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Omnichannel Retail Operations with Buy-Online-and-Pick-up-in-Store

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Abstract. Many retailers have recently started to offer customers the option to buy online and pick up in store (BOPS). We study the impact of the BOPS initiative on store operations. We build a stylized model where a retailer operates both online and offline channels. Customers strategically make channel choices. The BOPS option affects customer choice in two ways: by providing real-time information about inventory availability and by reducing the hassle cost of shopping. We obtain three findings. First, not all products are well suited for in-store pickup; specifically, it may not be profitable to implement BOPS on products that sell well in stores. Second, BOPS enables retailers to reach new customers, but for existing customers, the shift from online fulfillment to store fulfillment may decrease profit margins when the latter is less cost effective. Finally, in a decentralized retail system where store and online channels are managed separately, BOPS revenue can be shared across channels to alleviate incentive conflicts; it is rarely efficient to allocate all the revenue to a single channel.

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Keywords: retail operations • omnichannel • strategic customer behavior • decentralization

1. Introduction

As customers become accustomed to online shopping, brick-and-mortar retailers have increasingly supplemented their shops with online businesses (Jopson 2013). The online channel has traditionally been viewed as a separate way to sell products. Today, however, many retailers have realized the need to integrate their existing channels to enrich customer value proposition and improve operational efficiency. As a result, there is an emerging focus on “omnichannel retailing” with the goal of providing customers with a seamless shopping experience through all available shopping channels (Bell et al. 2014, Brynjolfsson et al. 2013, Rigby 2011). When asked about omnichannel priorities, the retailers surveyed by Forrester Research reported that fulfillment initiatives ranked higher than any other channel integration program; moreover, among all omnichannel fulfillment initiatives, allowing customers to buy online and pick up in store (BOPS) is regarded as the most important one (Forrester Research 2014). According to Retail Systems Research (RSR), as of June 2013, 64% of retailers have implemented BOPS (Rosenblum and Kilcourse 2013).

Retailers benefit from allowing customers to pick up their online orders in store. Specifically, BOPS generates store traffic and potentially increases sales (Clifford 2011). According to a recent UPS study, among those who have used an in-store pickup option, 45% of

them have made a new purchase when picking up the purchase in store (UPS 2015). Typically, a substantial amount of store sales is generated through such cross-selling: it is estimated that, on average, when a customer comes to the store intending to buy \$100 worth of merchandise, they leave with \$120 to \$125 worth of merchandise (Halzack 2015). Thus, unsurprisingly, more and more retailers are starting to offer the BOPS functionality on their websites (Rosenblum and Kilcourse 2013).

A key challenge facing retailers is to choose the right set of products for BOPS. Most retailers generally agree that BOPS should not be a blanket functionality that is blindly applied to all products across all categories. According to senior vice president and general manager of Walmart.com, Steve Nave, one of the reasons for being selective is to focus on those products that would “drive more customers into the stores” (Tuttle 2011). On the websites of major retailers such as Toys “R” Us, customers will find that some products are not eligible for BOPS. For example, new releases such as the LEGO Star Wars Sith Infiltrator are not available for store pickup. These items are sold in stores, but shoppers need to check their local stores for availability if they do not wish to wait for online delivery. In contrast, for most of the extensive line of LEGO products sold on toysrus.com, the BOPS option is available. Since retailers typically carry large numbers of SKUs

online, a key challenge is to understand the main criteria for selecting which product to allow for in-store pickup.

Many retailers regard BOPS as a way to reach new customers, as this new fulfillment option has become increasingly popular among shoppers (Clifford 2011). With BOPS, customers experience instant gratification, avoid shipping and delivery changes, and enjoy the convenience of hassle-free shopping (their items have already been picked and packed by store staff by the time they arrive). With this unique combination that has never been offered before, it is not unrealistic for retailers to expect market expansion. However, another more pessimistic view is that BOPS simply shifts customers from online fulfillment to store fulfillment; customers who use BOPS would have purchased online anyway. To understand the impact of BOPS on retailers' bottom lines, it is useful to distinguish between the demand cannibalization and demand creation scenarios described above.

The advent of BOPS blurs the distinction between store and online operations. Although BOPS orders originate online, they are fulfilled using inventory in retail stores. Consequently, a successful BOPS implementation requires good coordination between the online and offline channels. Very few retailers have completely dismantled their online and offline channel silos, maintaining a single accounting ledger with an associated organizational structure for all sales regardless of channel (Forrester Research 2014). When online and offline channels are operated by separate teams, the company needs to decide how to allocate BOPS revenue. On this subject, there is no consensus: 46% of retailers allow the online channel to receive full credit for the transaction, 31% award full credit to the store channel, and 23% divide them between channels (Forrester Research 2014). This lack of consensus is not surprising, since both channels have legitimate reasons to claim credit. The store incurs operating costs for fulfilling demand, whereas the online channel is the source of demand in the first place.

In this paper we focus on the following research questions:

1. For what types of product will the BOPS option be profitable?
2. How does BOPS impact the retailer's customer base?
3. How should BOPS revenue be allocated between store and online channels?

To address these questions, we develop a stylized model that captures essential elements of omnichannel retail environments. There is a retailer who operates online and store channels, with the goal of maximizing total expected profit over both channels. Customers strategically choose among buying online, buying in store, and buying online for store pickup, to maximize

individual utility. We first analyze the centralized system; specifically, for a particular product with given financial parameters, we study optimal inventory decisions under BOPS and examine the impact of BOPS on total profits. Using these results, we determine whether a product should be carried in store and whether BOPS should be offered. Finally, we consider the decentralized system and examine how to allocate BOPS revenue between channels.

Our first main finding is that BOPS may not be suitable for all products. Specifically, for products that are bestsellers in retail stores, the benefit of BOPS may be outweighed by the drawback, which is as follows. Since products that are available for store pickup must be in stock, BOPS indirectly discloses real-time store inventory status. Customers initiating a BOPS order online and finding that the desired item is out of stock will not visit the store. In this way, stockouts of blockbuster products may drive customers away, thus reducing store traffic and cross-selling opportunities. In other words, BOPS may compromise the function of best-selling products in attracting customers to the store.

Our second result is that BOPS helps retailers expand their market coverage. Because BOPS mitigates the stockout risk and hassle costs during the shopping journey, more people will be willing to consider buying from the retailer. However, apart from attracting new customers, BOPS can also sway the channel choices of existing customers. Among these existing customers, some who had waited for their orders to be shipped to them (i.e., online fulfillment) may now choose to pick up their orders (i.e., store fulfillment) instead. This shift is unprofitable if the profit margin is lower in stores compared to the online channel.

Finally, in decentralized systems where store and online channels are operated by separate entities, we identify a misalignment of incentives. Specifically, the store neglects the fact that potential BOPS customers may purchase online instead when there is no stock in the store for them to pick up. Online sales generate value for the company, but the store is not explicitly compensated when they occur. Consequently, the store stocks too much inventory if they retain 100% of BOPS revenue. To correct for this potential incentive problem, it is optimal to give the store channel partial credit for fulfilling BOPS demand.

2. Literature Review

This paper studies the management of online and offline channels. With the advent of e-commerce around the turn of the century, many manufacturers or suppliers introduced a direct online selling channel, which competes with their own retail partners. Much of the literature on channel management studies this type of business setting. Chiang et al. (2003) study a price setting game between a manufacturer and its independent

retailer. They find the manufacturer is more profitable even if no sales occur in the direct channel, because the manufacturer can use the direct channel to improve the functioning of the retail channel by preventing the prices from being too high, leading to more sales or orders from the retailer. Some other papers also study the pricing game but are more concerned with specific pricing mechanisms, e.g., price matching between channels (Cattani et al. 2006) and personalized pricing (Liu and Zhang 2006). Apart from pricing, Tsay and Agrawal (2004) consider firms' sales effort and find that both parties can benefit from the addition of a direct channel. Chen et al. (2008) study service competition between the two channels and characterize the optimal channel strategy for the supplier. Netessine and Rudi (2006) study the practice of drop-shipping, where the supplier stocks and owns the inventory and ships products directly to customers at retailers' request. In contrast to this stream of work, our paper focuses on a single retailer who manages both online and store channels, as commonly observed in retail environments today.

Omnichannel management has received a lot of attention in industry; the topic is broadly surveyed in Bell et al. (2014), Brynjolfsson et al. (2013), and Rigby (2011). In addition, there are a few other papers. Ansari et al. (2008) empirically study how customers migrate between channels in a multichannel environment and the role of marketers in shaping migration through their communications strategy. Chintagunta et al. (2012) study customer channel choice in grocery stores and empirically quantify the relative transaction costs when households choose between the online and offline channels. Ofek et al. (2011) focus on the impact of product returns on a multichannel retailer and use a theoretical model to examine how pricing strategies and physical store assistance levels change as a result of the additional online outlet. Gallino and Moreno (2014) empirically investigate the impact of BOPS on a retailer's sales in both online and offline channels. Interestingly, they find that instead of increasing online sales, the implementation of BOPS is associated with a reduction in online sales and an increase in store sales and traffic. Whereas most papers in this area are empirical, our paper develops a tractable theoretical framework. Using our model, we study omnichannel inventory management and channel coordination within the firm.

There are models in operations management that study the role of inventory availability on demand, given that customers have to incur hassle costs and bear the stockout risk when visiting stores. Dana and Petruzzi (2001) is the first paper that extends the classic newsvendor model by assuming demand is a function of both price and inventory level. Since then, many researchers have investigated how to attract people to

pay the hassle cost to come to the store: Su and Zhang (2009) show that it is always beneficial to the retailer if he can credibly make an *ex ante* quantity commitment. Yin et al. (2009) compare the efficacy of two different in-store inventory display formats to manipulate customer expectations on the availability. Allon and Bassamboo (2011) explore the issue of cheap talk when the information shared by the retailer is not verifiable. Alexandrov and Lariviere (2012) examine the role of reservations in the context of revenue management. Cachon and Feldman (2015) focus on retailer's pricing issue and find that a strategy that embraces frequent discounts is optimal. In this paper we study a new way to attract customers to store, BOPS, by which the retailer shares with customers the real-time information about store inventory status.

A critical feature of our model is that customers will make additional purchases once they enter the store. There are many papers in marketing (e.g., Li et al. 2005, Akçura and Srinivasan 2005, Li et al. 2011) and operations management (e.g., Netessine et al. 2006, Gurvich et al. 2009, Armony and Gurvich 2010) examining how to make use of the cross-selling opportunities during the interaction with customers. In this paper, instead of studying the design of a cross-selling strategy, we will focus on the impact of cross-selling benefits on the implementation of the new omnichannel fulfillment strategy, i.e., BOPS.

This paper provides a different angle to the stream of work on strategic customer behavior in retail management. Su (2007) studies a dynamic pricing problem with a heterogeneous population of strategic as well as myopic customers and shows that optimal price paths could involve either markups or markdowns. Aviv and Pazgal (2008) study two types of markdown pricing policies (i.e., contingent and announced fixed-discount) in the presence of strategic customers. There is a rich body of work on operational strategies that consider strategic customers, e.g., capacity rationing (Liu and van Ryzin 2008), supply chain contracting (Su and Zhang 2008), quick response (Cachon and Swinney 2009), opaque selling (Jerath et al. 2010), posterior price matching (Lai et al. 2010), and product rollovers (Liang et al. 2014). Most of the existing literature consider models in which customers decide whether to make an immediate purchase or to wait for future discounts. In contrast, our paper concentrates on customers' channel choice. In other words, instead of studying the decision of *when* to buy, we pay attention to the decision of *where* to buy.

The topic of decentralization has been studied by many researchers in the operations management area. There are two streams of literature, focusing on *inter-firm* and *intra-firm* coordination. For the former, there is a large body of literature on the design of optimal contracts to optimize supply chain performance; see, for

example, Lee and Whang (1999), Taylor (2002), Cachon and Lariviere (2005). Readers can refer to Cachon (2003) for a comprehensive review. The other research stream addresses conflicts of interest within a firm. Harris et al. (1982) study an intrafirm resource allocation problem where different divisional managers of the firm possess private information that is not available to the headquarters. Porteus and Whang (1991) examine different incentive plans to coordinate the marketing and manufacturing managers of the firm. A similar cross-functional coordination problem is also studied by Kouvelis and Lariviere (2000). In retail assortment planning, Cachon and Kök (2007) study category management, where each category is managed separately by different managers. In line with this research stream, we look at incentive conflicts between the store channel and the headquarters of an omnichannel retailer.

3. Model

There is a retailer who sells a product through two channels, store and online, at price p . In the store channel, the retailer faces a newsvendor problem: there is a single inventory decision q to be made before random demand is realized, so there may eventually be unmet demand or leftovers in the store. The unit cost of inventory is c , and the salvage value of leftover units is normalized to zero. The online channel is modeled exogenously: the retailer simply obtains a net profit margin w from each unit of online demand. This model focuses on store operations and can be separately applied to any particular product the retailer carries.

The market demand D is random and follows a continuous distribution F and density f . Customers choose between store and online channels to maximize their utility. Each individual customer has valuation v for the product. When shopping in store, each customer incurs hassle cost h_s (e.g., traveling to the store or searching for the product in aisles); similarly, when shopping online, each customer incurs hassle cost h_o (e.g., paying shipping fees or waiting for the product to arrive). There is a key difference between store and online hassle costs: h_s is incurred *before* customers find and purchase the product in the store, whereas h_o is incurred *after* customers make the purchase online. To ensure that customers are willing to consider both channels, we assume that both hassle costs are smaller than the surplus $v - p$.

We first consider the scenario before BOPS is introduced; here, each customer makes a choice between shopping online directly or going to the store. If she chooses to buy online directly, her payoff is simply given by

$$u_o = v - p - h_o.$$

On the other hand, if she chooses to go to the store, her payoff is

$$u_s = -h_s + \hat{\xi}(v - p) + (1 - \hat{\xi})(v - p - h_o).$$

To understand this expression, note that the customer first incurs the hassle cost h_s upfront. Then, once she is in the store, she may encounter two possible outcomes: (1) if the store has inventory, then she can make a purchase on the spot and receive payoff $v - p$; (2) if the store is out of stock, she can go back to buying the product online and receive payoff $v - p - h_o$. The customer expects the former to occur with probability $\hat{\xi}$. Based on this belief, the customer compares the expected utility from each channel and chooses accordingly.

Next, we consider retailer's decision problem. First, the retailer anticipates that a fraction $\hat{\phi} \in [0, 1]$ of customers will visit the store; i.e., if total demand is D , the retailer expects that the number of customers coming to the store will be $\hat{\phi}D$. Given this belief, the retailer's profit function is

$$\begin{aligned} \pi(q) = & pE \min(\hat{\phi}D, q) - cq + rE(\hat{\phi}D) \\ & + wE((1 - \hat{\phi})D) + wE(\hat{\phi}D - q)^+. \end{aligned} \quad (1)$$

Given the store inventory level q , the newsvendor expected profit from selling the product in the store channel is shown in the first two terms above. In addition, since customers tend to make additional purchase when they come to the store (UPS 2015, Halzack 2015), there is an additional profit r from every customer coming to the store; this is the third term in the profit function above. The last two terms above show the retailer's online profit. The fourth represents profit from customers who shop online directly, and the last represents profit from customers who switch to online after encountering stockouts in store. With the profit function above, the retailer chooses q to maximize expected profit.

To study the strategic interaction between the retailer and the customers, we shall use the notion of rational expectations (RE) equilibrium (see Su and Zhang 2008, 2009; Cachon and Swinney 2009). One important feature of a RE equilibrium is that beliefs must be consistent with actual outcomes. In other words, the retailer's belief $\hat{\phi}$ must coincide with the true proportion ϕ of customers choosing the store channel, and customers' beliefs over in-store inventory availability probability $\hat{\xi}$ must agree with the actual in-stock probability corresponding to the retailer's chosen quantity q . According to Deneckere and Peck (1995) and Dana (2001), this probability is given by $A(q) = E \min(\phi D, q) / E(\phi D)$ where $\phi > 0$. The reason is as follows. Conditional on her own presence in the market, an individual customer's posterior demand density is $g(x) = xf(x)/ED$. Therefore, given this posterior demand density, the

availability probability is $\int (\min(\phi x, q)/\phi x)g(x)dx = A(q)$, since the product is available with probability $\min(\phi x, q)/\phi x$ when there are x customers in the market. Then, we have the following definition for a RE equilibrium. Henceforth, we refer to the RE equilibrium as “equilibrium” for brevity.

Definition 1. A RE equilibrium $(\phi, q, \hat{\xi}, \hat{\phi})$ satisfies the following:

- (i) Given $\hat{\xi}$, if $u_s \geq u_o$, then $\phi = 1$; otherwise $\phi = 0$.
- (ii) Given $\hat{\phi}$, $q = \arg \max_q \pi(q)$, where $\pi(q)$ is given in (1).
- (iii) $\hat{\xi} = A(q)$.
- (iv) $\hat{\phi} = \phi$.

Conditions (i) and (ii) state that under beliefs $\hat{\xi}$ and $\hat{\phi}$, customers and the retailer are choosing the optimal decisions. Conditions (iii) and (iv) are the consistency conditions.

First, it is easy to see that there always exists a *nonparticipatory* equilibrium $(0, 0, 0, 0)$. If the retailer expects no one comes to the store to buy the product, he will stock nothing there, i.e., $q = 0$; If customers believe there is no inventory in the store, they will not come, i.e., $\phi = 0$. In the end, we have a self-fulfilling prophecy and beliefs are trivially consistent with the actual outcome.

Is there any *participatory* equilibrium where customers are willing to visit store and the retailer has stock in the store as well (i.e., $\phi = 1$ and $q > 0$)? When such an equilibrium exists, it Pareto-dominates the nonparticipatory equilibrium, because it generates positive payoffs for both the retailer and customers. We shall adopt the Pareto dominance equilibrium selection rule. The following proposition gives the equilibrium result; we use the superscript $(\cdot)^\circ$ to denote the equilibrium outcome for this basic scenario. All proofs are presented in Supplementary Appendix A.

Proposition 1. If $h_s \leq \xi^\circ \cdot h_o$ and $p - c > w$, then customers visit store and $q^\circ = \bar{F}^{-1}(c/(p - w))$. Otherwise, no one comes to store and $q^\circ = 0$. Here, $\xi^\circ = E \min(D, \bar{F}^{-1}(c/(p - w)))/ED$ is the equilibrium in-stock probability at the store.

According to Proposition 1, to have positive sales in the store, we need to ensure that the store channel is attractive to both the customers and the retailer. As for the retailer, it is profitable for him to sell through the store channel only if he can get a higher margin by selling offline than online (i.e., $p - c > w$). Nonetheless, even if store fulfillment is attractive to the retailer, store sales can occur only if customers are willing to pay a visit to the store. The first condition of Proposition 1 ensures that (i) the store in-stock probability is large enough, and (ii) the online hassle cost dominates the store hassle cost, so that when put together, customers are willing to risk encountering stockouts and come to

the store. Under the conditions of Proposition 1, there is a participatory equilibrium.

Now we turn to the scenario where the retailer implements BOPS on the product. With this added functionality, customers assess information online and face one of two possible situations. The first possibility is that the product is out of stock at the store and BOPS is not an option; in this case, the customer simply buys from the online channel. The other possibility is that the product is in stock and BOPS is feasible; in this case, the customer chooses where to shop, and we discuss this decision problem below. We stress that with the introduction of BOPS, customers no longer have to form beliefs about inventory availability because this information is immediately accessible online. In other words, a useful by-product of BOPS is inventory availability information, which is provided on a real-time basis.

When BOPS is a viable option, the customer faces a choice between three alternatives: buy online, buy in store, or use BOPS. To distinguish between the last two options, we introduce a new model parameter h_b , which is the hassle cost associated with using BOPS. Although BOPS customers still need to go to the store after making their purchases online, the process is different from buying in store; for example, BOPS customers do not search for products in store because their orders would already have been picked and packed by store staff. Therefore, the BOPS hassle cost h_b differs from the store and online hassle costs h_s, h_o . With this setup, all three alternatives yield the utility $v - p - h_i$, where the hassle cost h_i corresponds to the shopping mode chosen by the customer. In other words, utility maximization boils down to choosing the shopping mode with the lowest cost. When the online channel offers the lowest hassle cost, customers never go to the store. When the store hassle cost is lowest, customers buy in store but only after verifying online that the product is in stock. When the BOPS hassle cost is lowest, customers place orders online for store pickup.

We are now ready to write down the retailer's profit function with BOPS. When customers choose to go to the store (i.e., when the online hassle cost h_o exceeds either the store hassle cost h_s or the BOPS hassle cost h_b), the profit function is

$$\pi(q) = pE \min(D, q) - cq + rE \min(D, q) + wE(D - q)^+.$$

This is because when the store inventory level is q , there are on average $E \min(D, q)$ customers who come to the store, since they come to the store only when a corresponding unit is available. The first two terms above correspond to the newsvendor profit from selling the product, and the third term corresponds to the additional cross-selling profit. Finally, when demand exceeds store inventory, customers who find that the

store is out of stock can still choose to buy online; this yields the last term. In the other case where all customers prefer shopping in the online channel (i.e., when h_o is the smallest hassle cost), the retailer will stock nothing in the store (i.e., $q = 0$) and earn an expected profit $\pi = wED$.

We use superscript (*) to denote the market outcome with BOPS, which is given in the following proposition:

Proposition 2. *If $\min(h_s, h_b) \leq h_o$ and $p - c > w - r$, then customers visit the store and $q^* = \bar{F}^{-1}(c/(p + r - w))$. Otherwise, no one comes to store and $q^* = 0$.*

Proposition 2 (after BOPS) differs from Proposition 1 (before BOPS) in three significant ways. First, the condition $h_s \leq \xi^\circ \cdot h_o$ in Proposition 1 is weakened to $\min(h_s, h_b) \leq h_o$ in Proposition 2; in particular, the term corresponding to the in-stock probability ξ° vanishes. This discrepancy suggests that the risk of stockouts is no longer of concern after the introduction of BOPS. Indeed, BOPS provides real-time inventory information that essentially guarantees availability once an order is placed. In this way, BOPS attracts customers to the store. The second difference is that the condition $p - c > w$ in Proposition 1 is weakened to $p - c > w - r$ in Proposition 2. The former condition requires the margin to be higher in store than online for the retailer to carry the product in store, but the latter condition combines the store margin with the cross-selling benefit. In other words, BOPS makes it more attractive for retailers to carry products in store; because of the cross-selling benefit r , the retailer may wish to carry a product in store even when the store margin is lower than the online margin. However, inventory now becomes more important: with BOPS, the retailer loses both the product margin $p - c$ as well as the cross-selling benefit r in the event of a stockout. This brings us to the third difference between Propositions 1 and 2: the critical fractile, and hence the in-stock probability, is higher with BOPS. This occurs because the underage cost increases from $p - c - w$ to $p - c - w + r$ after the introduction of BOPS. Consequently, the retailer has the incentive to increase inventory to lure more customers to the store.

In summary, we find that BOPS impacts store operations in two main ways. First, BOPS expands the set of products that may be offered at the store. For such products, omnichannel customers who were previously unwilling to buy in store can be swayed by BOPS to visit the store. These products may originally be online exclusives but are now profitable to bring to retail stores. Second, for products that were originally carried at the store, BOPS leads to an increase in the in-stock probability. In other words, the store channels more inventory and would consequently end up with more leftover inventory. Excess inventory appears to be an inevitable downside of BOPS implementations

(Bose 2014); despite this downside, the next section shows that BOPS may be accompanied by increased profits.

4. Information Effect and Convenience Effect

In this section we compare the market outcomes before and after the introduction of BOPS (i.e., Propositions 1 and 2). With the following comparison results, we are able to identify two main effects of BOPS, i.e., the information effect and the convenience effect.

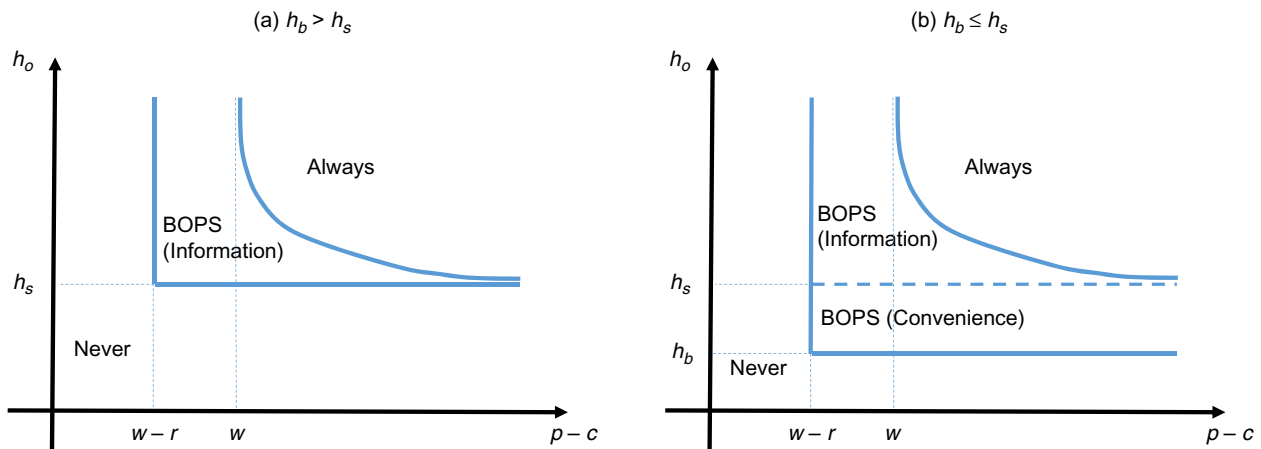
Let us first describe the framework for our analysis. Based on Propositions 1 and 2, we note there are three parameter regions. In some cases, customers who were initially unwilling to visit the store will find the trip more appealing after the BOPS option is made available. In some other cases, BOPS will have no impact on channel choice: customers always prefer a particular channel regardless of the BOPS option. These possibilities are summarized in Figure 1. Specifically, our three parameter regions are as follows:

- i. In the “Always” regions (i.e., $h_s \leq (E \min(D, \bar{F}^{-1} \cdot (c/(p - w)))/ED)h_o$ and $p - c > w$), customers always buy the product in store, regardless of the implementation of BOPS;
- ii. In the “Never” regions (i.e., $\min(h_s, h_b) > h_o$ or $p - c \leq w - r$), customers never come to the store, preferring to buy the product online;
- iii. In the “BOPS” regions (i.e., $h_s > (E \min(D, \bar{F}^{-1} \cdot (c/(p - w) \wedge 1))/ED)h_o$, $\min(h_s, h_b) \leq h_o$ and $p - c > w - r$), customers come to the store only if BOPS is available. The “BOPS” regions are further labeled “Information” or “Convenience” as discussed in the next few paragraphs.

In the following analysis, we will examine the impact of BOPS on the retailer’s profit by separately considering different parameter regions in Figure 1. We begin with the following proposition.

Proposition 3. *If $h_s \in (E \min[D, \bar{F}^{-1}(c/(p - w) \wedge 1)]/ED)h_o, h_o]$ and $p - c > w - r$, then customers visit the store only if BOPS is available. Further, BOPS increases total profit (i.e., $\pi^* > \pi^\circ$).*

The conditions in Proposition 3 correspond to the “BOPS” regions labeled “Information” in Figures 1(a) and 1(b). In these parameter regions, BOPS influences customer shopping behavior through the information sharing mechanism discussed in Section 3. By revealing real-time information about store inventory status, BOPS draws additional customers to the store; these customers were previously unwilling to visit the store because they were discouraged by the possibility of stockouts. In such cases, Proposition 3 confirms that BOPS leads to increased profit for the retailer. This increase in profit arises because the store profit margin

Figure 1. (Color online) Do Customers Buy the Product in Store?

$p - c$, combined with the cross-selling benefit r , exceeds the online margin w . In other words, through information provision, BOPS brings about a demand shift to the more profitable store channel.

There is a subtle difference between the two “BOPS (Information)” regions of Figures 1(a) and 1(b). Although demand shifts to the store in both cases, they occur in different ways. In the “BOPS (Information)” region of Figure 1(a), since the pickup hassle cost h_b exceeds the store hassle cost h_s , offering BOPS induces customers to buy in store after verifying availability online, without actually using the BOPS functionality. On the other hand, in the corresponding region of Figure 1(b), customers indeed buy online and pick up in store when the option is available. We discuss these two behaviors separately in the next two paragraphs.

When customers verify availability online without actually using the BOPS functionality, BOPS simply serves as a source of information. The same market outcome arises if the retailer simply provides real-time availability information on the website (i.e., directly showing whether or not store is in stock). This strategy has been adopted by retailers such as Gap and Levi’s. Our model can be applied to study this pure information sharing mechanism, which can be regarded as a special case with $h_b > h_s$. In this special case, BOPS generates an interesting dynamic: after the implementation of BOPS as an added online functionality, online sales may *decrease*, while store sales may increase. This phenomenon was first identified by Gallino and Moreno (2014), who undertake a comprehensive empirical study of a U.S. retailer with a recent BOPS implementation.

On the other hand, when the pickup process is relatively hassle free, customers will indeed buy online and pick up in store. In this case, apart from eliminating the risk of stockouts as described above, BOPS also provides customers with a more convenient means of shopping. In this sense, comparing the two “BOPS

(Information)” regions in Figures 1(a) and 1(b), customer surplus is higher in the latter than in the former.

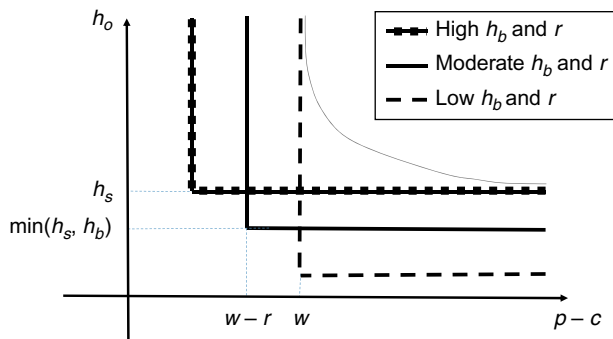
The next proposition examines the “BOPS” region labeled “Convenience” in Figure 1(b).

Proposition 4. *If $h_b \leq h_o < h_s$ and $p - c > w - r$, customers visit the store only if BOPS is available. Further, BOPS increases total profit (i.e., $\pi^* > \pi^\circ$).*

The above result highlights the importance of shopping convenience for BOPS to attract customers to the store. By additionally providing convenience, BOPS becomes more powerful than a pure information sharing mechanism. In the “BOPS (Convenience)” region of Figure 1(b), a pure information sharing mechanism can never attract customers to the store; even if customers are guaranteed availability in store, they still prefer to buy online because the online hassle cost is lower than the store hassle cost (i.e., $h_o < h_s$). However, once BOPS is available and provides convenience that trumps an online order (i.e., $h_b < h_o$), customers may prefer to buy online and pick up in store. This shopping mode benefits the retailer because customers may buy additional products (yielding profit r) when they pick up their products. As long as the store margin $p - c$ and cross-selling benefit r exceeds the online margin w , the convenience dimension of BOPS will lead to increased profit for the retailer.

Proposition 4 provides a word of caution for retailers. Although making the pickup process more convenient is potentially a good way to improve the profitability of BOPS, retailers should exercise care in preserving the cross-selling benefit. In particular, some retailers have introduced drive-through service that allows customers to receive their orders without leaving their cars (Clifford 2012, Shannon 2012). Although this will help to reduce hassle in the pickup process, it will also prevent people from entering the store and thus lead to a loss of the cross-selling benefit r . According to Proposition 4, if the margin from selling this particular product in the store is very high (i.e., $p - c > w$),

Figure 2. (Color online) Impacts of BOPS Hassle Cost h_b and Cross-Selling Benefit r



then it is still profitable for the retailer to implement BOPS even if $r = 0$. However, if profit margins are lower in store than online, then the cross-selling profit r plays an important role; in this case, drive-through service may hurt the retailer's overall profit by neutralizing the advantages of cross-selling.

There is a delicate balance between pickup convenience and cross-selling potential. Whereas customers appreciate a more convenient pickup process, retail managers wishing to make the most out of the cross-selling opportunity may choose to locate the pickup counter at far corners of the store so that shoppers have to walk through the entire store before picking up their online orders (Murphy 2015). This trade-off is illustrated in Figure 2. At one extreme, setting the pickup counter at the back of store maximizes both pickup cost h_b and cross-selling benefit r (i.e., the dotted L-line). At the other extreme, providing drive-through pickup service minimizes both h_b and r (i.e., the dashed L-line). As both h_b and r increase, the L-line in Figure 1 moves up and left, and the "BOPS" region changes. The optimal location of the L curve depends on retailer's portfolio of products. According to Figure 2, if most of the retailer's products have high store profit margins (i.e., $p - c$ is large) and can be purchased easily online (i.e., h_o is small), then the retailer should seek to make the pickup process more convenient; in contrast, if most of the retailer's products have low store profit margins (i.e., $p - c$ is small) and are difficult to purchase online (i.e., h_o is large), then setting the pickup counter far from the store entrance is a better strategy.

The next proposition tells a different side of the story. Although BOPS brings about many benefits, it may lead to reduced profits in some cases.

Proposition 5. *If $h_s \leq (E \min(D, \bar{F}^{-1}(c/(p-w)))/ED)h_o$ and $p - c > w$, customers visit the store regardless of the implementation of BOPS. Further, if $r > 0$, then BOPS decreases total profit (i.e., $\pi^* < \pi^\circ$).*

The conditions of Proposition 5 correspond to the "Always" regions in Figures 1(a) and 1(b). In these

regions, customers choose to visit the store regardless of BOPS. Here, BOPS has an important but easily overlooked effect. Prior to the introduction of BOPS, all customers were already willing to visit the store, but after BOPS is made available, fewer customers will come to the store. This is because customers who attempt to place an order online but find that the item is not in stock for pickup will no longer go to the store. As store traffic decreases, the retailer loses the potential profit from cross-selling. The loss of cross-selling benefits (i.e., whenever $r > 0$) leads to a reduction in total profits, as shown in Proposition 5. Since BOPS can be selectively implemented, our result suggests that the BOPS option should not be offered on products that have been attracting considerable demand to the store.

Our results differ from existing findings in the literature because we study a different information sharing mechanism. In our model BOPS provides real-time information about the store inventory status, i.e., customers are informed that the product is available until inventory runs out. However, in Su and Zhang (2009), the focus is on quantity commitment, i.e., the retailer commits to an initial inventory level in the store. With quantity commitment, the retailer may be able to use a small amount of store inventory to attract a large number of customers to visit the store. In particular, when the cross-selling benefit is very large, the retailer may still choose to stock the product in the store even if it is more profitable to sell online, with the hope of attracting customers to make additional purchases in store. Such a "loss leader strategy" is no longer feasible when the retailer implements BOPS, because customers have access to real-time store inventory information and will not visit the store after the product is out of stock. Therefore, we find that BOPS, by providing real-time inventory information, may decrease profits, whereas Su and Zhang (2009) find that quantity commitment is generally valuable.

In summary, BOPS has two effects: it provides customers with real-time information about in-store inventory availability, and it introduces a new shopping mode that may add convenience to customers. The former effect (information effect) helps attract customers to the store by letting them know about inventory availability, but it is a double-edged sword in that when inventory is not available, it turns away customers who might be willing to visit the store. The latter effect (convenience effect) applies when customers use the store pickup functionality, as opposed to simply using BOPS as a source of availability information; it draws customers to the store and may even open up new sources of demand.

When put together, the information and convenience effects of BOPS yield different profit implications. Figures 1(a) and 1(b) present a clear distinction: in the "BOPS" regions, BOPS leads to higher profits, but in

the “Always” regions, BOPS leads to lower profits. The difference between these two regions is that, prior to the introduction of BOPS, customers were already willing to visit the store in the latter but not in the former. These results suggest that BOPS should be offered for products with weak store sales but not those with strong records to begin with. In other words, it is likely profitable to implement BOPS on in-store “underdogs” but may not be so for in-store “favorites.”

5. Heterogeneous Customers

In this section we incorporate customer heterogeneity. For example, some customers may reside further away from the store than others; some may be more impatient than others and thus are more averse to waiting for online delivery. In our model, the store and online hassle costs h_s, h_o may now differ across customers. Specifically, customers are uniformly distributed across the following “square” $\{(h_s, h_o) \mid h_s \in [0, H], h_o \in [0, H]\}$, where $H > v - p$ (i.e., some customers have a prohibitively high hassle cost in one channel). The goal is to study the impact of BOPS on a retailer’s customer base in such a heterogeneous market.

We begin by considering the scenario in the absence of BOPS. In this case, each customer has three options: go to the store, buy online, or leave the market. The corresponding utilities are as follows:

$$\begin{aligned} u_s &= -h_s + \xi(v - p) + (1 - \xi)u_o^+, \\ u_o &= v - p - h_o, \\ u_l &= 0, \end{aligned}$$

where ξ denotes the belief about store inventory availability as before. Note that customers who find the

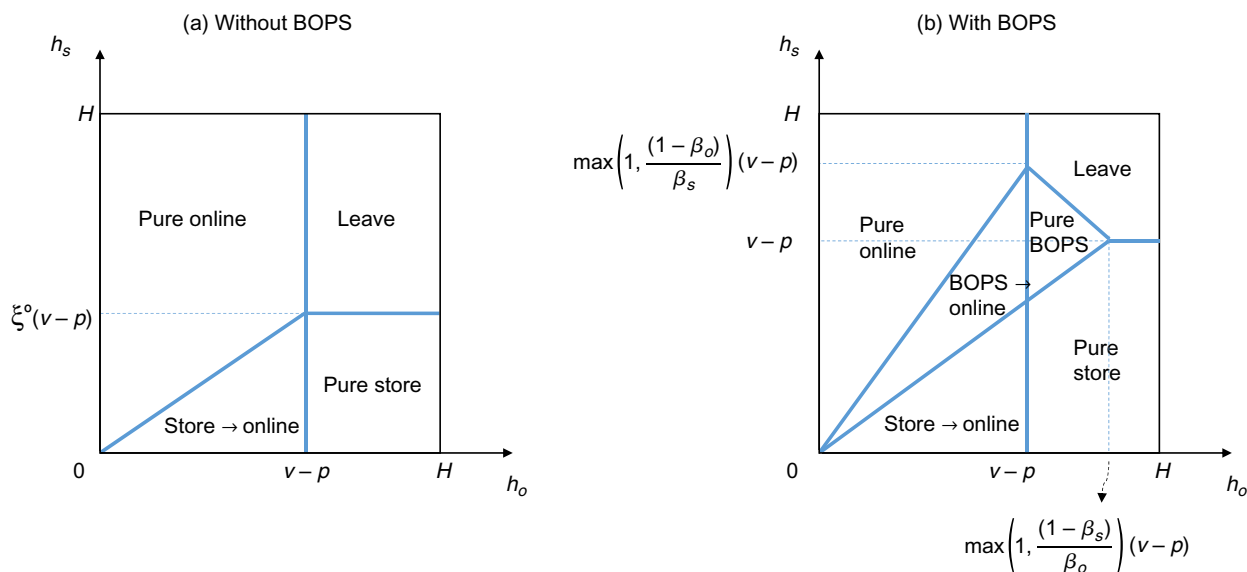
store out of stock will buy online only if doing so is preferred over leaving the market. Because customers make utility-maximizing choices (which depend on their hassle costs h_s, h_o), the market is divided into four segments, as depicted in Figure 3(a). Specifically, there are “pure online” customers (who buy online directly), “store → online” customers (who visit the store but switch online when the store is out of stock), “pure store” customers (who visit the store exclusively), as well as customers who simply leave the market. Denote the fractions of these four types of customer as $\alpha_o, \alpha_{so}, \alpha_s$, and α_l , respectively. Given that customers are uniformly distributed in $\{(h_s, h_o) \mid h_s \in [0, H], h_o \in [0, H]\}$, we can find that $\alpha_o = (v - p)/H - \xi(v - p)^2/(2H^2)$, $\alpha_{so} = \xi(v - p)^2/(2H^2)$, $\alpha_s = (\xi(v - p)(H - (v - p)))/H^2$, and $\alpha_l = [H - (v - p)][H - \xi(v - p)]/H^2$.

On the supply side, the retailer faces the following profit function:

$$\begin{aligned} \pi(q) &= pE \min((\hat{\alpha}_s + \hat{\alpha}_{so})D, q) - cq + rE(\hat{\alpha}_s + \hat{\alpha}_{so})D \\ &\quad + wE\hat{\alpha}_oD + wE \frac{\hat{\alpha}_{so}}{\hat{\alpha}_s + \hat{\alpha}_{so}}((\hat{\alpha}_s + \hat{\alpha}_{so})D - q)^+ \end{aligned} \quad (2)$$

where $\hat{\alpha}_o, \hat{\alpha}_{so}, \hat{\alpha}_s$, and $\hat{\alpha}_l$ denote the retailer’s beliefs over the α ’s above. Given the store inventory level q , the newsvendor expected profit from selling the product in the store channel is shown in the first two terms above. The third term captures the additional cross-selling profit r from every customer coming to the store. The last two terms above show the retailer’s online profit. The fourth represents profit from customers who shop online directly; the last represents profit from customers who switch to online after encountering stock-outs in store, in which case we assume store customers have equal chance of being rationed. With the profit

Figure 3. (Color online) Market Segmentation With and Without BOPS



function above, the retailer chooses q to maximize expected profit.

Definition 2. A RE equilibrium $(\alpha_o, \alpha_{so}, \alpha_s, \alpha_l, q, \hat{\xi}, \hat{\alpha}_o, \hat{\alpha}_{so}, \hat{\alpha}_s, \hat{\alpha}_l)$ satisfies the following:

- (i) Given $\hat{\xi}$, then $\alpha_o = (v - p)/H - \hat{\xi}(v - p)^2/(2H^2)$, $\alpha_{so} = \hat{\xi}(v - p)^2/(2H^2)$, $\alpha_s = (\hat{\xi}(v - p)(H - (v - p)))/H^2$, and $\alpha_l = [H - (v - p)][H - \hat{\xi}(v - p)]/H^2$.
- (ii) Given $\hat{\alpha}_o, \hat{\alpha}_{so}, \hat{\alpha}_s$ and $\hat{\alpha}_l$, $q = \arg \max_q \pi(q)$, where $\pi(q)$ is given in (2).
- (iii) $\hat{\xi} = A(q)$, where $A(q) = E \min((\alpha_s + \alpha_{so})D, q)/E(\alpha_s + \alpha_{so})D$.
- (iv) $\hat{\alpha}_s = \alpha_s$, $\hat{\alpha}_o = \alpha_o$, $\hat{\alpha}_{so} = \alpha_{so}$ and $\hat{\alpha}_l = \alpha_l$.

The following proposition gives the RE equilibrium. As before, we use the superscripts \cdot° and \cdot^* to denote the no-BOPS and BOPS scenario, respectively.

Proposition 6. If $p - c > w(v - p)/(2H - (v - p))$, then there are customers visiting store ($\alpha_s^\circ = \xi^\circ(v - p)(H - (v - p))/H^2 > 0$, $\alpha_{so}^\circ = \xi^\circ(v - p)^2/(2H^2) > 0$) and $q^\circ = (\alpha_s^\circ + \alpha_{so}^\circ)\bar{F}^{-1}(c/(p - w(v - p)/(2H - (v - p))))$, where the equilibrium store in-stock probability is $\xi^\circ = \min(D, \bar{F}^{-1}(c/(p - w(v - p)/(2H - (v - p)))))/ED$. Otherwise, no one comes to store and $q^\circ = 0$, $\xi^\circ = 0$.

Next, we turn to the scenario where the retailer implements BOPS on the product. When a customer uses BOPS, she experiences hassle in both online and offline worlds. For example, she needs to go through the online payment process, and she also has to go to the store to pick up the product. As a result, we assume the hassle cost of using BOPS is given by $h_b = \beta_s h_s + \beta_o h_o$, where $\beta_s, \beta_o \in (0, 1)$. Further, as explained before, all customers have access to information about store inventory status before they visit the store.

Now, we consider customer choice in the presence of BOPS. There are two cases to consider. First, when the store is in stock, the customer faces a choice between four alternatives: buy online (with payoff $v - p - h_o$), buy in store (with payoff $v - p - h_s$), use BOPS (with payoff $v - p - h_b$), or leave (with payoff 0). Based on their individual hassle costs, customers choose their shopping mode with the highest payoff. Second, when the store is out of stock, only customers with $h_o < v - p$ will choose to buy online, while the rest will leave. With the above decisions, the market is divided into six segments, as depicted in Figure 3(b). In addition to the four segments described before, we now see “BOPS → online” customers (who use BOPS if the store is in stock but switch online otherwise) and “pure BOPS” customers. Denote the fraction of these two new types of customer as α_{bo}^* and α_b^* . We can calculate the sizes of these six customer segments as follows:

$$\alpha_i^* = \iint_{A_i^*} \frac{1}{H^2} dh_s dh_o, \quad i = o, so, s, l, bo, b,$$

where

$$\begin{aligned} A_o^* &= \{(h_s, h_o) \mid v - p - h_o > \max(v - p - h_s, v - p - h_b, 0)\}; \\ A_{so}^* &= \{(h_s, h_o) \mid v - p - h_s > \max(v - p - h_o, v - p - h_b, 0), \\ &\quad v - p - h_o > 0\}; \\ A_s^* &= \{(h_s, h_o) \mid v - p - h_s > \max(v - p - h_o, v - p - h_b, 0), \\ &\quad 0 > v - p - h_o\}; \\ A_l^* &= \{(h_s, h_o) \mid 0 > \max(v - p - h_o, v - p - h_s, v - p - h_b)\}; \\ A_{bo}^* &= \{(h_s, h_o) \mid v - p - h_b > \max(v - p - h_o, v - p - h_s, 0), \\ &\quad v - p - h_o > 0\}; \\ A_b^* &= \{(h_s, h_o) \mid v - p - h_b > \max(v - p - h_o, v - p - h_s, 0), \\ &\quad 0 > v - p - h_o\}. \end{aligned}$$

Next, the retailer’s profit function can be expressed as follows:

$$\begin{aligned} \pi(q) &= pE \min((\alpha_s^* + \alpha_b^* + \alpha_{so}^* + \alpha_{bo}^*)D, q) - cq \\ &\quad + rE \min((\alpha_s^* + \alpha_b^* + \alpha_{so}^* + \alpha_{bo}^*)D, q) + wE\alpha_o^*D \\ &\quad + wE \frac{\alpha_{so}^* + \alpha_{bo}^*}{\alpha_s^* + \alpha_b^* + \alpha_{so}^* + \alpha_{bo}^*} \\ &\quad \cdot ((\alpha_s^* + \alpha_b^* + \alpha_{so}^* + \alpha_{bo}^*)D - q)^+. \end{aligned}$$

To understand this expression, note when the store inventory level is q , there are on average $E \min((\alpha_s^* + \alpha_b^* + \alpha_{so}^* + \alpha_{bo}^*)D, q)$ customers who come to the store, since they come to the store only when a corresponding unit is available. The first two terms above correspond to the newsvendor profit from selling the product, and the third term corresponds to the additional cross-selling profit. The last two terms represent the profit from the online channel: the fourth term is the profit from those who buy online directly, while the fifth term is the profit from those who prefer to go to store but buy online instead because of store stockouts.

Proposition 7. When there is BOPS, the market outcome is given as follows:

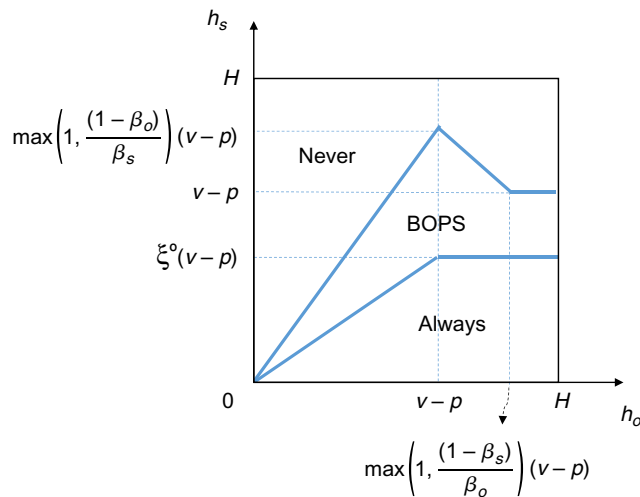
- If $p - c > w((\alpha_{so}^* + \alpha_{bo}^*)/(\alpha_s^* + \alpha_b^* + \alpha_{so}^* + \alpha_{bo}^*)) - r$, then there are customers visiting store and

$$q^* = (\alpha_s^* + \alpha_b^* + \alpha_{so}^* + \alpha_{bo}^*) \cdot \bar{F}^{-1}\left(\frac{c}{p + r - w(\alpha_{so}^* + \alpha_{bo}^*)/(\alpha_s^* + \alpha_b^* + \alpha_{so}^* + \alpha_{bo}^*)}\right).$$

- If $p - c \leq w(\alpha_{so}^* + \alpha_{bo}^*)/(\alpha_s^* + \alpha_b^* + \alpha_{so}^* + \alpha_{bo}^*) - r$, then no one ever comes to store and $q^* = 0$.

With a homogeneous population of customers, we identified three possible scenarios (as shown in Figure 1 in Section 4). Customers may (i) always visit the store, (ii) never visit the store, or (iii) visit the store only after BOPS is implemented. With a heterogeneous customer population, these types of behavior may coexist, as shown in Figure 4 (which is obtained from comparing Figures 3(a) and 3(b)). In other words, there

Figure 4. (Color online) When Do Customers Go to the Store?



are three types of customers, each exhibiting a specific response to BOPS. Moreover, the retailer’s profit from each type of customer follows the same pattern as before. If a customer always visits the store (as those in the “Always” region), then the retailer’s profit from this customer decreases after BOPS is implemented; she stops coming to the store once she knows that the store is out of stock; thus, the retailer loses the potential cross-selling benefit. Next, if a customer visits the store only after BOPS is implemented (as those in the “BOPS” region), then BOPS increases retailer’s profit. Finally, if a customer never shops in the store (as those in the “Never” region), then offering BOPS does not affect the retailer’s profit.

The next proposition shows the impact of BOPS on the retailer’s overall customer base.

Proposition 8. (i) BOPS helps to expand market coverage, i.e., $\alpha_s^* + \alpha_o^* + \alpha_b^* + \alpha_{so}^* + \alpha_{bo}^* > \alpha_s^\circ + \alpha_o^\circ + \alpha_{so}^\circ$.

(ii) Suppose $r = 0$. If there are customers visiting store when there is no BOPS, then there exists \bar{w} such that the implementation of BOPS decreases total profit (i.e., $\pi^* < \pi^\circ$) if $\beta_s + \beta_o < 1$ and $w > \bar{w}$.

Before BOPS is implemented, customers who face high hassle costs in both store and online channels do not consider purchasing from the retailer. Part (i) of Proposition 8 shows that BOPS could provide a way for the retailer to reach these customers. By alleviating the risk of stockouts and reducing the hassle of shopping, BOPS could attract some new customers to join the market. This market expansion effect could also be seen from the reduction of the “leave” region in Figure 3(b) compared to Figure 3(a).

While reaching out to new customers, BOPS may change the behavior of existing customers. Specifically, the more convenient BOPS is, the more existing online customers will choose to pick up their orders in store;

this shift will hurt profits if the store profit margin is lower than the online profit margin. This potential drawback of BOPS may exist even when $r = 0$, as shown in Proposition 8(ii). In other words, apart from possibly eliminating cross-selling opportunities (when $r > 0$) as discovered earlier, BOPS has another potential drawback of shifting demand to a less profitable store channel.

6. Decentralized System

In this section we study the scenario where the store and online channels are operated by two separate teams, with the goal of understanding how BOPS revenue should be allocated. We begin by examining the case with homogeneous customers and then later extrapolate our findings to the case with heterogeneous customers. (A detailed analysis of the decentralized system for the heterogeneous market is given in Supplementary Appendix B.) We assume that the conditions in Proposition 2 hold (i.e., $\min(h_s, h_b) \leq h_o$ and $p - c > w - r$) and BOPS hassle cost is lowest (i.e., $h_b < \min(h_s, h_o)$); otherwise, there would be nobody using BOPS and the issue of revenue allocation becomes irrelevant as the system collapses into two independent channels.

We use $\theta \in [0, 1]$ to denote the share of BOPS revenue that the store obtains. In other words, for every customer who purchases online and picks up in the store, the store earns θp from selling the product. Note that once the customer comes to the store, the store could also get an additional profit r through cross-selling. Therefore, the total revenue that the store could receive from fulfilling each unit of BOPS demand is $\theta p + r$. Then, the store’s expected profit as a function of the stocking decision \tilde{q} is given as follows:

$$\tilde{\pi}_s = (\theta p + r)E \min(D, \tilde{q}) - c\tilde{q}.$$

Here, we use the “tilde” symbol ($\tilde{\cdot}$) to denote the decentralized case.

Proposition 9. In the decentralized system, the store will stock \tilde{q}^* , which is given as follows:

- If $\theta p + r - c > 0$, then $\tilde{q}^* = \bar{F}^{-1}(c/(\theta p + r))$.
- If $\theta p + r - c \leq 0$, then $\tilde{q}^* = 0$.

In practice, according to the survey conducted by Forrester Research (Forrester Research 2014), the two most common revenue sharing schemes are either giving the store full credit (i.e., $\theta = 1$) or letting the online channel keep all the revenue (i.e., $\theta = 0$). According to Proposition 9, when $\theta = 1$, the store will definitely stock the product to serve BOPS users, because he can not only receive a positive profit margin from selling this particular product, but he may also be able to cross sell other products to those who come to store for pickup. However, if $\theta = 0$, BOPS customers represent a pure

cost to the store; then, the store may choose not to stock the product in store, unless the cross-selling benefit is large enough to offset the loss from serving BOPS customers (i.e., $r > c$).

What is the optimal share of BOPS revenue that should be allocated to the store? We use $\tilde{\pi}^*(\theta)$ to denote total profit in the decentralized system with revenue allocation θ . For any given θ , the next proposition compares decentralized and centralized inventory decisions and shows that the store is usually either overstocked or understocked, relative to the centralized benchmark. However, there is an optimal revenue share, under which the decentralized system achieves the centralized optimal profit.

Proposition 10. *Total profit $\tilde{\pi}^*(\theta)$ is quasiconcave in θ . Moreover,*

- if $\theta < (p - w)/p$, then $\tilde{q}^* < q^*$ and $\tilde{\pi}^*(\theta) < \pi^*$;
- if $\theta = (p - w)/p$, then $\tilde{q}^* = q^*$ and $\tilde{\pi}^*(\theta) = \pi^*$;
- if $\theta > (p - w)/p$, then $\tilde{q}^* > q^*$ and $\tilde{\pi}^*(\theta) < \pi^*$.

Proposition 10 points out an incentive conflict between the store channel and the retail organization. If the store channel obtains a large share of BOPS revenue, they tend to stock too much. This is because the store channel considers only store profits but neglects the fact that customers may still be willing to shop online after the store runs out of inventory for customers to pick up. In contrast, if the store is allocated only a small share of BOPS revenue, they tend to stock too little. Since the store channel incurs the inventory cost for fulfilling BOPS demand, it is natural to suppress inventory to decrease exposure to potential losses. In general, it is optimal to give the store partial credit for the revenue earned from BOPS customers. In fact, our result also shows that such a simple revenue sharing mechanism is sufficient for the retailer to fully coordinate the store and online channels.

Proposition 10 shows that the optimal revenue share $\theta^* = (p - w)/p$ coordinates the decentralized system and achieves the centralized optimal profit π^* . With this optimal revenue share, the incentives of the store channel are aligned with the entire organization. According to Proposition 9, the decentralized store channel holds stock if and only if $\theta p + r - c > 0$. However, from the perspective of the entire organization, as we have shown in the previous section, it is optimal to stock the product in the store as long as $p - c > w - r$, i.e., whenever the store margin $p - c$, combined with the cross-selling benefit r , exceeds the online margin w . The revenue share θ that aligns both sets of incentives is precisely $\theta^* = (p - w)/p$.

Note that the optimal share for the store channel $\theta^* = (p - w)/p$ is decreasing in w . The reason is as follows. As the online margin w increases, it becomes more profitable to sell through the online channel. However, in the absence of BOPS, the store will continue to

stock the same amount of inventory since they tend to neglect the profit from online orders. Through sharing the BOPS revenue, the retail organization has a natural way to correct for the misaligned incentive. By allocating less revenue to the store channel for fulfilling BOPS demand, the retail organization can induce the store channel to lower their inventory level. This compensates for the incentive conflict and allows more demand to flow to the more profitable online channel.

Although Proposition 10 shows that the optimal revenue sharing mechanism will achieve full centralized profits in a homogeneous market, Supplementary Appendix B presents a different result for a heterogeneous market. Specifically, when the proportion of customers who use the BOPS functionality is too low, the amount of BOPS revenue to be shared between the channels may be insignificant and as a result, a simple revenue sharing mechanism cannot fully coordinate the omnichannel retail system. The analysis in Supplementary Appendix B highlights the benefit as more customers adopt BOPS: the increased stream of BOPS revenue can provide headquarters with more leverage to alleviate incentive conflicts between the store and online channels.

Omnichannel retailers who recognize the incentive conflicts brought about by BOPS have begun to experiment with simple revenue sharing schemes. A common and simple approach is to assign full credit for the sale of a BOPS item to both store and online channels. In other words, some double counting on internal books is subsequently adjusted. Depending on accounting protocols, this method is usually akin to allocating equal revenue shares to each channel. Since the optimal revenue share may not be 50%, the simple heuristic described above has room for improvement, and our analysis provides a possible way to think about how to do so.

In practice, a retailer may carry a large number of SKUs with different prices and margins. Admittedly, it would be impractical to set a different revenue sharing parameter θ for each SKU. Instead, a retailer may want to have a common θ for a group of products. In such case, since the optimal profit function $\tilde{\pi}^*(\theta)$ is quasiconcave in θ , the optimal θ^* 's given in Proposition 10 for the group of products could serve as benchmarks for the retailer to find a common compromise θ that is close enough to each of the different θ^* 's.

7. Conclusion

In this paper we study a specific omnichannel fulfillment strategy: buy-online-and-pick-up-in-store. We develop a stylized model that captures essential elements of omnichannel retail environments; in particular, customers strategically choose channels for purchase and fulfillment. We find that BOPS attracts customer demand through an information effect and

a *convenience* effect. The former effect arises because BOPS reveals real-time information about store inventory availability. Products that are available for store pick up must be in stock. With this assurance, customers are more willing to visit the store. The latter effect arises because BOPS offers a new and possibly more convenient mode of shopping. By helping customers pick out items and move them to checkout counters, BOPS reduces the hassle of shopping.

Even though BOPS is a popular fulfillment option among customers, we find that retailers need to be cautious when implementing it. Retailers can benefit from this new fulfillment strategy by being selective when choosing the set of products eligible for in-store pickup. BOPS can help attract more customers to the store and thus boost the sales of products that were previously not selling well; however, for store bestsellers, offering the BOPS option may have the unintended consequence of reducing store traffic. Moreover, although BOPS can be a good strategy for a retailer to build up its customer base, BOPS may at the same time drive existing online customers to the store channel where the profit margin might be lower compared to the online channel. Finally, retailers with decentralized operations can maximize profits by allocating BOPS revenue between the online and store channels appropriately, and giving full credit to either channel is seldom optimal.

To simplify the analysis, we have imposed two assumptions in our model: (1) The online channel is exogenous and always in stock, and (2) all customers check the information online when BOPS is offered. As robustness checks, we have built two model extensions to relax the assumptions above. Specifically, in Supplementary Appendix C, we consider the case where the retailer has limited inventory in both the store and online channels; in Supplementary Appendix D, we consider customers who simply head to the store by default (e.g., they may forget or simply not care to check websites beforehand). Our key results remain valid in these model extensions.

Beyond the scope of our current analysis is the potential impact of BOPS on operational costs. On the one hand, BOPS helps to reduce online shipping costs since it transfers the burden of last-mile delivery to customers. On the other hand, BOPS is accompanied by new fulfillment responsibilities wherein a retailer's comparative advantage may not lie. For example, stores need to train their workforce to perform pick-and-pack tasks in a timely fashion (Forrester Research 2014), and to handle increased demand, stores need to hire more employees to deal with online orders (Lutz 2012). A more careful cost-based analysis of BOPS is left as an interesting topic for future research.

Some products, such as clothes, have nondigital attributes that can be communicated only in the offline

channel (Lal and Sarvary 1999). Customers who buy online may not know how much they like the product, and some online purchases may eventually be returned. Gao and Su (2017) develop a similar model where a retailer could deliver product information in an omnichannel environment. One of the information mechanisms they study is virtual showrooms, by which customers can virtually try on a product online; for example, on the website of UK luxury shirt brand Thomas Pink, customers can check the fit of a shirt through a digital avatar. Such informational mechanisms can be a double-edged sword: while they help to reduce online returns, omnichannel customers may not patronize the store after a negative virtual try-on experience. Additional research can further clarify the effectiveness of omnichannel informational strategies.

The omnichannel strategy discussed in this paper, BOPS, addresses purchases that originate online but are completed in the store. In the spirit of Bell et al. (2014), who provide a framework for omnichannel retail, BOPS customers receive information online, but their demand is fulfilled in the store. The reverse type of shopping behavior is where customers research the product in stores and then shop online, usually at lower prices. This is known as showrooming behavior and has been critiqued widely: showroomers and e-tailers are accused of free-riding on inventory displays at brick-and-mortar stores (Zimmerman 2012a, b). Recent research by Balakrishnan et al. (2014) shows that showrooming behavior intensifies retail competition, and Mehra et al. (2013) study how a brick-and-mortar retailer can counteract showrooming behavior through strategies such as price matching and retail club memberships. Taking the e-tailer's perspective, Bell et al. (2013) empirically study the value of providing offline showrooms to mitigate customer uncertainty. We hope that our model in this paper can contribute to this exciting line of research.

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References

- Akçura MT, Srinivasan K (2005) Research note: Customer intimacy and cross-selling strategy. *Management Sci.* 51(6):1007–1012.
- Alexandrov A, Lariviere MA (2012) Are reservations recommended? *Manufacturing Service Oper. Management* 14(2):218–230.
- Allon G, Bassamboo A (2011) Buying from the babbling retailer? the impact of availability information on customer behavior. *Management Sci.* 57(4):713–726.

- Ansari A, Mela CF, Neslin SA (2008) Customer channel migration. *J. Marketing Res.* 45(1):60–76.
- Armony M, Gurvich I (2010) When promotions meet operations: Cross-selling and its effect on call center performance. *Manufacturing Service Oper. Management* 12(3):470–488.
- Aviv Y, Pazgal A (2008) Optimal pricing of seasonal products in the presence of forward-looking consumers. *Manufacturing Service Oper. Management* 10(3):339–359.
- Balakrishnan A, Sundaresan S, Zhang B (2014) Browse-and-switch: Retail-online competition under value uncertainty. *Production Oper. Management* 23(7):1129–1145.
- Bell D, Gallino S, Moreno A (2013) Inventory showrooms and customer migration in omni-channel retail: The effect of product information. Working paper, University of Pennsylvania, Philadelphia.
- Bell DR, Gallino S, Moreno A (2014) How to win in an omnichannel world. *MIT Sloan Management Rev.* 56(1):45–53.
- Bose N (2014) Will in-store pick-up of online sales pay off for retailers? *Reuters* (November 28), <http://www.reuters.com/article/usa-holidaysales-delivery-idUSL2N0TF19820141128>.
- Brynjolfsson E, Hu YJ, Rahman MS (2013) Competing in the age of omnichannel retailing. *MIT Sloan Management Rev.* 54(4):23–29.
- Cachon GP (2003) Supply chain coordination with contracts. Graves S, de Kok T, eds. *Handbooks in Operations Research and Management Science*, Vol. 11 (Elsevier, North Holland, Amsterdam), 227–339.
- Cachon GP, Feldman P (2015) Price commitments with strategic consumers: Why it can be optimal to discount more frequently... than optimal. *Manufacturing Service Oper. Management* 17(3):399–410.
- Cachon GP, Kök AG (2007) Category management and coordination in retail assortment planning in the presence of basket shopping consumers. *Management Sci.* 53(6):934–951.
- Cachon GP, Lariviere MA (2005) Supply chain coordination with revenue-sharing contracts: Strengths and limitations. *Management Sci.* 51(1):30–44.
- Cachon GP, Swinney R (2009) Purchasing, pricing, and quick response in the presence of strategic consumers. *Management Sci.* 55(3):497–511.
- Cattani K, Gilland W, Heese HS, Swaminathan J (2006) Boiling frogs: Pricing strategies for a manufacturer adding a direct channel that competes with the traditional channel. *Production Oper. Management* 15(1):40–56.
- Chen K-Y, Kaya M, Özer Ö (2008) Dual sales channel management with service competition. *Manufacturing Service Oper. Management* 10(4):654–675.
- Chiang W-YK, Chhajed D, Hess JD (2003) Direct marketing, indirect profits: A strategic analysis of dual-channel supply-chain design. *Management Sci.* 49(1):1–20.
- Chintagunta PK, Chu J, Cebollada J (2012) Quantifying transaction costs in online/off-line grocery channel choice. *Marketing Sci.* 31(1):96–114.
- Clifford S (2011) Wal-Mart has a Web plan to bolster in-store sales. *New York Times* (March 10), <http://www.nytimes.com/2011/03/11/business/11shop.html>.
- Clifford S (2012) Luring online shoppers offline. *New York Times* (July 4), <http://www.nytimes.com/2012/07/05/business/retailers-lure-online-shoppers-offline.html>.
- Dana JD Jr (2001) Competition in price and availability when availability is unobservable. *RAND J. Econom.* 32(3):497–513.
- Dana JD Jr, Petruzzini NC (2001) Note: The newsvendor model with endogenous demand. *Management Sci.* 47(11):1488–1497.
- Deneckere R, Peck J (1995) Competition over price and service rate when demand is stochastic: A strategic analysis. *RAND J. Econom.* 26(1):148–162.
- Forrester Research (2014) Customer desires vs. retailer capabilities: Minding the omni-channel commerce gap. Technical report, Forrester Research, McLean, VA.
- Gallino S, Moreno A (2014) Integration of online and offline channels in retail: The impact of sharing reliable inventory availability information. *Management Sci.* 60(6):1434–1451.
- Gao F, Su X (2017) Online and offline information for omnichannel retailing. *Manufacturing Service Oper. Management* 19(1):84–98.
- Gurvich I, Armony M, Maglaras C (2009) Cross-selling in a call center with a heterogeneous customer population. *Oper. Res.* 57(2):299–313.
- Halzack S (2015) From new mobile offerings to a potential off-price business, a look at what's in store for Macy's. *Washington Post* (January 13), <https://www.washingtonpost.com/news/business/wp/2015/01/13/from-new-mobile-offerings-to-a-potential-off-price-business-a-look-at-whats-in-store-for-macys/>.
- Harris M, Kriebel CH, Raviv A (1982) Asymmetric information, incentives and intrafirm resource allocation. *Management Sci.* 28(6):604–620.
- Jerath K, Netessine S, Veeraraghavan SK (2010) Revenue management with strategic customers: Last-minute selling and opaque selling. *Management Sci.* 56(3):430–448.
- Jopson B (2013) US bricks-and-mortar retailers seek online success. *Financial Times* (December 27), <http://www.ft.com/cms/s/0/6773a16c-69dc-11e3-aba3-00144feabdc0.html#axzz4AX99pipn>.
- Kouvelis P, Lariviere MA (2000) Decentralizing cross-functional decisions: Coordination through internal markets. *Management Sci.* 46(8):1049–1058.
- Lai G, Debo LG, Sycara K (2010) Buy now and match later: Impact of posterior price matching on profit with strategic consumers. *Manufacturing Service Oper. Management* 12(1):33–55.
- Lal R, Sarvary M (1999) When and how is the Internet likely to decrease price competition? *Marketing Sci.* 18(4):485–503.
- Lee H, Whang S (1999) Decentralized multi-echelon supply chains: Incentives and information. *Management Sci.* 45(5):633–640.
- Li S, Sun B, Montgomery AL (2011) Cross-selling the right product to the right customer at the right time. *J. Marketing Res.* 48(4):683–700.
- Li S, Sun B, Wilcox RT (2005) Cross-selling sequentially ordered products: An application to consumer banking services. *J. Marketing Res.* 42(2):233–239.
- Liang C, Cakanyildirim M, Sethi SP (2014) Analysis of product rollover strategies in the presence of strategic customers. *Management Sci.* 60(4):1033–1056.
- Liu Q, van Ryzin GJ (2008) Strategic capacity rationing to induce early purchases. *Management Sci.* 54(6):1115–1131.
- Liu Y, Zhang ZJ (2006) Research note—the benefits of personalized pricing in a channel. *Marketing Sci.* 25(1):97–105.
- Lutz A (2012) Toys “R” Us is hiring 45,000 employees for the holiday season. *Business Insider* (September 25), <http://www.businessinsider.com/toys-r-us-holiday-hiring-2012-9>.
- Mehra A, Kumar S, Raju JS (2013) “Showrooming” and the competition between store and online retailers. Working paper, University of Pennsylvania, Philadelphia.
- Murphy IP (2015) Delivering convenience: The keys to buy online, pickup in store. *Retail Dive* (June 25), <http://www.retaildive.com/news/delivering-convenience-the-keys-to-buy-online-pickup-in-store/401058/>.
- Netessine S, Rudi N (2006) Supply chain choice on the Internet. *Management Sci.* 52(6):844–864.
- Netessine S, Savin S, Xiao W (2006) Revenue management through dynamic cross selling in e-commerce retailing. *Oper. Res.* 54(5):893–913.
- Ofek E, Katona Z, Sarvary M (2011) “Bricks and clicks”: The impact of product returns on the strategies of multichannel retailers. *Marketing Sci.* 30(1):42–60.
- Porteus EL, Whang S (1991) On manufacturing/marketing incentives. *Management Sci.* 37(9):1166–1181.
- Rigby D (2011) The future of shopping. *Harvard Bus. Rev.* 89(12):65–76.
- Rosenblum P, Kilcourse B (2013) Omni-channel 2013: The long road to adoption, RSR 2013 benchmark report, Retail Systems Research, Miami.
- Shannon S (2012) Now at Tesco: Drive-through grocery pickup. *Bloomberg* (September 3), <http://www.bloomberg.com/news/articles/2012-09-03/now-at-tesco-drive-through-grocery-pickup>.

- Su X (2007) Intertemporal pricing with strategic customer behavior. *Management Sci.* 53(5):726–741.
- Su X, Zhang F (2008) Strategic customer behavior, commitment, and supply chain performance. *Management Sci.* 54(10):1759–1773.
- Su X, Zhang F (2009) On the value of commitment and availability guarantees when selling to strategic consumers. *Management Sci.* 55(5):713–726.
- Taylor TA (2002) Supply chain coordination under channel rebates with sales effort effects. *Management Sci.* 48(8):992–1007.
- Tuttle B (2011) Why retailers prefer “ship to store” over plain old shipping to the customer’s home. *Time* (March 11), <http://business.time.com/2011/03/11/why-retailers-prefer-ship-to-store-over-plain-old-shipping-to-the-customers-home/>.
- Tsay AA, Agrawal N (2004) Channel conflict and coordination in the e-commerce age. *Production Oper. Management* 13(1):93–110.
- UPS (2015) UPS online shopping study: Empowered consumers changing the future of retail. Press release, June 3, United Parcel Service of America, Atlanta.
- Yin R, Aviv Y, Pazgal A, Tang CS (2009) Optimal markdown pricing: Implications of inventory display formats in the presence of strategic customers. *Management Sci.* 55(8):1391–1408.
- Zimmerman A (2012a) Can retailers halt “showrooming”? *Wall Street Journal* (April 11), <http://www.wsj.com/articles/SB10001424052702304587704577334370670243032>.
- Zimmerman A (2012b) Showdown over “showrooming.” *Wall Street Journal* (January 23), <http://www.wsj.com/articles/SB10001424052970204624204577177242516227440>.