The Bright and Dark Sides of Customer Switching

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Abstract

We investigate price and stock competition between two retailers selling to a market with uncertain size. Prior to knowing the actual market size, retailers choose stocking quantities before prices under prestocking but adopt the reverse sequence under prepricing. After the actual market size is realized, each customer chooses to purchase from a retailer to maximize utility. Each retailer satisfies its local demand up to availability. A customer with unmet demand at the local retailer may continue to visit the other retailer; we call this phenomenon customer switching. Absent customer switching, retailers always choose the same price and stocking quantity, and tailor decisions to suit market conditions. In the presence of customer switching, product value and market condition are crucial to whether and how retailers adapt their strategies. Retailers can adopt differential strategies, whereby the retailer that overprices the other stocks more as well, to profit from accommodating the spillover demand. Customer switching can also force the retailers to price low and stock less while both could benefit from pricing high and stocking more. These findings are robust with respect to the decision sequence. Compared to prepricing, prestocking weakens retailers' incentive for strategic divergence but enables them to make higher profits when the market condition is sufficiently optimistic.

Keywords

Customer switching; price competition; stock competition; strategic divergence

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1. Introduction

Distribution systems that keep stocks close to customers are common. The explosive development of information technology and omni-channel operations have caused retailers, which used to manage selling primarily through physical stores, to turn to ecommerce. Nearly all major department stores — including Macy's, Kohl's, Walmart and Sears — have closed hundreds of stores and begun to shift operations online (Peterson 2019). Despite the growth of online and physical outlets, a

lingering problem is stockout, which occurs when the stocking quantity at a store is not sufficient to satisfy demand. The cause is usually the stock deployment that occurs before the actual demand is known. A Grocery Manufacturers Association survey states that 16% of US shoppers cannot find desired items online. Research indicates that shoppers at physical stores encounter stockouts in one out of five trips to food and drug retailers, one out of four trips to department and specialty stores, and one out of three trips to electronics retailers (Howland 2018). A customer survey conducted by YouGov also revealed that 83% (70%) of UK respondents were unable to find their desired products in stores (online).

Switching to other stores or brands is a common customer response to stockout (Sloot et al. 2005). With the exponential growth of online shopping, a customer unable to find desired items can quickly move to competitors' sites and purchase identical items, when available. Such sales bring $36.3 billion to brick-and-mortar stores and $34.8 billion to Amazon and other e-retailers. More than 24% of Amazon's revenue comes from customers who had tried to first purchase in physical stores (Howland 2018). The process of matching excess demand by excess supply involves customers with unmet demand at one place looking for the product at another place, known as customer switching. Technology advances have granted customers unprecedented access to information from various sources — including physical stores, online platforms, and social networks — and facilitated their switching behavior (Ansari et al. 2008; Su et al. 2016).

Stockouts result in lost sales to retailers with insufficient stocks, and customer switching brings additional sales opportunities to retailers with available stocks. This intensifies the strategic interactions among retailers. Despite the practicality of customer switching, few previous studies have explored its operations impacts. To fill this gap, we develop a framework to investigate price and stock competition between retailers in the presence of customer switching. The issues of how retailers adapt their strategies for customer switching and whether they can benefit from this market phenomenon are of particular academic interest and practical relevance. We strive to understand the

factors crucial to retailers' strategy adaptation for customer switching, and generate concrete insights into the effects of stockout-based substitution on retailers' operations and profits.

Specifically, we analyze a duopolistic setting in which retailers sell identical or substitutable products to a market of uncertain size, which is either small or large. The chance of the market being small reflects market condition, which is optimistic if this chance is low but is pessimistic otherwise. A customer receives the same value by obtaining a product from each retailer, which we call product value. Customers are heterogeneous in their preferences for product feature, which interplays with price to influence customers' utility-based decisions to purchase from retailers and switch upon stockout. Retailers choose prices and stocking quantities prior to the realization of the actual market size. Under prestocking, they choose stocking quantities before prices. This sequence is appropriate for situations where production leadtime is long and price setting is convenient. It has been widely used in the economics and operations literature on joint price and production decisions. Under prepricing, retailers adopt the reverse sequence, choosing prices before stocking quantities. Dana (2001) remarks that this process fits well with newspaper stands, magazine vendors, and video rental outlets, which make long-run price decisions but short-run stock decisions. Once the actual market size is revealed, each customer visits a retailer to maximize utility. The customers who visit a retailer form its local demand. Upon stockout at a retailer, an unsatisfied customer may switch to the other retailer provided that the customer receives a nonnegative utility. Following the literature, we refer to the demand thus formed as spillover demand and refer to the fraction of customers with unmet demand at a local retailer who switch to the other retailer as spillover fraction.

We characterize pure-strategy profiles for retailers' stocking quantities and prices. A retailer is cautious if its stocking quantity satisfies only the demand when the actual market size is small but is ambitious if its stocking quantity is sufficient to satisfy the demand when the actual market size is large. Hence, an ambitious retailer serves a large market but undertakes an overstocking risk, while a cautious retailer serves a small market but encounters stockout when the actual market size is large. In a symmetric profile, retailers set the same price to share the market equally. They can both be

cautious and stock to satisfy the minimum local demand, or they can both be ambitious and stock to satisfy the maximum local demand. In an asymmetric profile, they adopt differential strategies whereby the ambitious retailer prices higher and stocks more than the cautious retailer. The previous literature (e.g., Dana 2001; Jiang and Anupindi 2010) focuses exclusively on symmetric profiles. By endogenizing the spillover process, we establish the asymmetric profile as a viable strategic choice by which retailers can deal with customer switching.

The sustainability of an asymmetric profile depends on the alignment of retailers' incentives for different strategies. Specifically, a retailer has an incentive to be ambitious when the competitor is cautious but has an incentive to be cautious when the competitor is ambitious. These incentives are not aligned in the absence of customer switching, in which case retailers compete only for local demand. The rise of customer switching ushers in a potential stream of spillover demand between retailers. As product value increases, customers' incentive to switch upon stockout strengthens, expanding the spillover demand. It enables the retailers, when they adopt an asymmetric profile, to adjust prices and stocks to manage demand generation and satisfaction for profit improvements, but it is inconsequential to their decisions when they adopt a symmetric profile. This increases retailers' likelihood of strategic divergence. As the market condition becomes more optimistic (pessimistic), the market is more (less) likely to be large, which increases the retailer's likelihood of adopting an ambitious (cautious) strategy. The interplay between product value and market condition can lead to incentive alignment and sustain the asymmetric profile as retailers' strategic choice.

Our results reveal that customer switching has mixed effects on retailers' operations and profits. Absent customer switching, retailers adopt symmetric profiles: an optimistic (pessimistic) market condition entices them to adopt an ambitious (cautious) strategy. The rise of customer switching does not always force retailers to adapt their strategies. When retailers do adapt strategies in the face of customer switching, they adopt differential strategies when the market is optimistic but adopt a symmetric cautious strategy otherwise. In the former situation, retailers resort to strategic divergence to create stock imbalance, whereby one retailer is in stock while the other retailer is out

of stock, to generate spillover demand and profit from balancing pricing and stocking to satisfy different customer streams. In the latter situation, the intensified strategic pressure arising from customer switching forces retailers to be cautious whereas they would both be ambitious absent customer switching. Customer switching then leaves both retailers pricing lower, stocking less, and suffering profit losses. Importantly, as retailers adapt strategies for stockout-based substitution, their likelihood of encountering stockouts increases. All these findings are robust with respect to decision sequence. Compared to prepricing, prestocking weakens retailers' incentive to adopt differential strategies but enables them to profit more in sufficiently optimistic market conditions.

The remainder of this paper is organized as follows. Section 2 reviews the literature. Section 3 introduces the model setting. Sections 4 and 5 analyze equilibrium outcomes when retailers adopt prestocking and prepricing respectively. Finally, section 6 concludes the paper. All the proofs are presented in the online appendix.

2. Literature Review

Our work is related to the stream of inventory literature on stockout-based substitution. Most studies consider monopolistic settings and assume a certain pattern of substitution among products for consumer choice. Netessine and Rudi (2003) examine optimal stocking policies for a given product line. Each product has an exogenous random demand. When the demand for a product exceeds its stocking quantity, a given fraction of excess demand switches to other products. Wang and Parlar (1994) and Ernst and Kouvelis (1999) analyze similar product substitution models. Mahajan and van Ryzin (2001a) analyze a setting wherein customers substitute products by following a decreasing order of utility. Cachon et al. (2005) investigate the interaction between assortment planning and customer search. In their model, search is not triggered by stockouts. We model competition between retailers and investigate how spillover demand affects retailers' strategic interactions and profit performance.

Few studies have examined strategic stock competition with demand spillovers. Parlar (1988) analyzes a setting in which two firms manage inventories for substitutable products. When a

stockout occurs at one firm, a predetermined fraction of excess demand turns to the other. Lippman and McCardle (1997) analyze an oligopoly model in which industry demand is split among firms according to specific rules, and the excess stock at one firm meets the excess demand at another. Mahajan and van Ryzin (2001b) extend their research by using a general demand model and obtain structural insights into stocking policies. Anupindi and Bassok (1999) refer to the process of product substitution among competing retailers as search and consider the vertical interaction between manufacturers and retailers. Our study similarly considers the situation in which customer switching carries excess demand at one retailer to the other retailer, forming its spillover demand.

Prices are exogenous in most related studies; therefore, only stock competition is analyzed. Price-setting models are usually framed in monopolistic newsvendor settings (e.g., Mills 1959; Karlin and Carr 1962; Petruzzi and Dada 1999; Lariviere and Porteus 2001). We treat price as a decision variable and study its interplay with stock decision in a competitive setting. Wang (2006) analyzes the effects of the sequence of price and production decisions in an oligopoly model. Dana (2001) studies price and stock decisions in a duopolistic setting where customers make purchase decisions based on price and expected stock availability. While stockout-based substitution is not considered in these works, it is a key element in our model. Jiang and Anupindi (2010) analyze price and stock competition in a duopolistic setting wherein stockout-based substitution is driven either by customers or by retailers. Zhao and Atkins (2008) extend the analysis to an oligopolistic setting. These models are premised on a deterministic price-dependent local demand function and an exogenous spillover fraction. The novel feature of our study is that customers make utility-driven decisions about which retailer to visit first and to whom to switch in the event of stockout. This practical feature endows retailers with a stronger capability to manage demand generation and satisfaction, but exposes them to more intense strategic interactions.

By endogenizing the formation of local and spillover demands to depend on retailers' prices and stocks, we make two main contributions to the literature. First, in contrast to past studies that focus exclusively on symmetric profiles, we establish the asymmetric profile, whereby competing

retailers use differential prices and stocking quantities, as a valid strategic choice in the presence of customer switching. This paper is the first to characterize the asymmetric profile in a competitive newsvendor setting with joint price and stock decisions. Importantly, we show that pricing and stocking are strategic complements to retailers facing customer switching, extending the result in Dana (2001) which ignores demand spillovers and focuses on symmetric profiles. Second, the insights gained through our model have strong managerial implications. We find that customer switching can benefit retailers who adopt differential strategies to generate spillover demand and allocate total demand in between for customer satisfaction and enhanced profits. However, it can also force retailers to choose to encounter stockouts and suffer losses. Moreover, stockouts can occur more frequently as retailers adapt strategies for stockout-triggered customer switching.

3. Model Preliminaries

We consider a duopolistic setting in which two retailers sell substitutable products in a market of uncertain size, which is either large or small. The market is in the high (low) state when it is large (small). We normalize the small market size to 1 and let the large market size be $z > 1$. The probabilities that the market is small and large are $\text{Prob}\{d = 1\} = \mu = 1 - \text{Prob}\{d = z\}$ where $0 \leq \mu \leq 1$, and the expected market size is $d_m \triangleq \mu + z(1 - \mu)$. The chance of occurrence for the low market state (μ) reflects the market condition, which is optimistic when μ is small but pessimistic otherwise. The binomial distribution has been used in the literature to model an uncertain market (e.g., Jerath et al. 2010) and suffices to capture the dynamics triggered by customer switching. Customers are heterogeneous in their preferences for product features such as color, shape, size, and accessories. We model this heterogeneity by assuming that customers are uniformly located along a Hotelling line on [0,1], with the position of a customer indicating the customer's feature preference. The features offered in the products by retailers 1 and 2 are located at 0 and 1, respectively. The utility that a customer receives by purchasing from retailer i is defined as follows:

$$U(p_i, x_i) = v - p_i - tx_i, i = 1,2. \quad (1)$$

where p_i is retailer i's price. A customer receives value v by purchasing from either retailer because the retailers' products offer similar functionalities. We refer to v as product value. In equation (1), x_i is the customer's location with respect to retailer i and measures the extent to which product i meets the customer's preference. Marginal disutility t reflects the importance of price relative to feature match in customers' utility consideration. We assume away factors such as brand loyalty and service satisfaction in retailer selection to focus on retailers' price and stock competition. A retailer i sets stocking quantity q_i at marginal procurement cost c.

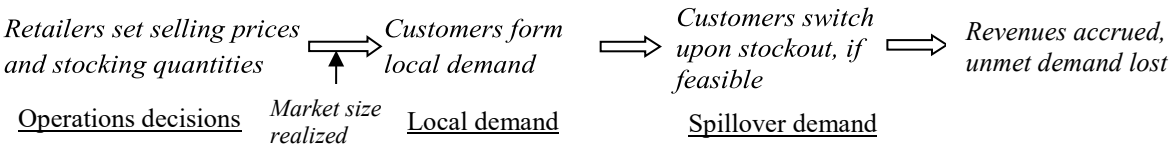


Figure 1. Decision framework

Figure 1 illustrates our decision framework. The retailers set prices and stocking quantities prior to knowing the actual market size. We consider two decision sequences. Under prestocking, which is widely used in the literature on joint production and price decisions in competitive settings, retailers decide stocking quantities before prices. Under prepricing, they adopt the reverse sequence, which fits with situations in which price decisions occur on a long-term basis but stock decisions occur on a short-term basis (Dana 2001). For differentiation purpose, we use superscripts S and F to indicate prestocking and prepricing, respectively. Once retailers set prices and stocking quantities, their prices are publicly known, while their stocking quantities are unobservable to customers. In reality, retailers publicize and commit to their selling prices but usually keep their inventory status undisclosed. Aydinliyim et al. (2017) remark that only one firm among the Top 500 Internet retailers "consistently divulges stock levels at all times."

Customers first choose to purchase from retailers, forming their local demand. When a retailer is unable to fully satisfy its local demand, customers with unmet demand may continue to visit the other retailer, called customer switching, and form its spillover demand. We analyze the situation without customer switching and use its performance as a benchmark for evaluating the

effects of this customer behavior. For differentiation purpose, we add superscripts T and N to quantities of interest with and without customer switching. We discuss in detail below the formation of local and spillover demands.

Local demand

After the market size is realized, a customer visits a retailer to maximize utility, defined in (1), and all the customers who visit a specific retailer form its local demand. We assume that product value v is high enough to ensure that the market is fully covered[1]. Suppose that retailers set prices $p = (p_1, p_2)$. Let $\hat{x}(p) \in [0,1]$ be the location on the Hotelling line that satisfies the following equation:

$$v - p_1 - t\hat{x}(p) = v - p_2 - t(1 - \hat{x}(p)). \quad (2)$$

With $\hat{x}(p) \triangleq \frac{1}{2} + \frac{p_2 - p_1}{2t}$, the customers located in $[0, \hat{x}(p)]$ first visit retailer 1, and the remaining customers first visit retailer 2. Given market size $d \in \{1, z\}$, the local demand at retailer i is $d\alpha_i(p)$, where $\alpha_1(p) = \hat{x}(p)$ and $\alpha_2(p) = 1 - \hat{x}(p)$ are the market shares of the two retailers. Thus, the retailers' market shares depend on their price difference. The sales quantity for retailer i when the market size is d can be expressed as follows:

$$s_{i,d}^N(p, q) = Min\{q_i, d\alpha_i(p)\}, i = 1,2. \quad (3)$$

Spillover demand

In the presence of customer switching, customers whose demand is unmet by the local retailer can continue to visit the other retailer provided that they receive a nonnegative utility. Specifically, if retailer j encounters stockout, a customer with unmet demand at retailer j visits retailer $i \neq j$ if the customer's utility satisfies $U(p_i, x_i) \geq 0$. This gives rise to a potential stream of spillover demand to a retailer from its competitor. The marketing literature has categorized three classes of costs in switching processes (Burnham et al. 2003). One is the financial cost, including the fee for breaking the contract and the loss of reward points. The second is the procedure cost due to the time, effort

[1] The conditions for ensuring that this assumption holds are $v > \frac{t(2z+3\mu-2z\mu)}{2\mu}$ under prestocking and $v > \frac{3t}{2} + \frac{cz}{z+\mu-z\mu}$ under prepricing.

and uncertainty involved in locating, adopting, and using a new brand. The third is the relational cost which is primarily on social and psychological aspects. Most relevant to our model is the procedure cost incurred by customers in searching for substitutable products. Technological advances and IT-enabled platforms have greatly reduced the costs of locating products and finalizing transactions. We ignore the switching cost in the customer's utility function to focus on the operations impacts of customer switching.

To quantify the spillover demand, we define

$$\alpha_i^T(p) = min\{\hat{x}_i(p_i),1\} - \alpha_i(p), \tag{4}$$

where $\hat{x}_i(p) = \frac{v-p_i}{t}$, and $min\{\hat{x}_i(p_i),1\}$ is the fraction of customers who have an incentive to purchase from retailer i given its price. With $\alpha_i(p)$ reflecting retailer i's market share, $\alpha_i^T(p)$ is the fraction of customers who visit retailer j as their first choice but who are willing to switch to retailer i upon stockout, which we call the spillover fraction. An increase in product value v increases the spillover fraction, expanding the potential stream of spillover demand. Local and spillover demands combine to form the effective demand for retailer i, which is expressed as follows:

$$D_{i,d}^T(p,q_j) \triangleq d\alpha_i(p) + \frac{\alpha_i^T(p)}{\alpha_j(p)}\left(d\alpha_j(p) - q_j\right)^+, \tag{5}$$

where $\left(d\alpha_j(p) - q_j\right)^+$ is the unmet local demand at retailer j, and $\frac{\alpha_i^T(p)}{\alpha_j(p)}$ is the fraction of customers with unmet demand who switch to retailer i. We assume that, if a shortage occurs, the retailer rations its stocks among customers equally, so that each customer has an equal chance to obtain the product. This assumption has been used in the literature for similar situations (e.g., Shao et al. 2013; Huang and Liu, 2015). The stocking quantity for retailer j affects local demand satisfaction and the size of spillover demand to retailer i.

Given prices $p = (p_1, p_2)$, the effective demand at retailer i is capped by $D_{i,m}^T(p) \triangleq \alpha_i(p) + (z-1)min\{1, \hat{x}_i(p_i)\}$, which occurs when the market size is large ($d = z$), and retailer j stocks to

satisfy only the minimum local demand ($q_j = \alpha_j(p)$). Revenues accrue to retailers after they satisfy the effective demand. The sales quantity when the market size is d can be expressed as follows:

$$S_{i,d}^T(p,q) = Min\{q_i, D_{i,d}^T(p,q)\}. \quad (6)$$

Customer switching intensifies strategic interactions between retailers. A retailer manages prices to compete for market share and adjust customers' incentives to switch in a stockout situation. A reduction in a retailer's price lowers its average profit but boosts its market share and strengthens the switching incentive of customers with unmet demand at the other retailer. A higher stocking quantity at a retailer enables it to make more sales, reducing the spillover and effective demand to the other retailer. We analyze pure-strategy outcomes in which retailers can adopt a symmetric profile to choose the same price and stocking quantity or adopt an asymmetric profile to choose differential prices and stocking quantities. We study how customer switching influences retailers' strategy adoption through a comparative investigation and explore the rationale behind equilibrium formation.

Under either prestocking or prepricing, price decisions are made before the actual market size is realized. In reality, firms may adjust prices after the market uncertainty is resolved, which is called pricing flexibility in the literature (e.g., van Mieghem and Dada 1999; Chod and Rudi 2005). In our model setting, we analyze the sequence wherein retailers choose stocking quantities before but choose prices after the market size is realized. By referring to the profile wherein their stocking quantities are the same (different) as a symmetric (asymmetric) profile, we find that retailers' equilibrium strategy adoption is similar in structure to that in our main model, despite the price decisions made after the realization of the actual market size.

4. Prestocking

Under prestocking, we analyze two situations differentiated by the presence of customer switching and use the outcomes to discuss the operations impacts of customer switching.

4.1 No customer switching

In the absence of customer switching, the profit for retailer i by serving local demand only is

$$\pi_i^N(p|q) = p_i \mathrm{E}[s_{i,d}^N(p,q)] - cq_i, \tag{7}$$

where $s_{i,d}^N(p,q)$ is the sales quantity when the actual market size is d and is defined in equation (3).

Given stocking quantities $q = (q_1, q_2)$ for the two retailers, their procurement costs are sunk, and they choose prices to compete for market share and maximize revenues by satisfying local demands. It can be verified that their prices $p^{SN}(q) = (p_1^{SN}(q), p_2^{SN}(q))$ must satisfy $\alpha_i(p^{SN}(q)) \leq q_i \leq z\alpha_i(p^{SN}(q))$. Thus, a retailer's stocking quantity is bounded by its local demands that occur in the low and high market states. This implies that a retailer fully sells its stocks in the high market state but may have leftovers in the low market state. The sales quantities in the high and low market states are $s_{i,d=z} = q_i$ and $s_{i,d=1} = \alpha_i(p)$, respectively. A detailed derivation is provided in the appendix.

Lemma 1. *Under prestocking, in the absence of customer switching, given stocking quantities* $q = (q_1, q_2)$*, the unique equilibrium prices are* $p_i^{SN}(q) = \frac{t(3\mu+4(1-\mu)q_i+2(1-\mu)q_{3-i})}{3\mu}, i = 1,2$*, and the retailers' market shares are* $\alpha_i(p) = \frac{1}{2} + \frac{(1-\mu)(q_{3-i}-q_i)}{3\mu}, i = 1,2.$

Lemma 1 states the retailers' equilibrium prices given their stocking quantities. Stocking more than the competitor entitles a retailer to a higher price. While its market share decreases relative to the other retailer's, the retailer can deploy stocks to satisfy the demand in the high market state. Retailers choose stocking quantities in anticipation of quantity-dependent price decisions. A retailer is cautious if its stocking quantity is only enough to satisfy the demand in the low market state, but it is ambitious if its stocking quantity is sufficient to satisfy the demand in the high market state. Thus, a cautious retailer always fully sells its stocks to make constant sales but encounters stockout in the high market state, while an ambitious retailer undertakes an overstocking risk because it has leftovers in the low market state.

We denote retailers' strategy profile as (n_1, n_2), where $n_i \in \{C, A\}, i = 1,2$ indicates retailer i's type: cautious (C) or ambitious (A). In a symmetric profile, (C, C) or (A, A), the retailers set the

same price to occupy the same market share and choose the same stocking quantity as well. In an asymmetric profile, (C, A) or (A, C), retailers set differential prices and stocking quantities. An ambitious retailer serves an expected market size of d_m, while a cautious retailer serves a market size of one. We refer to the product of the market share and average profit from each unit of sales as profitability, which indicates the profit that a retailer can make by serving a market of size one. A retailer's profit is then its profitability scaled by the size of the market it serves. Table A1 in the appendix presents retailers' prices, stocking quantities, and profits when they adopt various strategy profiles under prestocking absent customer switching.

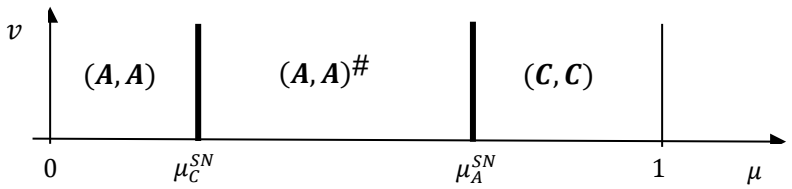
Lemma 2. *Under prestocking, in the absence of customer switching:*

1) *The price and stocking quantity for a retailer are higher under* (A, A) *than under* (C, C).
2) *An ambitious retailer prices lower and occupies a smaller market share under* (C, A) *than under* (A, A), *while a cautious retailer prices higher and occupies a larger market share under* (C, A) *than under* (C, C).
3) *The price for each retailer increases as the market condition becomes more optimistic*.

Each retailer serves a larger demand under (A, A) than under (C, C) and thus sets a higher stocking quantity, which relieves its pricing pressure and enables it to set a higher price. An ambitious retailer scales down its price and occupies a reduced market share under (C, A) than under (A, A). Thus, an ambitious retailer faces stronger pricing pressure and attains lower profitability when the competitor is cautious than when it is ambitious. A cautious retailer scales up its price and occupies an increased market share under (C, A) than under (C, C). Thus, a cautious retailer is under weaker pricing pressure and attains higher profitability when the competitor is ambitious than when it is cautious. The retailer's price increases as market condition becomes more optimistic because, under prestocking, procurement cost is sunk, and a retailer sets the price to balance the revenues by selling its stocks in the high market state and by competing for demand in the low market state. As the market condition improves, the high market state is more likely to occur, which relieves the

pricing pressure on the retailer and induces it to raise price and rely more on selling in the high market state for revenue.

Proposition 1. *Under prestocking, in the absence of customer switching, let* μ_A^{SN} *be the unique solution in* μ *that satisfies* $\pi^{SN}(A,A) = \pi_1^{SN}(C,A)$*, where* $\pi^{SN}(A,A) = \frac{td_m^2 - c\mu z}{2\mu}$*,* $\pi_1^{SN}(C,A) = \frac{t(1+M_n^S)^2 - c\mu(1+M_n^S)}{2\mu}$ *and* $M_n^S = \frac{d_m - 1}{d_m + 1 + \mu}$*, then retailers adopt symmetric profile* (A,A) *when* $\mu \in [0, \mu_A^{SN})$ *but adopt symmetric profile* (C,C) *when* $\mu \in [\mu_A^{SN}, 1]$.



Notes: In area $(A,A)^{\#}$, both symmetric profiles are sustainable, but profile (A,A) dominates profile (C,C). The threshold μ_C^{SN} is the unique solution in μ that satisfies $\pi^{SN}(C,C) = \pi_2^{SN}(C,A)$, where $\pi^{SN}(C,C) = \frac{t - c\mu}{2\mu}$ and $\pi_2^{SN}(C,A) = \frac{t(1+(1+\mu)M_n^S)^2 - c\mu z(1-M_n^S)}{2\mu}$.

Figure 2. Strategic profiles under prestocking in the absence of customer switching

Proposition 1 states that, under prestocking, in the absence of customer switching, retailers always adopt a symmetric profile. To explain the rationale for this outcome, we explore a retailer's incentive to adopt a strategy different from the competitor's. When the competitor is cautious, being ambitious rather than cautious has opposite effects on a retailer. On the one hand, it yields a market-expansion effect that makes the retailer stock in order to satisfy the demand in a larger market. On the other hand, it yields a profitability loss by triggering price adjustments that reduce the retailer's market share and expose the retailer to an overstocking loss that lowers its average profit. A more optimistic market condition implies that the high market state is more likely to occur, strengthening the market-expansion effect and mitigating the retailer's overstocking loss through the choice to be ambitious rather than cautious. A retailer has an incentive to diverge from a cautious competitor when the market condition is sufficiently optimistic ($0 \leq \mu \leq \mu_C^{SN}$), in which case its gain from the market-expansion effect is strong enough to outweigh its profitability loss.

In the case where the competitor is ambitious, being cautious rather than ambitious enables a retailer to grab a larger market share and obtain a higher average profit by avoiding the overstocking loss, which yields a profitability gain, but also restricts it to stocking to satisfy the demand in the low market state, which yields a market-reduction effect. A more pessimistic market condition mitigates the market-reduction effect and scales up the profitability gain for the retailer through the choice to be cautious rather than ambitious. A retailer has incentive to diverge from an ambitious competitor when the market condition is sufficiently pessimistic ($\mu_A^{SN} < \mu \leq 1$), in which case its gain in profitability outweighs its loss from the market-reduction effect.

Absent customer switching, incentive misalignment precludes the sustainability of the asymmetric profile at equilibrium. Being ambitious rather than cautious benefits a retailer through a market-expansion effect but causes it to suffer a profitability loss due to reductions in market share and average profit. A retailer faces stronger pricing pressure and suffers a larger profitability loss by being ambitious when the competitor is cautious than when it is ambitious. Whenever the market-expansion effect outweighs the profitability loss to incentivize the retailer to be ambitious when the competitor is cautious, the retailer must have the incentive to be ambitious when the competitor is ambitious as well. The retailer then prefers to converge with an ambitious competitor whenever it prefers to diverge from a cautious competitor. Following a similar logic, the retailer prefers to converge with a cautious competitor whenever it prefers to diverge from an ambitious competitor.

As retailers only choose symmetric profiles, it is their dominant strategy to be ambitious when the market condition is optimistic ($\mu \in [0, \mu_C^{SN}]$) but to be cautious when the market condition is pessimistic ($\mu \in [\mu_A^{SN}, 1]$). In other market conditions ($\mu \in (\mu_C^{SN}, \mu_A^{SN})$), they can either converge to be cautious or converge to be ambitious, while the latter strategic choice enables them to make greater profits and is Pareto dominating.

4.2. Customer switching

The rise of customer switching produces a potential stream of spillover demand between retailers to intensify their strategic interactions. Given stocking quantities $q = (q_1, q_2)$, retailers set prices to compete for market share and adjust customers' incentive to switch upon stockout. Their prices $p^{ST}(q) = (p_1^{ST}(q), p_1^{ST}(q))$ must ensure that their stocking quantities are bounded by the minimum local demands and the maximum effective demands which include local and spillover demands.

Lemma 3. *Under prestocking, in the presence of customer switching, given stocking quantities q, the retailers' prices are $p_i^{ST}(q) = \frac{t(3\mu+4(1-\mu)q_i+2(1-\mu)q_{3-i})}{3\mu}$, and their market shares are $\alpha_i(p) = \frac{1}{2} + \frac{(1-\mu)(q_i-q_{3-i})}{3\mu}$, $i = 1,2$.*

Lemma 3 states the retailers' quantity-dependent pricing strategies. The retailers choose stocking quantities in anticipation of these price decisions. When they adopt a symmetric profile, (C, C) or (A, A), their decisions are the same as those of their counterparts absent customer switching. In this case, they behave as if customer switching did not exist. Table A2 in the appendix presents the stocking quantities, prices, and profits for retailers in asymmetric profile (C, A); the outcomes for asymmetric profile (A, C) are obtainable by switching the roles of the two retailers. In the asymmetric profile, the ambitious retailer stocks to satisfy both local and spillover demands in the high market state, and the cautious retailer stocks to satisfy the local demand in the low market state. There are two scenarios for the generation of the spillover demand: partial and full spillover. Take asymmetric profile (C, A) for instance. Under partial spillover, the ambitious retailer 2 prices to induce a fraction of customers with unmet demand at the cautious retailer 1 to switch. Under full spillover, the ambitious retailer 2 prices to induce all customers with unmet demand at the cautious retailer 1 to switch.

Lemma 4. *Under prestocking, in the presence of customer switching, in an asymmetric profile:*

1) The ambitious retailer overprices and stocks more than the cautious competitor.

2) The profits for both retailers non-decrease with the product value.

In the asymmetric profile, the cautious retailer undercuts the ambitious retailer to grab a larger market share than the ambitious retailer but stocks to satisfy only the local demand in the low market state to avoid the overstocking loss. This causes the cautious retailer to stock less than the ambitious retailer whose stocking quantity is sufficient to satisfy the local and spillover demands in the high market state. Pricing and stocking are thus strategic complements for retailers, which is consistent with the finding in the literature (Dana 2001; Rumyantsev and Netessine 2007; Gaur et al. 2005) of a positive correlation between price and inventory. In contrast to the previous literature, we model spillover process to depend on retailers' strategic decisions and establish the complementarity result when they adopt differential strategies.

Product value is crucial to the formation of spillover demand and the profits for diverging retailers. In the case where retailers adopt differential strategies to manage partial spillover, a higher product value induces customers to switch upon stockout, increasing the spillover demand. This is intuitive because, as a product becomes more valuable, consumers are more willing to search alternative retailers when their first choice is out of stock. The increase in spillover demand endows retailers with a stronger capability to generate and satisfy demand. The ambitious retailer, who attracts and serves spillover demand, raises its price. This bolsters the price for the cautious retailer as well but to a lesser extent because the cautious retailer satisfies only the local demand and is under pressure to compete for market share. Consequently, the market share and average profit increase for the cautious retailer, enabling it to profit more from local selling. The profit for the ambitious retailer increases as well because it satisfies spillover demand in addition to local demand at a higher price despite a reduced market share. In the case where diverging retailers manage full spillover, all consumers are willing to switch upon stockout, and a further increase in product value has no effect on retailers' operations decisions and profits.

Lemma 5. *Under prestocking, in the presence of customer switching, the retailers refrain from generating and satisfying spillover demand when* $v \leq v_T^S$*, but they can adopt an asymmetric profile*

to manage partial spillover when $v_T^S < v \le v_0^S$ *and full spillover when* $v > v_0^S$*, where* $v_T^S = \frac{t(2d_m+\mu)(2+\mu)}{2(1+\mu+d_m)\mu}$ *and* $v_0^S = \frac{t(2z+3\mu+3\mu^2-2z\mu^2)}{\mu(2+\mu)}$.

Lemma 5 states that, for sufficiently low product values ($v \le v_T^S$), the two retailers have no incentive to manage spillover demand because doing so would force them to lower prices and suffer profit losses. It is obvious that v_T^S increases in t. Hence, as prices become less crucial to customers' utility consideration, retailers have a stronger incentive for differential strategies to accommodate customer switching. For high product values ($v > v_T^S$), adopting an asymmetric profile could allow retailers to manage partial or full spillover. Recall that the profits of diverging retailers increase with the product value when they manage partial spillover but are insensitive to the product value when they manage full spillover. Based on their profits in these two scenarios, Lemma 5 states that, once they adopt differential strategies, retailers manage partial spillover when the product value is medium ($v_T^S < v \le v_0^S$) but full spillover when the product value is high ($v > v_0^S$).

The retailers choose between symmetric and asymmetric profiles to cater to customer switching. Proposition 2 states the outcomes of their strategic choice.

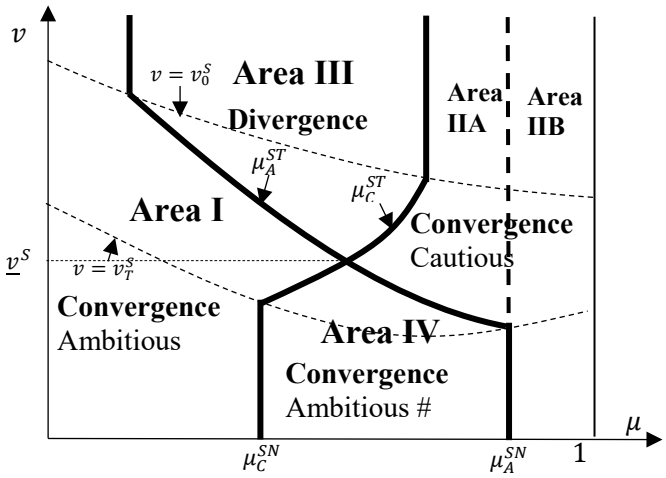
Proposition 2. *Under prestocking, in the presence of customer switching:*

1) when $v < v_T^S$*, retailers' profiles are the same as they are in the absence of customer switching.*

2) when $v \ge v_T^S$*, let* μ_A^{ST} *and* μ_C^{ST} *be the unique solutions in* μ *to satisfy, respectively,* $\pi^{ST}(A,A) = \pi_1^{ST}(C,A)$ *and* $\pi^{ST}(C,C) = \pi_2^{ST}(C,A)$*, where* $\pi^{ST}(A,A) = \frac{td_m^2-c\mu z}{2\mu}$, $\pi^{ST}(C,C) = \frac{t-c\mu}{2\mu}$, $\pi_1^{ST}(C,A) = \frac{t(1+M^S)^2-c\mu(1+M^S)}{2\mu}$, $\pi_2^{ST}(C,A) = \frac{t(1+(1+\mu)M^S)^2-c\mu(\frac{z}{2}(1-M^S)+(z-1)\alpha_2^T(p^{ST}))}{2\mu}$, $M^S = Max\{\frac{2(z-1)(1-\mu)(v\mu-t)}{t(2z(1-\mu^2)+\mu(2+3\mu)-2)}, \frac{2(z-1)(1-\mu)}{2+\mu}\}$*, and let* $\underline{v}^S$ *be the unique solution in* v *that satisfies* $\mu_A^{ST} = \mu_C^{ST}$*, then:*

   a. $v_T^S \le v < \underline{v}^S$*, retailers adopt symmetric profile* (A,A) *when* $\mu \in [0, \mu_A^{ST})$ *but adopt symmetric profile* (C,C) *when* $\mu \in [\mu_A^{ST}, 1]$.

b. $v > \underline{v}^S$*, retailers adopt symmetric profile* (A, A) *when* $\mu \in [0, \mu_A^{ST})$*, adopt asymmetric profile when* $\mu \in [\mu_A^{ST}, \mu_C^{ST})$*, but adopt symmetric profile* (C, C) *when* $\mu \in [\mu_C^{ST}, 1]$.



Note. In Area IV, retailers can adopt a symmetric profile to be either ambitious or cautious, while the former is Pareto dominating.

Figure 3. Equilibrium strategic profiles under prestocking in the presence of customer switching

Customer switching is inconsequential to retailers' strategies when the product value is low ($v \leq v_T^S$), in which case, they adopt the same strategies as before. For other product values ($v > v_T^S$), customer switching substantially affects the prices and stocking quantities of diverging retailers. As illustrated in Figure 3, the two threshold market conditions, μ_A^{ST} and μ_C^{ST}, define the situations where retailers adopt various profiles. As the product value is still low ($v < \underline{v}^S$), they adopt a symmetric profile to be ambitious when the market condition is optimistic ($\mu \in [0, \mu_A^{ST})$) but adopt a symmetric profile to be cautious otherwise, which is similar to when customer switching is absent. For high product values ($v \geq \underline{v}^S$), retailers adopt an asymmetric profile in medium market conditions ($\mu \in [\mu_A^{ST}, \mu_C^{ST})$), to manage partial spillover when $v \in [\underline{v}^S, v_0^S]$ but full spillover when $v > v_0^S$. In other situations, they adopt a symmetric profile to be ambitious in optimistic market conditions ($\mu \in [0, \mu_A^{ST})$) but to be cautious in pessimistic market conditions ($\mu \in [\mu_C^{ST}, 1]$).

A focal issue in retailers' strategy adoption is the sustainability of the asymmetric profile, which results from the alignment of the retailers' incentives for differential strategies. In the absence

of customer switching, a retailer weighs the gain from market expansion against the profitability loss to decide whether to diverge from a cautious competitor, but it weighs the profitability gain against market reduction to decide whether to diverge from an ambitious competitor. These incentives are not aligned when retailers compete for local demand only. The rise of customer switching ushers in a stream of spillover demand. It is inconsequential to retailers when they adopt a symmetric profile, in which case they manage local demand only, but it forces them to adjust prices and stocks when they use differential strategies to accommodate the spillover demand. The product value and market condition influence the magnitude of the effect customer switching has on retailers' profits under an asymmetric profile, which weighs on their incentives for divergence.

A higher product value increases the retailers' likelihood of adopting differential strategies. Recall that a higher product value implies a larger spillover demand, causing retailers that adopt differential strategies to profit more by adjusting prices and stocks to manage demand satisfaction. The profit gain to the cautious retailer comes from the increases in market share and average profit in local selling, while the gain to the ambitious retailer comes from balanced pricing and stocking to satisfy a larger pool of local and spillover demands. Consequently, the profitability gain for a retailer by diverging from an ambitious competitor increases, while the profitability loss to a retailer by diverging from a cautious competitor is more than compensated for by the gain obtained from satisfying the spillover demand. In either case, divergence gains more traction than convergence in a retailer's strategy choice. This leads retailers to adopt the asymmetric profile when the product value is high enough ($v > \underline{v}^S$), and their incentive for differential strategies strengthens until the product value is so high that diverging retailers would manage full spillover, in which case their strategy adoption no longer depends on the product value.

A more pessimistic market condition (μ increases) makes the asymmetric profile less likely sustainable. It increases a retailer's likelihood of diverging from an ambitious competitor, because being cautious rather than ambitious would have a weaker market-reduction effect but yield a larger profitability gain in local selling by avoiding an overstocking loss. However, it decreases a retailer's

likelihood of diverging from a cautious competitor, because being ambitious rather than cautious would produce a weaker market-expansion effect, yield a higher overstocking loss to worsen the profitability, and generate a smaller gain from spillover sales. As such, incentive misalignment makes retailers less likely adopt differential strategies.

Observe that retailers converge to be ambitious when the market condition is sufficiently optimistic (see area I, Figure 3). Recall that, under prestocking, an ambitious retailer stocks more and tends to price high to generate revenue from the high market state, while a cautious retailer stocks less and tends to price low to compete for the market share in the low market state. The profitability gain to a retailer by diverging from an ambitious competitor is small because being ambitious enables the retailer to price high and attain a high average profit. As the market condition becomes sufficiently optimistic, this profitability gain can be so small relative to the loss from market reduction to disincentivize the retailer from diverging. This, together with the fact that a retailer prefers to diverge from a cautious competitor in optimistic market conditions, makes it the dominant strategy for retailers to be ambitious.

Product value influences retailers' convergence to be cautious when the market condition is pessimistic. For low product values ($v \leq \underline{v}^S$), asymmetric profile is not sustainable, and retailers converge to be cautious whenever a retailer prefers to diverge from an ambitious competitor. An increase in product value strengthens a retailer's incentive to diverge from an ambitious competitor, thus increasing retailers' likelihood of converging to be cautious. For high product values ($v > \underline{v}^S$), asymmetric profile is sustainable, and retailers converge to be cautious whenever a retailer prefers to converge with a cautious competitor. An increase in product value strengthens a retailer's incentive to diverge from a cautious competitor, thus decreasing retailers' likelihood of converging to be cautious. This is illustrated in area II in Figure 3.

Table 1 presents a detailed comparison of retailers' stocking quantities, prices, and profits in the absence and presence of customer switching. Proposition 3 summarizes the effects of customer switching on retailers' strategies and profits.

Table 1. Effects of customer switching on stocking quantities, prices and profits under prestocking

	Areas I, IIB, IV	**Area IIA**	**Area III**	
q_1^{SN}	=	≥	≥	q_1^{ST}
q_2^{SN}	=	≥	≥|≤	q_2^{ST}
p_1^{SN}	=	≥	≥	p_1^{ST}
p_2^{SN}	=	≥	≤|≥	p_2^{ST}
π_1^{SN}	=	≥	≤	π_1^{ST}
π_2^{SN}	=	≥	≤	π_2^{ST}

Notes: Areas I, IIA, IIB, III, and IV are the areas marked in Figure 3. In the case where retailers adopt an asymmetric profile, retailer 1 is the cautious retailer and retailer 2 is the ambitious retailer.

Proposition 3. *Under prestocking, referring to Figure 3 and Table 1, the effects of customer switching on retailers' strategies and profits are presented as follows:*

1) Customer switching is inconsequential to retailers' strategies and profits when the market condition is sufficiently optimistic or sufficiently pessimistic, or when the product value is low (areas I, IIB and IV in Figure 3).

2) Customer switching induces retailers to adopt an asymmetric profile when the market condition is moderate and the product value is high (area III in Figure 3). Both retailers profit more by adopting differential strategies than by converging to be ambitious, which they would do in the absence of customer switching: the cautious retailer stocks less and prices lower but avoids the overstocking loss, and the ambitious retailer benefits from efficiently balancing pricing and stocking to satisfy both local and spillover demands.

3) Customer switching causes retailers to converge to be cautious when the market condition is moderate to low and the product value is high (area IIA in Figure 3). Both retailers stock less, price lower, and profit less than by converging to be ambitious, which they would do in the absence of customer switching.

When the asymmetric profile is sustained in the presence of customer switching (area III in Figure 3), both retailers would adopt an ambitious strategy absent customer switching. Both retailers profit more from diverging than from converging to be ambitious, in which case they would manage local demand only. Specifically, the cautious retailer, who still satisfies local demand only, avoids an overstocking loss without suffering large reductions in price and sales, and the ambitious retailer efficiently balances pricing and stocking to satisfy local and spillover demands. In this case, utilizing differential strategies enables the retailers to cater to customer switching. This customer behavior can also make retailers dominantly prefer to be cautious, while they would converge to be ambitious when customer switching is absent (area IIA in Figure 3). Converging to be cautious makes each retailer stock less, price lower, and profit less than by converging to be ambitious. Thus, customer switching traps retailers in a Prisoner's Dilemma type of situation. In other circumstances, customer switching is inconsequential to retailers' strategies and hence profits.

Rapid IT and technological advances have made customer switching increasingly prevalent. Our results reveal its mixed effects on retailers' strategies and profits. Strategic divergence to create stock imbalance, whereby some retailers are in stock while others are out of stock, to generate and satisfy spillover demand is a valid retailer choice for dealing with customer switching. Under this strategy profile, the low-price retailer stocks less but sells all stocks despite encountering stockouts, while the high-price retailer stocks to satisfy the demand in the high market state but has leftovers in the low market state. Regardless of the choice, retailers benefit from stockout-based substitution. Customer switching may also press retailers to lower prices and stock less, whereas they can profit more by pricing and stocking higher, due to the spillover demand that intensifies the strategic interactions between retailers. Being cautious enables a retailer to avoid the overstocking loss that would occur if it stocks high to satisfy both local and spillover demands. When the potential overstocking loss is substantial, the dominant retailer strategy is to be cautious and to choose to encounter stockouts.

Stockout occurs more frequently after retailers adapt strategies for customer switching. In the case where they adopt differential strategies, which occurs when product value is high and the market condition is medium, retailers create stock imbalance in a high market state, when stockout occurs at the retailer with less stock and the retailer with more stock satisfies the spillover demand. By intensifying the strategic pressure on retailers, customer switching can force them to choose to encounter stockouts when the market condition is pessimistic. In either case, however, both retailers would adopt an ambitious strategy to fully satisfy demand in the absence of customer switching. A recent GTNexus report claims that stockout in both online and bricks-and-mortar stores has reached an "unprecedented" level. Our results indicate that this phenomenon can be partly attributed to the strategic adjustments that competing retailers make to deal with stockout-triggered customer switching, and is likely to persist.

5. Prepricing

We next analyze the prepricing sequence, whereby retailers decide prices prior to stocking quantities before the realization of the actual market size. Their prices determine their market shares and affect customers' incentive to switch upon stockout. Stocking quantities help retailers reap sales and adjust the spillover demand after the realization of the actual market size.

5.1 No customer switching

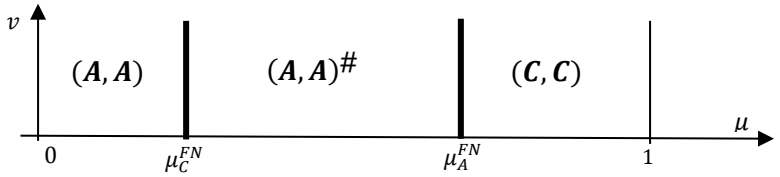
In the absence of customer switching, given $p = (p_1, p_2)$, retailers independently decide stocking quantities to maximize their profits gained from satisfying local demands. The profit for retailer i is given in equation (7). The retailer has no incentive to stock either below the minimum or above the maximum local demand that may occur, i.e., $\alpha_i(p) \le q_i(p) \le z\alpha_i(p)$. The sales quantities in different market states are $s_{i,d=1}(p,q) = \alpha_i(p)$ and $s_{i,d=z}(p,q) = q_i(p)$.

Lemma 6. *Under prepricing in the absence of customer switching, given* $p = (p_1, p_2)$*, the retailers' stocking quantities* $q^{FN}(p) = (q_1^{FN}(p), q_2^{FN}(p))$ *must satisfy* $q_i^{FN}(p) = \alpha_i(p)$ *or* $z\alpha_i(p)$*,* $i = 1,2$.

Lemma 6 states that, without customer switching, given prices that determine market shares, a retailer stocks to either satisfy the demand in the low market state or satisfy the demand in the high market state. In the former case, the retailer is cautious and always sells its stocks fully. In the latter case, the retailer is ambitious and always satisfies demand fully despite having leftovers in the low market state. Anticipating their stocking strategies, retailers determine prices to maximize their individual profits. Table A3 in the appendix presents the retailers' strategic profiles and profits under prepricing. The solution structure is similar to that under prestocking, as shown in Table A1. In addition to occupying the same market share as its competitor, a retailer makes the same average profit under symmetric profiles (A, A) and (C, C). As retailers adopt an asymmetric profile, a more pessimistic market condition (μ increases) induces the cautious retailer to stock more but induces the ambitious retailer to price higher. This differs from the situation under prestocking, when both retailers would stock less and price lower.

Absent customer switching, driven by the same dynamics as under prestocking, retailers under prepricing adopt a symmetric profile to be ambitious in an optimistic market condition ($\mu \in [0, \mu_A^{FN}]$) but are cautious in a pessimistic market condition ($\mu \in (\mu_A^{FN}, 1]$).

Proposition 4. *Under prepricing, in the absence of customer switching, let* μ_A^{FN} *be the unique solution to* μ *that satisfies* $\pi^{FN}(A, A) = \pi_1^{FN}(C, A)$*, where* $\pi^{FN}(A, A) = \frac{td_m}{2}$*,* $\pi_1^{FN}(C, A) = \frac{t(1+M_n^F)^2}{2}$ *and* $M_n^F = \frac{c\mu(z-1)}{3td_m}$*, then the retailers adopt symmetric profile* (A, A) *when* $\mu \in [0, \mu_A^{FN}]$ *but adopt symmetric profile* (C, C) *when* $\mu \in (\mu_A^{FN}, 1]$.



Note: In area $(A, A)^{\#}$, both symmetric profiles are sustainable, but profile (A, A) dominates profile (C, C). The threshold μ_C^{FN} is the unique solution in μ that satisfies $\pi^{FN}(C, C) = \pi_2^{FN}(C, A)$, where $\pi^{FN}(C, C) = \frac{t}{2}$ and $\pi_2^{FN}(C, A) = \frac{td_m(1-M_n^F)^2}{2}$.

Figure 4. Equilibrium strategy profiles under prepricing in the absence of customer switching

Between the two threshold market conditions above which retailers converge to be cautious under prepricing and prestocking, we show that $\mu_A^{FN} < \mu_A^{SN}$; thus, retailers' likelihood of converging to be cautious is lower under prestocking than under prepricing. Note that retailers converge to be cautious whenever a retailer prefers to diverge from an ambitious competitor. Under prestocking, a retailer manages prices to balance revenues by selling all stocks in the high market state and by competing to sell in the low market state. Retailers thus face weaker pricing pressure than under prepricing, in which case, they price to compete for market share before stocking to manage sales across states. The influence of weakened pricing pressure is strong on the ambitious retailer who prices high to sell stocks but is weak on the cautious retailer who prices low to compete for demand. Consequently, the profitability gain to a retailer by being cautious to compete with an ambitious competitor is lower under prestocking than under prepricing, because it could set a high price to attain a high average profit by being ambitious in the former case. A retailer is thus less likely to diverge from an ambitious competitor, and retailers are less likely to converge to be cautious under prestocking than under prepricing.

5.2. Customer switching

In the presence of customer switching, given prices $p = (p_1, p_2)$, a retailer i must stock $q_i^{FT}(p)$ to satisfy either the local demand in the low market state ($\alpha_i(p)$), the local demand in the high market state ($z\alpha_i(p)$), or the maximum effective demand ($D_{i,m}^T(p)$). Anticipating their quantity decisions, retailers choose prices to maximize their individual profits. Under a symmetric profile, (A, A) or (C, C), retailers manage to satisfy local demands only, and their prices and stocks are the same as those of their counterparts in the absence of customer switching. Under an asymmetric profile, (A, C) or (C, A), retailers manage pricing and stocking to accommodate spillover demand. Table A4 in the appendix presents stocking quantities, prices, and profits under (C, A). The outcomes under profile (A, C) are symmetric, with the roles of the two retailers switched.

Table A4 presents three scenarios that are differentiated by how the ambitious retailer under an asymmetric profile manages customers' incentive to switch upon stockout. Besides partial and full spillover, which also prevail under prestocking (see Table A2), the ambitious retailer can now price just enough to induce all customers to purchase from it; we call this bounded spillover. Regardless, pricing and stocking remain strategic complements to diverging retailers. Under partial or bounded spillover, through price and stock adjustments, the profit for the cautious retailer increases due to a higher price and more constant sales generated by an increase in the market share, and the profit for the ambitious retailer increases due to balanced pricing and stocking in selling to both local and spillover demands.

Lemma 7. *Under prepricing, in the presence of customer switching, retailers refrain from managing spillover demand when* $v \leq v_T^F$*, but they adopt an asymmetric profile to manage partial spillover when* $v_T^F < v \leq v_0^F$*, bounded spillover when* $v_0^F < v \leq Max\{v_1^F, v_0^F\}$*, and full spillover otherwise, where* $v_T^F \triangleq \frac{2(c+3t)}{5} + \frac{6c(2-5z)-9t}{10(2-5d_m)}$, $v_0^F \triangleq 2t + \frac{c-4cz}{1-4d_m}$ *and* $v_1^F \triangleq c + \frac{2t+4td_m}{3}$.

Similar to the situation under prestocking, for sufficiently low product values ($v \leq v_T^F$), retailers forgo the sales opportunities brought about by customer switching. For other product values ($v > v_T^F$), they value asymmetric profile as a strategic option and find the best means of managing spillover demand. The profits for the retailers who adopt differential strategies increase with product value when they manage partial or bounded spillover but remain insensitive to product value when they manage full switchover. Based on their profits across scenarios, Lemma 7 states that diverging retailers would manage partial spillover at low product values ($v_T^F < v \leq v_0^F$), bounded spillover for medium product values ($v_0^F < v \leq Max\{v_1^F, v_0^F\}$), and full spillover otherwise.

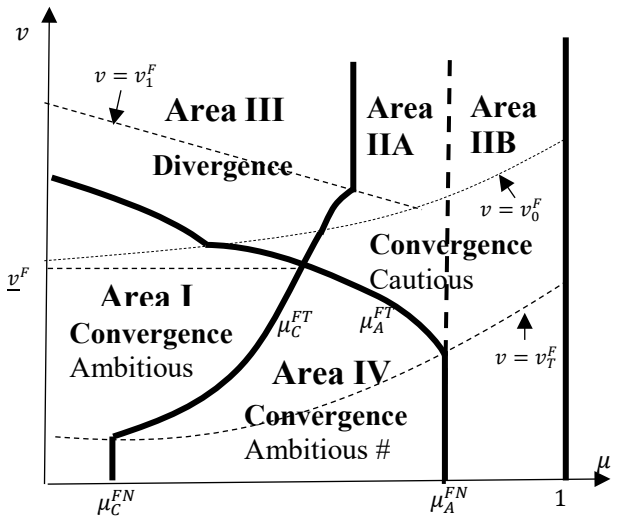
Proposition 5. *Under prepricing, in the presence of customer switching:*

1) *When* $v < v_T^F$*, retailers' profile is the same as in the absence of customer switching.*
2) *When* $v \geq v_T^F$*, let* μ_A^{FT} *and* μ_C^{FT} *be the unique solutions in* μ *that satisfy* $\pi^{FT}(A,A) = \pi_1^{FT}(C,A)$ *and* $\pi^{FT}(C,C) = \pi_2^{FT}(C,A)$*, where* $\pi^{FT}(A,A) = \frac{td_m}{2}$, $\pi^{FT}(C,C) = \frac{t}{2}$, $\pi_1^{FT}(C,A) = \frac{t(1+M^F)^2}{2}$,

$\pi_2^{FT}(C,A) = \frac{td_m(1-M^F)^2+2N^F(M^F)}{2}$, $M^F = Max\{\frac{2((v-2t-2c)(1-\mu)+c)(z-1)}{(5+8d_m)t}, \frac{v-c-2t}{2t}, \frac{2(d_m-1)}{3}\}$ *and* $N^F(x) = (d_m(3tx+c)-cz)\hat{x}(p^{FT}) + (p_1^{FT}(d_m-1)-c(z-1))\alpha_2^T(p^{FT})$, *and let* $\underline{v}^F$ *be the unique solution in* v *that satisfies* $\mu_A^{FT} = \mu_C^{FT}$, *then:*

a. $v_T^F \le v < \underline{v}^F$, *retailers adopt symmetric profile* (A,A) *when* $\mu \in [0, \mu_A^{FT})$ *but adopt symmetric profile* (C,C) *when* $\mu \in [\mu_A^{FT}, 1]$.

b. $v \ge \underline{v}^S$, *retailers adopt symmetric profile* (A,A) *when* $\mu \in [0, max(\mu_A^{FT}, 0))$, *adopt an asymmetric profile when* $\mu \in [max(\mu_A^{FT}, 0), \mu_C^{FT})$, *but adopt symmetric profile* (C,C) *when* $\mu \in [\mu_C^{FT}, 1]$.



Note. In Area IV, retailers can adopt a symmetric profile to be either ambitious or cautious, while the former is Pareto dominating.

Figure 5. Equilibrium strategic profiles under prepricing in the presence of customer switching

In the presence of customer switching, under the same forces driving equilibrium formation, retailers' strategy profiles are similar in structure under prepricing to those under prestocking. A notable difference is that retailers have a stronger incentive to adopt differential strategies under prepricing in optimistic market conditions. Recall that retailers face weaker pricing pressure under prestocking than under prepricing, and the influence is stronger on an ambitious retailer than on a cautious retailer and becomes more obvious as the market condition becomes more optimistic. The profitability gain to a retailer by being cautious rather than ambitious is higher under prepricing than

under prestocking. When the market condition is sufficiently optimistic, the increase in profitability can be so large as to outweigh the market-reduction effect and incentivize a retailer to diverge from an ambitious competitor. In this situation, since a retailer has an incentive to diverge from a cautious competitor, incentive alignment sustains the asymmetric profile under prepricing, whereas retailers would converge to be ambitious under prestocking.

The effects of customer switching on retailers' strategic adjustments and profit performance are robust with respect to the decision sequence. Table A5 in the appendix presents the comparison outcomes for the stocking quantities, prices, and profits for retailers under prepricing with and without customer switching. Proposition A1 in the appendix summarizes the effects of customer switching on retailers' strategies and profits. The key insights obtained for the case where retailers practice prestocking prevail under prepricing. Strategic divergence to manage spillover demand for profit enhancement, which is a valid choice to deal with customer switching, is more prevalent than it is under prestocking but results in more frequent stockouts at retailers under prepricing in optimistic market conditions.

5.4. Impacts of decision sequence

The decision sequence subtly influences how retailers use pricing and stocking to manage demands and make profits. We detail below how the decision sequence affects their profits.

Proposition 6. *Between the two decision sequences:*

1) In the absence of customer switching, retailer profits are higher under prestocking when $0 \leq \mu \leq \hat{\mu}^N$ *where* $\hat{\mu}^N < \mu_A^{FN}$*, but are higher under prepricing otherwise.*

2) In the presence of customer switching,

a) When retailers adopt a symmetric profile under prestocking but adopt an asymmetric profile under prepricing, prices and profits are higher under prestocking when the market condition is sufficiently optimistic.

b) *When retailers adopt an asymmetric profile under prestocking but adopt a symmetric profile under prepricing, prices and profits are higher under prepricing when the market condition is sufficiently pessimistic.*

Part 1 of proposition 6 presents the comparison outcomes for the two decision sequences in the absence of customer switching. Recall that, under prestocking, once stocking quantities are set, procurement costs are sunk, and retailers set prices to balance revenues across market states. Under prepricing, they set prices prior to stocking quantities to balance procurement costs and revenues. Wherever the retailers always converge in operations (to be ambitious when $0 \leq \mu \leq \mu_A^{FN}$ and to be cautious when $\mu_A^{SN} < \mu \leq 1$), their stocking quantities are the same under the two sequences. When the market condition is sufficiently optimistic ($0 \leq \mu \leq \hat{\mu}^N$), the weakened pricing pressure under prestocking enables retailers to price higher and profit more than under prepricing. Otherwise, cost considerations force retailers to price higher and, with the same stocking quantities, enable them to profit more under prepricing. Retailers converge to be ambitious under prestocking but cautious under prepricing in medium market conditions ($\mu_A^{FN} < \mu \leq \mu_A^{SN}$). In this case, they stock more and therefore expose to a higher overstocking risk, and price lower to profit less under prestocking than under prepricing.

Part 2 shows the results when the retailers adapt strategies for customer switching under only one decision sequence. In the case where they adopt differential strategies only under prepricing, retailers make more profits than they do under prestocking when the market condition is optimistic. Strategic divergence enables the ambitious retailer to make spillover sales and the cautious retailer to occupy a larger market share in local selling under prepricing. However, their sales gains are not sufficient to compensate for reductions in average profits relative to those under prestocking. In the case where retailers adopt differential strategies only under prestocking, as the market condition turns pessimistic, they both price lower, the ambitious retailer faces a higher overstocking loss, and

the cautious retailer suffers a reduction in market share relative to the case under prepricing, causing both of them to profit less.

Comparing retailers' profits under the two sequences in other circumstances is tedious due to the multitude of scenarios that can arise as they adapt strategies for customer switching. We resort to a systematic numerical study to generate more insights. Similar to the case when customer switching is absent, we find that a threshold, say $\hat{\mu}^T$, exists such that retailers profit more by prestocking when the market condition is optimistic ($0 \leq \mu \leq \hat{\mu}^T$) but by prepricing when the market condition is pessimistic ($\hat{\mu}^T < \mu \leq 1$). The value of $\hat{\mu}^T$ is close to that of $\hat{\mu}^N$ in most instances. We conclude that retailers have a robust decision sequence preference provided that they adopt the proper strategies to deal with customer switching.

6. Concluding Remarks

We have analyzed joint price and stock competition between duopolistic retailers in the presence of customer switching. Before the actual market size is realized, retailers decide prices prior to stocking quantities under prepricing but apply the reverse decision sequence under prestocking. After the actual market size is realized, each customer visits a retailer to maximize utility that depends on price and feature preference. The customers who visit a retailer form its local demand. Customers with unmet demand at the local retailer may continue to look for the product at the other retailer provided that they receive a nonnegative utility. Retailers' prices determine their market shares and influence customers' tendency to switch upon stockout, and their stocking quantities cap their sales quantities and adjust the scale of the spillover demand.

In the absence of customer switching, retailers always converge in operations. They adopt a symmetric profile to stock and price high (low) when market conditions are optimistic (pessimistic). The rise of customer switching ushers in a potential stream of spillover demand. Product value and market condition are crucial factors influencing whether and how they adapt strategies to manage this phenomenon. Diverging to adopt differential strategies can be a valid choice. The low-price

retailer makes a higher risk-free profit by selling to local demand only than is made before strategy adaptation, while the high-price retailer profits more from balancing pricing and selling to a larger effective demand that includes spillover demand. The strategic divergence option becomes more attractive as the product value increases, which potentially expands the stream of spillover demand. However, by intensifying the strategic interactions between retailers, customer switching can force them to converge to be cautious and choose to encounter stockouts, whereas they could be better off by converging to be ambitious to price and stock more ambitiously, which they would do absent customer switching. This is the situation in which retailers may devise effective means to deter customer switching.

Stockout can become more frequent as a consequence of retailers' strategic adaptation for stockout-triggered customer switching. Specifically, stockout can occur when retailers diverge in operations, in which case, they create stock imbalance, with some in stock and others out of stock, in the high market state to generate spillover demand. It can also occur when the intensified strategic pressure arising from customer switching forces retailers to choose to encounter stockouts. In either situation, retailers would prepare sufficient stocks to satisfy demand in the absence of customer switching. These findings are robust with respect to the decision sequence. Compared to prepricing (pricing prior to stocking), prestocking (stocking prior to pricing) weakens retailers' incentive for strategic divergence to deal with customer switching when the market condition is optimistic. Moreover, irrespective of the presence of customer switching, retailers profit more under prestocking in optimistic market conditions but profit more under prepricing in pessimistic market conditions, provided that they adapt their strategies appropriately.

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