pure offline retailers set prices at $p^*$. Suppose that pure offline retailers set their price at $p'$, we need to consider the following three cases: (a) If price is higher than the lowest price charged by dual channel retailers ($p^* \ge p' > \underline{p}_d$), then according to Part 1 of Lemma 2, only offline consumers buy from them. Then, using the optimal search rule derived for offline consumers, it is more profitable for pure offline retailers to set the price equal to the threshold price, that is, $p' = p^*$. (b) If $p'$ is

[9] We prove here that the scenario described in Part 2 of Lemma 2 does not occur in equilibrium. That is, in equilibrium the lowest price charged by dual channel retailers ($\underline{p}_d$) is not higher than $p*$. This is proved through contradiction: if $\underline{p}_d > p*$, no consumers buy from dual channel retailers. Mixed consumers buy either online from pure online retailers or offline from pure offline retailers. In addition, offline consumers will continue price search when $\underline{p}_d$ is higher than the threshold price $p*$ according to the optimal search rule reported in Lemma 1. Finally, online consumers purchase from pure online retailers. Hence, dual channel retailers will not charge price $\underline{p}_d > p*$ in equilibrium, as it results in no demand.

not higher than the lowest price charged by dual channel retailers ($p' \leq \underline{p}_d \leq p^*$), it is also consistent with Part 1 of Lemma 2, and we can derive the same result as for case (a); that is, it is more profitable for pure offline retailers to set the price equal to the threshold price: $p^*$. (c) Pure offline retailers will not set $p'$ above the threshold price as this results in zero demand. Therefore, we obtain the result: $p^*$. Consequently, the CDF for the equilibrium prices of pure offline retailers is: $F_f(p) = \begin{cases} 0 & p < p^* \\ 1 & p \geq p^* \end{cases}$.

*Dual Channel Retailers*

Although dual channel retailers have an opportunity to compete for all three consumer segments, they choose to set their prices focusing on attracting mixed and offline consumers, because if they want to attract online consumers, they have to set prices equal to marginal cost, like pure online retailers, resulting in zero profit.

**Lemma 3.** *In equilibrium, (1) When the existence of a physical storefront substantially increases a consumer's confidence (i.e., $\theta_{od_o} \leq \theta_{d_o d_f}$), a dual channel retailer sets price following a mixed strategy in $[p_{\text{-}d}, p^*]$ with CDF* $F_d(p) = 1 - \left[\frac{\alpha}{(1-\alpha-\beta)(N_f+N_d)\left(1-\underline{p}_d/(\omega_0^2-\omega_{do}^2)\right)}\left(\frac{p^*}{p}-1\right)\right]^{\frac{1}{N_d-1}}$ *and* $\underline{p}_d = \frac{\left[1+\frac{\alpha}{(N_f+N_d)(1-\alpha-\beta)}\right]-\sqrt{\left[1+\frac{\alpha}{(N_f+N_d)(1-\alpha-\beta)}\right]^2-\frac{4\alpha p^*}{(N_f+N_d)(\omega_o^2-\omega_{do}^2)(1-\alpha-\beta)}}}{2/\left(\omega_o^2-\omega_{do}^2\right)}$.
*(2) When the existence of a physical storefront does not substantially increases consumers' confidence (i.e.,$\theta_{od_o} > \theta_{d_o d_f}$), a dual channel retailer sets price using a mixed strategy over $[p_{\text{-}d}, p^*]$ with CDF* $F_d(p) = 1 - \left[\frac{\alpha}{(1-\alpha-\beta)(N_f+N_d)(1-(\underline{p}_d+c)/\omega_o^2)}\left(\frac{p*}{p}-1\right)\right]^{\frac{1}{N_d-1}}$ *and* $\underline{p}_d = \frac{\left[1-\frac{c}{\omega_o^2}+\frac{\alpha}{(N_f+N_d)(1-\alpha-\beta)}\right]-\sqrt{\left[1-\frac{c}{\omega_o^2}+\frac{\alpha}{(N_f+N_d)(1-\alpha-\beta)}\right]^2-\frac{4\alpha p^*}{(N_f+N_d)\omega_o^2(1-\alpha-\beta)}}}{2/\omega_o^2}$.
*(See Online Appendix for proof.)*

Comparing equilibrium pricing strategies across different retailer types, we see that the lower bound of dual channel retailers' prices is higher than that of pure online retailers. This difference is the premium charged by dual channel retailers to mixed consumers, who prefer the reduced shopping risk owing to the offline presence of dual channel retailers. The upper bound of dual channel retailers' prices equals the equilibrium price of pure offline retailer. Dual channel retailers never set price above $p^*$, since this would result in a loss of sales from both mixed and offline segments. (Online Supplement A shows the steps to derive $p^*$ and $\underline{p}_d$). Additionally, in the offline market, as pure offline retailers set price at $p^*$, and $p_{\text{-}d} \leq p^*$, the lowest offline price equals the lowest price charged by offline stores of dual channel retailers (i.e., $\underline{p}_{off} = \underline{p}_d$). The pricing strategies for the different retailer types are summarized in Proposition 1.

**Proposition 1.** *In equilibrium (1) pure online retailers set price at marginal cost, (2) pure offline retailers set price equal to the threshold price ($p^*$ in* Lemma 1*), and (3) dual channel retailers charge mixed prices (*Lemma 3*).*

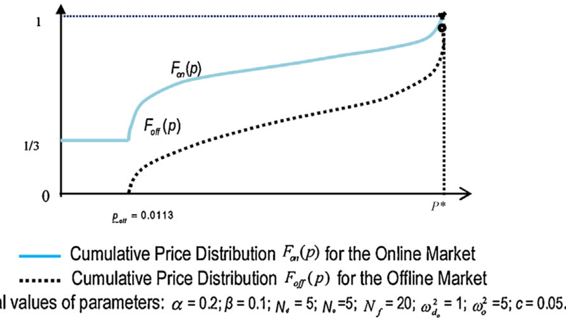



Fig. 1. Cumulative price distributions in the online and offline markets[a].

The equilibrium prices reported in Proposition 1 differ depending on the extent to which a physical storefront can reduce consumer's perceived shopping risk. Furthermore, as shown in the proof of Lemmas 2 and 3, even when the existence of a physical storefront does not increase consumers' confidence sufficiently, and demand from the online market is zero, dual channel retailers still benefit from an online presence for the sole purpose of information dissemination.

*Measuring Online versus Offline Price Dispersion*

We summarize in Lemma 4 the equilibrium price distributions at the market level based on the equilibrium pricing distributions for the three retailer types derived in Section "Equilibrium Pricing Strategies for Different Retailer Types".

**Lemma 4.** *In equilibrium, the price distribution in the offline market can be described by the CDF,* $F_{off}(p) = \begin{cases} N_d F_d(p)/(N_f+N_d) & \underline{p}_d \leq p < p^* \\ 1 & p = p^* \end{cases}$*, and the price distribution in the online market can be described by the CDF,* $F_{on}(p) = \begin{cases} N_o/(N_o+N_d) & 0 \leq p \leq \underline{p}_d \\ N_o/(N_o+N_d) + N_d F_d(p)/(N_o+N_d) & \underline{p}_d \leq p \leq p^* \end{cases}$.
*(See Online Appendix for proof.)*

Fig. 1 illustrates the cumulative price distributions in the online and offline markets as described in Lemma 4. The offline price distribution is continuous with a jump at $p*$, which is the equilibrium price set by dual channel retailers with a positive probability, and by all pure offline retailers. Further algebra shows that this mass point gets larger as the number of pure offline retailers ($N_f$) increases, consistent with the experimental finding in Baye and Morgan (2004). The online price distribution has a mass point at 0 with probability $N_o/(N_o+N_d)$, which is the equilibrium price charged by all pure online retailers. The mass point $p = 0$ is located at the lower boundary of the online price distribution, and the mass point $p = p^*$ is located at the upper boundary of the offline price distribution. These two mass points influence the degree of price dispersion of the corresponding market-level price distribution: the larger weight on the mass point, the more dispersed is the market level price distribution. The weight of the mass point in each market-level price distribution can be thought of as representing the "counter" force for price dispersion in the relevant market.

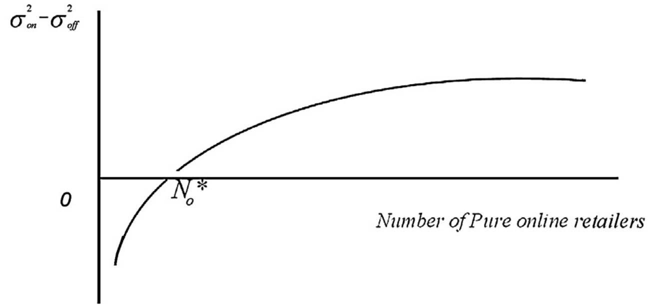
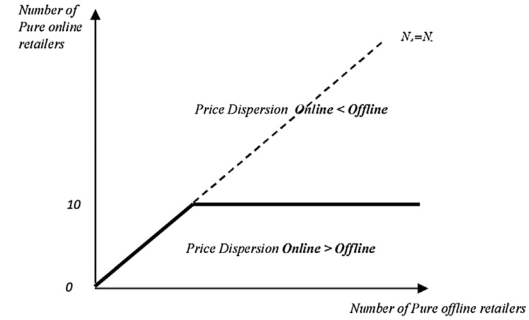



Fig. 2. Comparison of online versus offline price dispersion for different numbers of pure online retailers.




[a]Numerical values used for parameters: $\alpha = 0.2$; $\beta = 0.1$; $N_d = 8$; $\omega_{d_o}^2 = 1.5$; $\omega_o^2 = 3$; $c = 0.05$.

Fig. 3. Conditions where online price dispersion is larger/smaller than offline dispersion[a].

We next derive online and offline price dispersions based on the variance of the equilibrium price distributions. The most commonly used measures of price dispersion are the range and standard deviation/variance of a price distribution (Ancarani and Shankar 2004; Brynjolfsson and Smith 2000). Compared to the price range, which is based on only the highest and lowest price points and thus more susceptible to outliers, the computation of variance involves all the different prices within the distribution, and hence is a more comprehensive measure. We therefore compute and compare the variance of the equilibrium price distributions between online ($\sigma_{on}^2$) and offline ($\sigma_{off}^2$) markets under the following condition:

$$0 < c < N_d p^* / \left(2(N_d + N_f)\right) . \quad (1)$$

This condition ensures that search cost ($c$) is neither prohibitively high, so that no consumers consider searching offline, nor too low, so that everyone searches freely offline. The comparison of online versus offline price dispersion yields Proposition 2, which shows the conditions when the price dispersion is greater online than offline (see Online Appendix for proof).

**Proposition 2.** *Price dispersion is greater in the online than in the offline market (for any positive number of dual channel retailers) as long as pure online retailers outnumber pure offline retailers ($N_o > N_f$). When pure offline retailers outnumber pure online retailers, and the number of pure online retailers is less than threshold $N_o^*$, prices are more dispersed offline, otherwise prices are more dispersed online.*

To illustrate the findings in Proposition 2, Fig. 2 shows how the difference between online and offline price dispersion changes in the number of pure online retailers. It shows that as the number of pure online retailers increases, online prices are more dispersed. We find regions where online price dispersion is greater than offline price dispersion (see Fig. 3). When there are fewer pure online retailers than pure offline retailers, and the number of pure online retailers is less than threshold ($N_o^*$), price dispersion is greater offline; otherwise, price dispersion is greater online.

Next we want to further analyze and quantify the impact of the two factors (retailer type and shopping risk) on the difference of price dispersion between online and offline markets. The next section focuses on studying the impact form changing the number of stores of different retailer types. The subsequent section looks at the impact of shopping risk, through separately studying the consumer risk sensitivity component and the transaction uncertainty component.

### The Impact of Retailer type

The numbers of different retailer types are exogenously set in the main model. In this subsection, we allow retailer type to be part of retailers' decisions. That is, the number of dual channel retailers is the result of the decision for either pure online retailers to enter the offline market or pure offline retailers to enter the online market. The market entry decision is a trade-off between the cost and the benefit of entry, resulting in one out of four scenarios: (1) neither pure online nor pure offline retailers want to enter the other market due to high entry costs, (2) both retailer types enter the other market when entry costs are sufficiently low, (3) only pure online retailers enter offline, or (4) only pure offline retailers enter online. Below we discuss the most common one: scenario (4) in detail.

Let the number of pure online retailers, pure offline retailers, and dual channel retailers be $N_o{}'$, $N_f{}'$, and zero, respectively, prior to the pure offline retailers' decision on whether to enter the online market. Due to the pure offline retailers' online entry decision, the number of dual channel retailers will change. The probability for a pure offline retailer to enter online is denoted as $k$, then after entry, the expected number of dual channel retailers and pure offline retailers becomes $N_f{}'k$ and $N_f{}'(1-k)$, respectively. All other settings and assumptions are the same as in the main model.

The pricing strategies of pure online retailers and pure offline retailers can be derived in the same way as in the main model. However, dual channel retailers have additional considerations when setting prices: (1) the cost of online entry, denoted as $c_e$; (2) the probability of no dual channel retailers in the online market: $(1-k)^{N_f{}'}$; (3) the probability that a dual channel retailer charges the lowest price among all dual channel retailers: $\sum_{j=0}^{N_f{}'-1} \binom{N_f{}'-1}{j} k^j (1-k)^{N_f{}'-j-1} [1-F_d(p)]^j$, which can be simplified to $[1-kF_d(p)]^{N_f{}'-1}$ using the Binomial Theorem. We derive the equilibrium entry decision of pure offline retailers and report in Lemma 5 below.

**Lemma 5.** *In equilibrium, (1) When the existence of a physical storefront does substantially increase a consumer's online shopping confidence (i.e.,* $\theta_{od_o} \leq \theta_{d_o d_f}$*), the probability of a pure offline retailer entering the online market (k) satisfies:* $(1-k)^{N_f'} = \frac{\underline{p}_d N_f'(1-\frac{\underline{p}_d}{\omega_o^2-\omega_{d_o}^2})}{p^*(1-\frac{p^*+c}{\omega_o^2})} - \frac{c_e N_f' + \alpha(p^* - \underline{p}_d)}{p*(1-\beta-\alpha)(1-\frac{p^*+c}{\omega_o^2})}$*; (2) When the existence of a physical storefront does not substantially increase a consumer's confidence (i.e.,* $\theta_{od_o} > \theta_{d_o d_f}$*), the probability of a pure offline retailer entering the online market (k) satisfies:* $(1-k)^{N_f'} = \frac{\underline{p}_d N_f'(1-\frac{\underline{p}_d+c}{\omega_o^2})}{p^*(1-\frac{p^*+c}{\omega_o^2})} - \frac{c_e N_f' + \alpha(p^* - \underline{p}_d)}{p*(1-\alpha-\beta)(1-\frac{p^*+c}{\omega_o^2})}$ *(See Online Appendix for proof and the full expression for* $\underline{p}_d$*).*

The difference in online versus offline price dispersion depends on the ratio of pure online retailers to pure offline retailers. In particular, if pure online retailers outnumber pure offline retailers post entry ($N_o' > N_f'(1-k)$), prices are more dispersed online than offline. If pure offline retailers outnumber pure online retailers after entry ($N_o' \leq N_f'(1-k)$), there exists a unique threshold $N_o'^*$, such that when $N_o' \leq N_o'*$, prices are more dispersed offline than online; otherwise prices are more dispersed online than offline. We summarize the above in Proposition 3.

**Proposition 3.** *The pattern of online versus offline price dispersion qualitatively holds for endogenously determined retailer types (as long as, the number of pure online retailers is larger than a certain threshold).*

### *The Impact of Shopping Risk*

Shopping risk, defined as $\theta\omega^2$, is the perceived risk for a consumer with risk sensitivity $\theta$ when shopping at a retailer type with transaction uncertainty $\omega^2$. To have a comprehensive understanding of the impact of shopping risk on price dispersion, we decompose it into two components and analyze them separately.

#### *Impact of transaction uncertainty*

We focus on the case where mixed consumers' risk sensitivities are heterogeneous and $\theta_{od_o} \leq \theta_{d_o d_f}$ (the case in Part 1 of Lemma 3). First consider the extreme situation where there is no transaction uncertainty at any retailer type. It is then straightforward to see that both online and mixed consumers will purchase from pure online retailers, as they charge the lowest price. As a result, dual channel retailers do not consider competing for mixed consumers and will instead focus only on offline consumers, as their profits are maximized by charging the same price as pure offline retailers. Under this scenario, we find positive price dispersion online (as online market prices by pure online retailers are zero and prices by dual channel retailers are $p^*$), but no price dispersion offline (as in the offline market both dual channel retailers and pure offline retailers charge the same price $p^*$).

Transaction uncertainties can be further decomposed into (1) a *retail-type-specific* part, $D_{st}$, where $D_{st} = \omega_o^2 - \omega_{d_o}^2$, which measures the difference in transaction uncertainty of a retailer with or without a physical storefront and is related to such factors as delivery time, ability to return merchandise locally, after-sale service quality, and potential fraud; and (2) a *market-specific* part, $D_{mk}$, where $D_{mk} = \omega_{d_o}^2$ (as transaction uncertainty for pure offline retailers or the offline stores of dual channel retailers is normalized to zero), which measures the difference in transaction uncertainty between online and offline markets and is related to such factors as privacy and security concerns. Proposition 4 summarizes how changes in these two components of transaction uncertainty influence online versus offline price dispersion.

**Proposition 4.** *When shopping at pure online retailers is perceived to be riskier than shopping at online stores of dual channel retailers (i.e., retailer-type-specific uncertainty* $D_{st} > 0$*), the difference in online versus offline price dispersion increases as retailer-type-specific uncertainty (*$D_{st}$*) decreases, and vice versa. When shopping at pure online retailers is perceived to be no different from shopping at online stores of dual channel retailers (i.e., retailer-type-specific uncertainty* $D_{st} = 0$*), the difference in online versus offline price dispersion increases as market-specific uncertainty (*$D_{mk}$*) decreases, and vice versa. (See Online Appendix for proof)*

Proposition 4 implies that the retailer-type-specific uncertainty, $D_{st}$ has a primary influence on the difference in online versus offline price dispersion. The smaller $D_{st}$ is, the greater this difference will be, because a decrease in $D_{st}$ increases the perceived similarity between pure online retailers and online stores of dual channel retailers in terms of transaction uncertainty, resulting in more intensive competition online. Facing this situation, dual channel retailers can respond either by lowering prices and competing more aggressively online, or by charging higher prices and focusing on the offline market. Given that the latter option is more profitable, dual channel retailers will focus on the offline market. As a result, more retailers set prices at $p^*$, causing higher online and lower offline price dispersions.

The impact of the market-specific uncertainty $D_{mk}$ on online versus offline price dispersion is of secondary order. In particular, when $D_{st}$ is positive, $D_{mk}$ has no impact, since a decrease in $D_{mk}$ only causes some mixed consumers to shift their purchases from the offline to the online store of dual channel retailers, while the total demand for dual channel retailers remains the same. Therefore, dual channel retailers do not react to changes in $D_{mk}$. However, the impact of $D_{mk}$ is present when consumers perceive no difference in transaction uncertainty between pure online retailers and online stores of dual channel retailers ($D_{st}$ is zero). When $D_{st} = 0$, pure online retailers capture all online demand, forcing dual channel retailers to focus on the offline market (Dual channel retailers will not set their price at marginal cost as pure online retailers do, because that is less profitable). In equilibrium, dual channel retailers' pricing strategy causes prices to be concentrated on the upper boundary ($p^*$) of the online market price distribution, resulting in higher online and lower offline price dispersion. Consequently online price dispersion is greater relative to offline price dispersion. The above analysis suggests that pure online retailers can reduce shopping risk by becoming dual channel retailers and reducing retail-type-specific uncertainty by selling products both online and offline. For example, opening up a show-room, where consumers can see, touch, consult and return products, reduces shopping risk. Alternatively, pure online retailers can reduce market-specific uncertainty by investing in technology (e.g., making the internet more secure), although this is less effective since $D_{st}$ has a greater impact than $D_{mk}$ on the difference between online and offline market-level price dispersion,

### Impact of risk sensitivity

In this subsection, we analyze a model when mixed consumers' risk sensitivities are homogenous (i.e., $\theta$ is constant in [0,1]). Under this condition, the search behavior of mixed consumers remains the same as in the main model (Lemma 2). They first search online. If the lowest price among dual channel retailers $\underline{p}_d$ is less than $p*$, they will not search offline. Referring to those indifferent risk sensitivity levels specified in Lemma 2, we obtain: (1) mixed consumers, with risk sensitivities in the range $[0, \theta_{od_o})$, buy from a pure online retailer, (2) mixed consumers, with risk sensitivities in the range $(\theta_{od_o}, \theta_{d_od_f})$, buy from the online store of a dual channel retailer, (3) mixed consumers, with their risk sensitivities in the range $(\theta_{d_od_f}, 1]$, buy from the offline store of a dual channel retailer.

The first case above is similar to Part 2 of Lemma 3. The last two cases are similar to Part 1 in Lemma 3. As a result, we can follow the same derivation as for Proposition 2, and find that the nature of the difference in online versus offline price dispersion is unchanged, compared to the result in Proposition 2. This is summarized in Proposition 5.

**Proposition 5.** *When the risk sensitivities of mixed consumers (who may purchase either online or offline) are homogenous (i.e., $\theta$ is a constant in [0,1]), price dispersion is greater online than offline, given that pure online retailers sufficiently outnumber pure offline retailers.*

### Price Range as a Measure of Price Dispersion

Our main model used variance as a measure of price dispersion. In this section we use price range as an alternative measure for price dispersion in the online versus offline market to test the robustness of our finding in the main model.

Fig. 1 shows the price ranges for both online and offline markets. The price range online is $p^*$ ($p^*$ is the upper boundary of dual channel retailers' equilibrium prices, and zero is the equilibrium price charged by pure online retailers), while the price range offline is $p^* - p_{\text{-}d}$ ($p^*$ is the equilibrium price charged by pure offline retailers, and $\underline{p}_d$ is the lower boundary of dual channel retailers' equilibrium prices). Therefore the difference in online versus offline price dispersion is $\underline{p}_d$. Similar to the result from the main model (using variance as a dispersion measure), online price dispersion is greater than offline price dispersion when we use price range as the measurement.

## Extensions

We discussed in the Introduction section several key assumptions made in the stylized game theoretic model that we use to derive our main research findings reported in the last section. In this section, we extend our main model by relaxing those key assumptions to further demonstrate the robustness of our main findings, especially that price dispersion is greater online than offline.

### Geographic Location of Retailers

As the distance to a retailer tends to influence which offline retailer consumers will visit, we need additional assumptions about the locations of retailers and consumers in the offline market. In particular, we assume that both retailers' and consumers' locations are uniformly distributed in the offline market. We relax the assumption that search cost $c$ is identical and define it as the distance between the nearest retailer to a consumer's location. As consumers and retailers are uniformly distributed, $c$ is constant for each consumer.

The above modification does not change the search and purchase behavior of *online* and *mixed consumer segments*, as they can obtain price information online at no cost by assumption. However, it influences the search and purchase behavior of *offline consumers* because they do not know the price charged by retailers before visiting them (they know only the distribution of prices). Since the cost to visit an offline retailer increases with distance, a rational offline consumer will first visit the nearest retailer. Offline consumers apply the same stopping rule as in the main model (i.e., trade-off between the cost and benefit of additional search). The optimal search rule of offline consumers is the same as specified in Section "Consumers' Optimal Search and Purchase Decisions": $r - c - \int_{p}^{\overline{p}_{off}} pf_{off}(x)dx - \int_{\underline{p}_{off}}^{p} xf_{off}(x)dx \geq r - p$. A consumer stops searching and purchases when the expected utility from further search (LHS) is not higher than that from purchasing at the present retailer (RHS). Setting the LHS equal to the RHS, we obtain the threshold price $p*$, which satisfies $c = \int_{p_{-off}}^{p^*} F_{off}(x)dx$.

Pure online retailers' equilibrium pricing strategy remains the same, that is, price is set at marginal cost, since the demand for pure online retailers come from online and mixed consumers segments and those consumers' search and purchase behaviors are not affected by the geographically related offline search cost. However, the geographical location affects dual channel retailers' pricing strategies, as demand for dual channel retailers comes from mixed and offline consumers. The profit function of a dual channel retailer that sets price at $p$ is the same as in the main model: $\pi_d = \frac{p\alpha}{N_d+N_f} + p(1-\alpha-\beta)\left(1-\frac{p}{\omega_o^2-\omega_{d_o}^2}\right)[1-F_d(p)]^{N_d-1}$, except that the first term on the RHS—the expected profit from offline consumers—has a different meaning (since offline consumers first search the closest retailer, rather than starting with a random retailer). The uniform distributions for locations of both offline consumers and offline retailers ensure that demand from the offline consumer segment is $\alpha/(N_d + N_f)$ for offline stores of dual channel retailers, as the demand from offline consumers is equally divided among all physical stores, including all pure offline retailers and offline stores of dual channel retailers. As consumer demand remains unchanged, in equilibrium, the distribution of prices of dual channel retailers is the same as in the main model, and the lowest price charged by dual channel retailers ($\underline{p}_d$) is not higher than the threshold price ($p^*$), that is, $p_{\text{-}d} \le p^*$. It then follows from the same rationale as in the main model that in equilibrium pure offline retailers charge price $p^*$. Therefore, the pattern of online-versus-offline price dispersion remains the same.

### *Channel-Based Price Differentiation by Dual Channel Retailers*

We explore the case where dual channel retailers engage in channel-based price differentiation. We derive the indifference points of risk sensitivities, $\theta_{od_o} = \underline{p}_{d_o}/(\omega_o^2 - \omega_{d_o}^2)$, for mixed consumers who are indifferent as to shopping at a pure online retailer or at the online store of a dual channel retailer and $\theta_{d_od_f} = (\underline{p}_{d_f} - \underline{p}_{d_o}+\text{c})/\omega_{d_o}^2$ for those who are indifferent as to shopping at the online store or the offline store of a dual channel retailer, where $\underline{p}_{d_o}$, $\underline{p}_{d_f}$ are the lowest online and offline prices charged by dual channel retailers, respectively. Proposition 6 summarizes dual channel retailers' equilibrium pricing strategy when channel-based price differentiation is allowed.

**Proposition 6.** *When dual channel retailers are allowed to charge different prices online and offline, and the existence of a physical storefront: (a)* ***does not*** *substantially increase consumer confidence (i.e., $\theta_{od_o} > \theta_{d_od_f}$), dual channel retailers set the same prices in their online and offline stores. The pattern of online versus offline price dispersion is unchanged. (b)* **does** substantially increase consumer confidence *(i.e., $\theta_{od_o} \le \theta_{d_od_f}$), dual channel retailers set different prices in their online and offline stores. The online and offline price distributions of dual channel retailers have the same shape but have different levels. If pure online retailers outnumber pure offline retailers, prices are more dispersed online than offline. If pure offline retailers outnumber pure online retailers, prices remain more dispersed online than offline when the number of pure online retailers is larger than the threshold level. (See Online Appendix for proof).*

Interestingly, further analyses indicate that the difference in dual channel retailers' online versus offline equilibrium prices closely relates to the retailer-type-specific and market-specific transaction uncertainty. In particular, comparative statics show that $\partial\Delta_p/\partial D_{st} < 0$ and $\partial\Delta_p/\partial D_{mk} > 0$. The first comparative static reflects the negative relationship between dual channel retailers' online versus offline price difference and retailer-type-specific transaction uncertainty ($D_{st}$). When $D_{st}$ becomes smaller, the risk (and the required risk premium) between purchasing from pure online retailers and dual channel retailers reduces, and then dual channel retailers will charge lower online prices, which causes a greater difference between the dual channel retailers' online and offline prices.

The second comparative static denotes the positive relationship between price differences and market-specific transaction uncertainty ($D_{mk}$). A dual channel retailer's motivation to differentiate prices between channels (charging a higher price offline than online) largely depends on its ability to get mixed consumers to buy offline instead of online, obtaining higher profits per consumer. However, when $D_{mk}$ gets smaller, the market difference becomes smaller. Therefore, some mixed consumers who previously shopped offline will buy online. This shift reduces the dual channel retailer's incentive to differentiate between online and offline prices.

Following dual channel retailers' differentiated pricing reported in Proposition 6, we find that the pattern of online versus offline price dispersion is qualitatively consistent with that of the main model, as long as the number of dual channel retailers is sufficiently larger than the number of retailers operating in a single market (i.e., $(N_d)^2 > N_oN_f$). This common condition can be easily satisfied owing to the tremendous growth in dual channel retailers in recent years (Neslin and Shankar 2009).

### *Cost Difference within Retailer Type*

The differences in retailer locations, assortment, services, and so on may result in different wholesale prices and other operation costs among retailers, which may be a potential driver of price dispersion. The question we want to address in this section is whether the difference in marginal cost of operation between retailers will alter our findings on online versus offline price dispersion. To answer this question, we relax the assumption of symmetry in retailers of the same type, allowing marginal cost of operation to differ among pure online retailers.

We do not need to analyze the impact of different marginal cost of operation for pure offline retailers, because they will charge price $p^*$ even when their marginal costs of operation differ. This result follows directly from the "Diamond Paradox" (Diamond 1971): when search cost is positive, a unique equilibrium exists in which all firms set the monopoly price regardless of their marginal costs of operation and therefore consumers do not search. We consider different marginal cost of operation only for pure online retailers. We assume that marginal costs of operation for pure online retailers follow a uniform distribution in the range of $[\underline{mc}, \overline{mc}]$and then we re-analyze the equilibrium retailer pricing strategy and compare the resulting price dispersion between online and offline market. The finding is summarized in Proposition 7.

**Proposition 7.** *When marginal costs of operation of pure online retailers follow a uniform distribution over $[\underline{mc}, \overline{mc}]$, the difference in the online versus offline price dispersion is larger compared to that of our main model specified in* Proposition 2. *(See Online Appendix for proof.)*

Proposition 7 shows the robustness of our main finding. With heterogeneous marginal costs of operation, which result in different equilibrium prices among pure online retailers, price dispersion is still greater online, and even to a greater extent compared to the main model (with homogenous marginal cost of operation among different retailers).

*Using Transaction Prices to Study Market Price Dispersion*

In the main model we find conditions where dual channel retailers want to maintain an online presence even though there is no demand online. In this case, list prices (which do not lead to actual sales) may inflate online price dispersion, questioning the robustness of our main finding. In this section, we compare online versus offline price dispersion using transaction prices. For this extension we use range of price distribution as the measure of price dispersion. We consider two conditions:

Condition 1: The existence of a physical storefront does substantially increase a consumer's confidence (i.e., $\theta_{od_o} \leq \theta_{d_od_f}$), where the purchase behavior of mixed consumers with different risk sensitivities are specified in Lemma 2. We compare online versus offline price dispersion using transaction price, using the following two steps.

***Step 1: Derive online and offline price dispersion and compute the difference***. Online demand for pure online retailers consist of (1) a fraction $\beta$ of online consumers and (2) a faction of mixed consumers with risk sensitivity in the range of $[0, \theta_{od_o}))$. Both consumer segments pay a price equal to the marginal cost. A mixed consumer with a high level of risk sensitivity in the range of $((\theta_{d_od_f}, 1]$, buys from an offline store of a dual channel retailer charging $\underline{p}_d$. As a result, the equilibrium online price distribution (based on transaction prices) ranges from 0 to $\underline{p}_d$; thus price dispersion in the online market equals $\underline{p}_d$. In the offline market, mixed consumers with risk sensitivity in the range from $((\theta_{d_od_f}, 1]$ purchase from an offline store of a dual channel retailer, which charges price $\underline{p}_d$; while offline consumers purchase either from an offline store of a dual channel retailer or from a pure offline retailer that charges $p^*$. As a result, the equilibrium offline price distribution (based on transaction price) ranges from $p_d$ to $p^*$, thus price dispersion in the offline market equals $p^* - p_{\text{-}d}$ .Therefore the difference in price dispersion between the online and offline market equals $2p_{\text{-}d} - p^*$.

***Step 2: Determine the Sign of*** $(2\underline{p}_d - p*)$. From the proof of Lemma 3, we know that $p^* = p_{\text{-}d} + p_{\text{-}d}(1 - \alpha - \beta)(1 - \theta_{od_o})(N_d + N_f)/\alpha$. Substituting this expression of $p^*$ into $2p_{\text{-}d} - p^*$ results in $2p_{\text{-}d} - p^* = p_{\text{-}d}(1 - (1 - \alpha - \beta)(1 - \theta_{od_o})(N_d + N_f)/\alpha)$.

When $\alpha$ is sufficiently large and satisfies $p_{\text{-}d}\alpha/(N_d + N_f) \geq p\_d(1 - \theta_{od_o})(1 - \alpha - \beta)$, a dual channel retailer (which charges price $\underline{p}_d$) earns more profits from offline consumers than from mixed consumers, *online versus offline price dispersion* > 0. When $\alpha$ is sufficiently small and satisfies. $p_{\text{-}d}\alpha/(N_d + N_f) < p_{\text{-}d}(1 - \theta_{od_o})(1 - \alpha - \beta)$, a dual channel retailer earns less from offline consumers than from mixed consumers, *online versus offline price dispersion* < 0.

The intuition behind the online versus offline price dispersion (based on transaction prices) is as follows: Dual channel retailers can charge higher prices to offline consumers, who are less price-sensitive owing to a lack of online price information. As long as the offline segment is large enough, its size will compensate dual channel retailers' loss in profits in the online market. Therefore, whether online price dispersion is larger or smaller than offline price dispersion depends on the relative segment size of offline consumers.

Condition 2: The existence of a physical storefront does not substantially increase a consumer's confidence (i.e., $\theta_{od_o} > \theta_{d_od_f}$), where the purchase behavior of mixed consumers with different risk sensitivities are specified in Lemma 2.

In the *online market*, a fraction $\beta$ of online consumers purchase from pure online retailers and pay a price equal to marginal cost. Therefore the transaction price is 0, and online price dispersion equals 0. In the *offline market*, a proportion of mixed consumers with risk sensitivity ranging from $(\theta_{od_f}, 1]$ purchase from an offline store of a dual channel retailer, which charges price $\underline{p}_d$. Offline consumers purchase either from an offline store of a dual channel retailer or from a pure offline retailer, which charges $p^*$. As a result, the offline price dispersion becomes $p^* - p_{\text{-}d}$. The difference in online versus offline price dispersion equals $\underline{p}_d - p^*$, which is negative. We summarize these results in Proposition 8.

**Proposition 8.** *Transaction prices are more dispersed online than offline when the existence of a physical storefront does substantially increase a consumer's confidence (i.e.,* $\theta_{od_o} \leq \theta_{d_od_f}$*), and the segment of offline consumers is sufficiently large, satisfying* $\underline{p}_d\alpha/(N_d + N_f) \geq \underline{p}_d(1 - \theta_{od_o})(1 - \alpha - \beta)$. When *a physical storefront does not substantially reduce a consumer's confidence (i.e.,* $\theta_{od_o} > \theta_{d_od_f}$*), transaction prices are more dispersed offline than online. These results hold for any positive number of mixed consumers (*$1 - \alpha - \beta > 0$*).*

## Discussion and Conclusion

This paper investigates the effect of two key factors, retailer type and shopping risk, on online versus offline price dispersion and presents specific conditions under which price dispersion is higher online than offline. Results from our study shed light on an important question: why some empirical studies reported price dispersion to be higher online, despite that reduced online search cost should increase price competition.

Regarding the impact of retailer type on price dispersion between online and offline market, we find that an increase in the number of online retailers increases the difference in online versus offline price dispersion. This implies that retailers have more ability to price discriminate in online markets when there are more retailers in the online market. Hence, managers need not worry that increased online competition will reduce their ability to charge different prices for different channels. For the impact of shopping risk, we are able to report how a specific component of shopping risk affects the online versus offline price dispersion. In particular, the retailer-type-specific transaction uncertainty has a primary influence on online versus offline price dispersion. The existence of dual channel retailers reduces transaction uncertainty by allowing consumers to search online and buy offline, which suggests that dual channel retailers have a competitive advantage over single channel retailers. Greater online price dispersion happens when increased competition online leads dual channel retailers to raise prices and focus on demand from the offline market, where they can obtain higher profits. When the intensity level of online competition is high, dual channel retailers may simply maintain their online stores for the sole purpose of information dissemination, allowing consumers to search online but buy offline where shopping risk is lower, a form of webrooming frequently observed in practice (Adler 2014).

This paper contributes to the theoretical marketing literature by examining price dispersion in both online and offline markets, in contrast to previous analytical models that limited analysis of price dispersion to a single market. Furthermore, it thoroughly analyzes how retailer type and number of retailers, as well as shopping risk (transaction uncertainty vs. risk sensitivity), influence competing retailers' pricing strategies and the resulting difference in price dispersion between online and offline markets.

Our study has important managerial implications for dual channel retailers as the extent of online versus offline price dispersion, and the factors influencing this, provide guidance for critical retailer decisions including pricing strategies and channel choices. Our finding of greater price dispersion online than offline should remove the first hindrance for brick-and-mortar retailers who believe that expanding their presence online will limit their pricing options. On the contrary, we show that an increase in the number of online retailers actually increases the difference in price dispersion between online and offline markets. For example, in the travel industry an increase in the number of websites for hotel bookings and air travel has resulted in greater online price differences. Our model analyses suggest that both pure online retailers and pure offline retailers should consider adding either an offline or online presence. For pure offline retailers, becoming a dual channel retailer avoids losing offline consumers to dual channel retailers due to their lower prices, as dual channel retailers can attract a proportion of mixed consumers by charging a price no greater than the price of pure offline retailers. For pure online retailers, becoming a dual channel retailer extends their markets and improves profit margins, since they can charge a premium over the price set by pure online retailers, attracting mixed consumers who are willing to pay extra for the added security from a retailer's offline presence. These results give credence to the recent strategies used by pure online retailers such as Dell, which has also started to open offline stores.

Finally, our paper provides recommendations about marketing investments online. Dual channel retailers should make their online stores more attractive places for consumers to search for price information. While many online retailers (e.g., eBay, Amazon) are building mechanisms such as buyer ratings and consumer feedback to increase consumer trust, our analyses indicate that strategies that attempt to reduce online shopping risk may actually result in increased price dispersion online. Our analysis further suggests that dual channel retailers should retain their online presence even when there is no positive online demand, since an online presence increases offline demand by providing costless price information to consumers who may otherwise buy from pure offline retailers. This strategy is used by many retailers who do not sell through their online website. For example, the online stores of Holt Renfrew and Shoppers Drug Mart only offer e-flyers and directions to their nearest physical stores.

Our study has some limitations that offer opportunities for future research, as there are additional factors influence price dispersion but are not explicitly incorporated in our model. Consumer learning may influence price dispersion, as it reduces the need for search and reduces risk perceptions of shopping at particular retailers. It is important to note, however, even when shoppers learn about retailers to reduce transaction uncertainty, they still have different propensities to purchase online or offline, which is the risk sensitivity included in our analytical model (i.e., consumers are heterogeneous in their risk sensitivities toward transaction-specific shopping risks such as privacy concern and payment options). Future research is needed to determine how learning moderates this propensity at an aggregate level.

Another limitation of our model is that we considered only price search. Future research should consider search for information related to product attributes (e.g., for heterogeneous products). Under such conditions show-rooming will play a bigger role as consumers can search offline and subsequently purchase online, where prices may be lower.

Future research should also consider pricing strategies, like EDLP and HILO, which are related to price dispersion due to different pricing strategies used across retailer types. These pricing formats are related to shopping risk, as EDLP reduces price dispersion, and as such the risk of paying a higher price. However, EDLP versus HILO do add a necessary timing component, as consumers in HILO stores may delay purchase and stock-up when items are on sale. This will necessitate a multi-period game different from the single-period pricing game studied in this paper.

Another interesting area for future research will be to consider multi-product retailers and the assortment decision between online and offline stores in the study of market price dispersion. In their online stores they can provide consumers with more options, affecting their pricing strategies. Such an extension will require a comparison across heterogeneous products, and needs to consider the strategic decisions of product line pricing. We speculate that adding a product line (assortment) will increase search cost, which tends to increase price dispersion. Furthermore, this addition is expected to have a greater influence offline as online consumers can still search at low or no cost (e.g., using a shopping bot).

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## Appendix A.

*Procedure used for Data Collection*

We collected data on homogeneous products[10] from the three retailer types for three months, September–November, 2016, following the procedure used by Brynjolfsson and Smith (2000). We selected product categories that varied by price level and ease of assessing the value, variables that are expected to influence perceived shopping risk. Retailers were selected based on different retailer types, such that there were at least two retailers for each retailer type (dual channel retailers, pure online retailers and pure offline retailers) for each product. Pure offline retailers included retailers that sell mostly offline (e.g., Rexall, Shoppers Drug Mart, Superstore),[11] dual channel retailers consisted of national chains that sell both online and offline across the country (e.g., Best Buy, Sears, Toysrus, Walmart), and pure online retailers consisted of retailers that sell predominantly online (e.g., Amazon, Dell, ebay, NCIX, Newegg).[12] Price data, including shipping and handling surcharges, were collected by visiting online and offline retailers once a month.

Table A1 shows average prices, two measures of price dispersion (the mean price range and standard deviation) across products within a product category, for each retailer type and across online and offline markets. We found that average prices were higher online than offline (and this difference is statistically significant), and more importantly price dispersion was significantly higher online than offline. These results are consistent across product categories.

It should be noted that the price data includes shipping and handling surcharges, while many pure online retailers may provide free shipping for purchases over a certain amount. We therefore re-estimated the results in Table A1 taking into account such savings on shipping and handling (were relevant), and found that the results were consistent with those reported in Table A1.

Furthermore, a finding from our theoretic model is that online price dispersion increases as the number of pure online retailers increases. This is consistent with our empirical findings that price dispersion (as a proportion of the average price level) is higher for batteries, flash drives and toys which are sold by a larger number of pure online retailers (compared to pure offline retailers) than for the other product categories.[13]

[10] Identical products were selected to avoid any price variation due to product differentiation.

[11] Pure offline retailers also included retailers like Canadian Tires and Real Canadian Superstore, which have an online store but this can only be used to select items online after which consumers need to go to a local retailer to pick up items (i.e., they do not offer true online shopping). Pure offline retailers also included home improvement stores (Home Depot and Lowe's) and furniture stores (the Bricks and Leone's) since over 95% of their sales are through their Traditional stores (Fernando 2015).

[12] Pure online retailers included TigertDirect that sells most of its products online but has a few local offline retail outlets. For eBay we only collected data from products that sold through a buy it now price by established vendors with an eBay store. For Amazon we collected data from items sold through Amazon Prime.

[13] This is also consistent with results from empirical studies that have reported greater price dispersion online than offline, when the number of online stores is greater than the number of offline stores (Bailey 1998; Clay, Krishnan, and Wolff 2001; Tang and Xing 2001)

Table A1
Prices and price dispersion across different retailer types, and for online and offline market.

| Product categories[b] | Pure offline retailers[a] | | Dual channel retailers | | Pure online retailers | | Offline | | Online | | No products/no. obs. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean price | St. dev./range[c] | Mean price | St. dev./range | Mean price | St. dev./range | Mean price[d] | St. dev./range[d] | Mean price | St. dev./range | |
| Batteries | 14.62 | 1.46<br>2.13 | 13.65 | 2.61<br>3.69 | 15.61 | 4.51<br>7.47 | 14.25 $^{ns}$ | 2.21**<br>4.84** | 14.82 | 3.99<br>8.99 | 8/112 |
| Flashdrive | 22.33 | 0.99<br>1.44 | 18.88 | 3.59<br>5.08 | 14.65 | 3.50<br>9.98 | 20.61** | 3.21**<br>7.53**$^{s}$ | 16.37 | 5.15<br>12.30 | 8/144 |
| Espresso maker | 257.13 | 0.03<br>0.01 | 265.56 | 24.45<br>34.57 | 268.53 | 29.45<br>43.83 | 261.35$^{ns}$ | 16.96**<br>35.72** | 267.04 | 30.40<br>70.10 | 3/58 |
| Toys | 27.50 | 1.29<br>1.83 | 22.37 | 3.27<br>5.95 | 25.23 | 5.51<br>11.42 | 25.35** | 2.88**<br>6.88** | 23.51 | 5.73<br>15.94 | 7/114 |
| TVs | 649.62 | 0.60<br>0.99 | 615.99 | 88.87<br>168.03 | 614.10 | 104.60<br>186.19 | 632.81** | 44.95**<br>96.86** | 615.05 | 84.39<br>177.90 | 3/48 |
| Vacuum cleaners | 592.44 | 0.55<br>0.99 | 577.16 | 27.75<br>50.02 | 546.94 | 62.81<br>109.15 | 585.25** | 19.96**<br>55.29** | 562.05 | 65.82<br>166.81 | 7/242 |
| Total | 262.33 | 1.40<br>2.50 | 239.66 | 19.63<br>34.58 | 220.78 | 33.37<br>57.97 | 251.01** | 10.52**<br>18.54** | 230.22 | 26.50<br>46.27 | 36/718 |

[a] **Pure offline retailers:** Canadian Tires, Bed Bath & Beyond, Crate & Barrel, Home Depot, Leone, London Drugs, Lowe's, Rexall, Shoppers Drug Mart, Sobeys, Real Canadian Superstore, The Bricks, Zehrs; **Dual channel retailers:** Best Buy, Sears, Selfridges & Co, Staples, The Bay, The Source, Toysrus, Vision, Walmart; **Pure online retailers**: Amazon.ca, Canada Computers & Electronics, Dell.ca, Directcanada.com, ebay.ca, Electonicsforless.ca, Gibbys, Myteknology, NCIX.com, Newegg.ca, pc-canada.com, TigertDirect.ca, Vitamart.ca, Well.ca.

[b] **Batteries:** Duracell AA 4 pack, Duracell AA 16 pack, Duracell AA 20 pack, Duracell AAA 12 pack, Duracell AAA 16 pack, Duracell AAA 4 pack, Duracell AAA 20 pack, Duracell D 4 pack; **Flashdrive:** Kingston 16GB, Kingston 8GB, Verbatim Store 'n' Go USB Flash Drive 4GB 3pk, Verbatim Store 'n' Go USB Flash drive 32GB, lexar jump drive 64GB, SanDisk 8 GB, Cruzer Glide USB Flash Drive 16GB, Cruzer Glide USB Flash Drive 32GB; **Espresso Maker:** Nespresso – Pixie Espresso Maker, Nespresso – VertuoLine, Nespresso – VertuoLine bundle; **Toys:** Lego City Sea Scuba, Nexo Knights Mecha Horse, Nexo Knights Ultimate Flama, Nexo Knights Rumble Blade, Nexo Knights beast master. **TVs:** LG 43" Smart TV, LG 43," Sylvania 32" TV; **Vacuum:** Dyson Vacuum Small Ball, Dyson Cinetic DC77, Dyson DC66, Dyson V8, Dyson V6 Slim.

[c] St. Dev. = average standard deviation of prices across number of products within a category. Range = the average price range (max price–min price) across the number of products within a category.

[d] ** = Statistically significantly different $p < .05$. Significance test based on a paired t-test, comparing mean prices, variance and price range between the offline and online market.

## Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jretai.2018.01.003.

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