# Channel Coordination of Storable Goods

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**Abstract**

Manufacturers of consumer packaged goods invest heavily in trade promotions (i.e., temporary wholesale price discounts), but retailer stockpiling often yields trade promotions unprofitable. In this paper, we investigate how a manufacturer should respond to the retailer's and consumers' stockpiling ability by contracting with the retailer. Specifically, we examine when the manufacturer should restrict the retailer's stockpiling ability and when it should issue trade promotions. Our analysis suggests that: First, the manufacturer should restrict the retailer's stockpiling ability when the storage cost is low. Such restriction also benefits the retailer, resulting in a win-win outcome. Second, the manufacturer should offer trade promotions when the retailer cannot stockpile products and the storage cost is low but raise the wholesale price when the retailer can stockpile products. Third, stockpiling improves channel coordination and increases the manufacturer's profit. Therefore, the manufacturer should design products to be more storable.



**Keywords:** stockpiling, channel coordination, pricing, game theory

# 1 Introduction

Manufacturers of consumer packaged goods (CPG) invest heavily in trade promotions to reduce wholesale prices temporarily (e.g., 2-4 weeks). The purpose is to induce retailers to pass the promotion to consumers to boost sales (Edmunds 2017). Spending on trade promotions accounts for approximately two-thirds of CPG companies' marketing budget (Drèze and Bell 2003; Nielsen 2010) and 20% of their revenue (Hwang and Murphy 2019). However, 71% of trade promotions are not profitable (Raj 2019). An ACNielsen study shows that trade promotion is the top concern for manufacturers (Nielsen 1998).

One major reason for the inefficiency of trade promotions is that retailers take advantage of temporary wholesale price discounts to forward buy and stockpile products for future sales (Iyer et al. 2007; Desai et al. 2010). Durk Jaeger, the former head of Procter & Gamble's U.S. operation, noted that trade promotions were "impossibly inefficient" and abused by retailers (Economist 1992). When retailers pass discounts to consumers, consumers also stockpile products for future consumption (Ching and Osborne 2020). Industry reports suggest that nearly 30% of trade promotion spending is "wasted" because of stockpiling (Edgewood 2001). As a result, the top-level question for a manufacturer of storable goods is: how should it respond to the retailer's and consumers' stockpiling ability by contracting with the retailer? The manufacturer needs to understand how it should set prices and when it should offer trade promotions by accounting for the retailer's and consumers' stockpiling incentives.

In addition, an important contract design decision that a storable-goods manufacturer must consider is whether it should restrict the retailer's ability to stockpile its product. In practice, a manufacturer can restrict retailer stockpiling using scan-backs (Desai et al. 2010). With scan-backs, the manufacturer accesses scanner data to track the retailer's sales and gives discounts to the retailer for the products it *sells* to consumers instead of for those it *purchases* from the manufacturer in the period with trade promotions (Bell and Drèze 2001). As a result, scan-backs effectively disincentivize retailer stockpiling. A national-brand beverage manufacturer performed a yearlong field study and found that retailers loaded up when offered a trade promotion but did not do so when offered a scan-back (Bell and Drèze 2002). A manufacturer can also manage a retailer's inventory directly using the vendor-managed inventory (VMI) system (Anand et al. 2008). "In [this] system, the supplier decides on the appropriate inventory levels of each of the products" (Simchi-Levi et al., 2009, p.245). The core idea is that the manufacturer, instead of the retailer, makes the replenishment timing and quantity decisions, which eliminates retailer stockpiling. Manufacturers and retailers, such as Procter & Gamble, Walmart, and Kmart, have formed partnerships to adopt VMI (Waller et al. 1999). In addition, manufacturers can restrict retailer stockpiling by "imposing restrictions on the terms of the trade deal which prevents them (retailers) from forward buying" (Lal et al. 1996, p.33).

On the surface, it seems that if retailer stockpiling has partially caused the failure of trade promotions, eliminating retailer stockpiling would benefit manufacturers at the expense of retailers. However, despite the availability of tactics that enable manufacturers to restrict retailer stockpiling, not all manufacturers adopt them. Also puzzling is why certain retailers are willing to accept restrictive contracts to forfeit their ability to stockpile products. Motivated by these business observations, we investigate when a manufacturer should restrict the retailer's stockpiling and how this restriction affects the retailer.

Extant research on marketing channels has considered either consumer stockpiling in non-channel settings or retailer stockpiling in channels without consumer stockpiling. However, it is unknown how consumers stockpile in a channel setting and how the retailer's and consumers' stockpiling incentives interact with each other. Our research contributes to the literature by showing that consumer stockpiling effectively alleviates the double-marginalization problem and that consumer stockpiling may arise in a channel even in the absence of classical considerations such as demand uncertainty or price discrimination. In addition, we show that retailer stockpiling can also alleviate the double-marginalization problem and improve channel profit. However, when the retailer stockpiles, its stockpiling will crowd out consumer stockpiling. As such, the manufacturer cannot simultaneously enjoy the benefits of retailer stockpiling and consumer stockpiling; instead, it must choose between the two and decide whether to allow its retailer to stockpile. Such a tradeoff is also new to the literature.

Our analysis reveals that stockpiling improves channel coordination by squeezing channel margins to alleviate the double-marginalization problem. The *margin-squeezing effect* of stockpiling arises from inducing an intertemporal competition between channel members and their future selves, which manifests differently when consumers stockpile and when the retailer stockpiles.

When consumers stockpile, they can buy from the current retailer and stockpile or wait to buy from the future retailer to fulfill future demand. This option value of stockpiling induces the retailer to compete with itself intertemporally. Therefore, consumer stockpiling squeezes the retailer's margin and benefits the manufacturer. Anticipating this benefit, the manufacturer is willing to sacrifice its own margin by offering a trade promotion to induce consumer stockpiling. As a result, both the manufacturer's and retailer's margins decline, which alleviates the double-marginalization problem and improves channel coordination, benefiting the manufacturer, the retailer, and consumers.

When the retailer stockpiles, it can buy from the current manufacturer and stockpile or wait to buy from the future manufacturer for selling to future consumers. This option value of retailer stockpiling induces the manufacturer to compete with itself intertemporally and squeezes the manufacturer's margin. This margin-squeezing effect of retailer stockpiling hurts the manufacturer but benefits the retailer. In anticipation of this, the manufacturer raises its current wholesale price to discourage retailer stockpiling. Despite the elevated wholesale price, the retailer is still willing to stockpile for its future benefit, which improves the manufacturer's profit.

Both consumer stockpiling and retailer stockpiling improve channel coordination and increase the manufacturer's profit. However, retailer stockpiling crowds out consumer stockpiling. Therefore, the manufacturer cannot benefit from both types of stockpiling. The manufacturer prefers to induce consumer stockpiling to squeeze the retailer's margin rather than allowing the retailer to stockpile to squeeze the manufacturer's own margin. Consumers are willing to stockpile as long as the storage cost is low. Therefore, when the storage cost is low, the manufacturer restricts retailer stockpiling and offers trade promotions to trigger consumer stockpiling.

We also find that the retailer is better off when it is restricted from stockpiling. This is because absent its stockpiling ability, the retailer credibly commits to working with the manufacturer to induce consumer stockpiling. Thus, the manufacturer is willing to offer a trade promotion to help the retailer induce consumer stockpiling. If the retailer can stockpile products, the manufacturer raises the wholesale price to dissuade retailer stockpiling. Overall, the retailer is better off without its stockpiling ability to receive the trade promotion. Therefore, restricting the retailer's stockpiling ability can lead to a win-win outcome for the manufacturer and the retailer.

## 1.1 Literature Review

Our research contributes to the marketing channel literature by investigating how a manufacturer coordinates its channel when both the retailer and consumers can stockpile products (for comparison, see Table 1). Prior research has established that a decentralized channel suffers from the double-marginalization problem and that channel members' incentives are often misaligned (e.g., Jeuland and Shugan 1983; Tirole 1988). Research has focused on how a manufacturer should adjust its marketing decisions to coordinate its channel. For example, Iyer et al. (2007) and Guo and Iyer (2010) demonstrate that, even if information is costless to obtain, a manufacturer may not acquire perfect information because of channel conflicts. Dukes and Liu (2010) show that retailer in-store media can help channel members coordinate on advertising volume and product sales and mitigate supplier competition.

Several studies have examined the issue of consumer stockpiling in nonchannel settings. For example, Salop and Stiglitz (1982) show that consumer stockpiling generates price dispersion in a mixed-strategy equilibrium. In each period, some firms offer discounts to generate additional sales to consumers who stockpile, while others keep prices high. Bell et al. (2002) extend their model by incorporating consumption flexibility and obtain similar results. Jeuland and Narasimhan (1985) offer a price discrimination theory of consumer inventory. They assume that high-valuation consumers also bear a high storage cost. Therefore, a firm can price discriminate by offering temporary price promotions, thereby inducing low-valuation, low-holding-cost consumers to stockpile. Su (2010) and Besbes and Lobel (2015) further extend and confirm this insight. Hong et al. (2002) model competitive markets with both "captives" and "shoppers." Captives buy from a fixed store and do not stockpile, whereas shoppers buy from the cheapest store and may stockpile. The authors show that consumers may stockpile in equilibrium, which mitigates future price competition when the market consists of only "loyal" consumers. Anton and Das Varma (2005) show that, even under unchanging demand, competing firms may produce excessively in the first period to induce consumer stockpiling, which forces the rival firm to produce less in the second period. In doing so, a firm can capture the future market share of its rival through consumer stockpiling. However, as both firms do so, a prisoner's dilemma arises. Dudine et al. (2006) investigate a storable-goods monopolist facing changing demand over time and show that consumer stockpiling leads to higher prices and lower demand. Guo and Villas-Boas (2007) analyze consumer stockpiling in a differentiated market and find that consumer stockpiling may not necessarily arise as an equilibrium outcome; if it does, it may intensify future price competition. Unlike the above-mentioned papers, we consider consumer stockpiling in a channel setting, and show that consumer stockpiling can alleviate the double-marginalization problem and improve channel profits, a result that is new to this literature.

Several other studies have investigated retailers' stockpiling behavior in the absence of consumer stockpiling. Lal et al. (1996) find that in a market comprising both "loyal consumers" and "switchers," competing manufacturers randomly offer dynamic linear prices to a common retailer to compete for switchers. The retailer takes advantage of the dynamic linear prices to build up its inventory. Iyer et al. (2007) examine retailer inventory when market demand is uncertain and discuss the trade-offs between demand information and inventory in a distribution channel. Anand et al. (2008) consider a distribution channel in which a retailer carries "strategic inventory" in the first period to convince the manufacturer to lower its wholesale price in the second period. Cui et al. (2008) show that, in a distribution channel characterized by a dominant retailer, a manufacturer could price discriminate between the dominant retailer and smaller independents by offering dynamic linear prices and inducing retailer stockpiling.

Desai et al. (2010) extend the work of Anand et al. (2008) and document that dynamic linear prices improve distribution channel efficiency by inducing forward buying by retailers. They find that allowing forward buying can improve channel efficiency and both the manufacturer's and retailer's profits. Our study differs from that of Desai et al. (2010) in that we consider both retailer stockpiling and consumer stockpiling to unpack their different and intertwined effects on channel members. We can regard the model of Desai et al. (2010) as a specific case of our model when consumers have extremely high storage costs but retailers do not. Moreover, the model with only retailer stockpiling in Desai et al. (2010) is more relevant for storable durable goods (e.g., home appliances, consumer electronics), whereas our research, which considers both retailer and consumer stockpiling, is more relevant for repeatedly purchased storable goods that both retailers and consumers can stockpile. To our knowledge, the only study that considers both retailers' and consumers' stockpiling is that of Blattberg et al. (1981). Our study differs from that research in two important respects. First, Blattberg et al. (1981) assume that wholesale price is exogenously

Table 1: Benchmarking the current study against the literature

| | Channel Setting | Retailer Stockpiling | Consumer Stockpiling |
|---|---|---|---|
| Blattberg et al. (1981) | No | Yes | Yes |
| Salop and Stiglitz (1982) | No | No | Yes |
| Jeuland and Narasimhan (1985) | No | No | Yes |
| Lal et al. (1996) | Yes | Yes | No |
| Bell et al. (2002) | No | No | Yes |
| Hong et al. (2002) | No | No | Yes |
| Anton and Das Varma (2005) | No | No | Yes |
| Dudine et al. (2006) | No | No | Yes |
| Guo and Villas-Boas (2007) | No | No | Yes |
| Iyer et al. (2007) | Yes | Yes | No |
| Anand et al. (2008) | Yes | Yes | No |
| Cui et al. (2008) | Yes | Yes | No |
| Desai et al. (2010) | Yes | Yes | No |
| Su (2010) | No | No | Yes |
| Gangwar et al. (2013) | No | No | Yes |
| This article | Yes | Yes | Yes |

given instead of an endogenous decision the manufacturer makes. Second, we also examine the manufacturer's decision to restrict retailer stockpiling, which informs managers on this strategic decision.

The remainder of this paper is organized as follows. We set up the model and analyze the benchmark case of nonstorable goods without retailer stockpiling or consumer stockpiling in Section 2. We analyze the case when the manufacturer restricts retailer stockpiling in Section 3. We analyze the case when the manufacturer permits retailer stockpiling in Section 4. Finally, Section 5 concludes the paper with managerial implications and directions for future research.

## 2 Model

### 2.1 Model Setup

We consider a channel setting in which a manufacturer sells a repeatedly purchased storable product to consumers through an independent retailer. To capture the storable nature of the product, we consider a two-period dynamic game in which consumers and the retailer can buy the product in the current first period and carry it forward into the future second period, and we use $S \geq 0$

and $I \geq 0$ to denote consumers' and the retailer's storage, respectively. The cost of storage is a linear function of the storage volume; that is, $c(S) = h \cdot S$ for consumers and $c(I) = h \cdot I$ for the retailer, where $h$ is the unit storage cost that captures both the physical cost of storage (e.g., the space a refrigerator uses) and the spoilage cost for perishable goods.

Following Dudine et al. (2006), we assume that the demand in each period $t$ comes from a unit measure of identical consumers whose utility is quadratic in the consumption of the good, and the demand in period $t$ is $D_t(p_t) = 1 - p_t$, where $p_t$ is the retail price in period $t$.[1] Channel members and consumers are forward-looking and maximize their intertemporal utility. We standardize their discount factors to 1 and the manufacturer's marginal production cost to 0.

We consider a channel that is contracted through dynamic linear prices; that is, in each period, the manufacturer sets a wholesale price, and the retailer sets a retail price. The game proceeds as follows: The first period comprises multiple stages. In the first stage, the manufacturer decides whether to restrict the retailer from stockpiling its product. In the second stage, the manufacturer sets its first-period wholesale price, denoted by $w_1$ such that the retailer pays the manufacturer $P(q) = w_1 q$ for purchasing $q$ units of the product. We assume that consumers do not observe $w_1$. In the third stage, the retailer sets the first-period retail price denoted by $p_1$. In the fourth stage, the retailer and consumers simultaneously decide how many units to buy. If the manufacturer allows it to stockpile, the retailer can purchase in excess and stockpile $I$ units of the product for future sales. Consumers can purchase $S$ units of the product in excess, which will then be carried forward to the second period for future consumption. In the second period, the manufacturer sets its second-period wholesale price, denoted by $w_2$. Then, the retailer sets its second-period retail price $p_2$, and consumers make their second-period purchase decisions.

We analyze three cases: (1) a benchmark case of nonstorable goods, in which neither the retailer nor consumers can stockpile the product; (2) a case in which the manufacturer restricts retailer stockpiling, such that only consumers can stockpile the product; and (3) a case in which the manufacturer allows the retailer to stockpile, such that both the retailer and consumers can stockpile the product.

[1] The assumption of identical consumers is made for convenience, though the model also allows alternative interpretations (Dudine et al. 2006). For example, the market may consist of consumers with heterogeneous valuations and unit demand for the good, an approach that Anton and Das Varma (2005) adopt. More specifically, in each period there is a unit mass of consumers with unit demand for the good. Consumer valuation for the good is uniformly distributed over the unit interval. This generates the consumption demand $D_t(p_t) = 1 - p_t$.

### 2.2 Benchmark: Nonstorable Goods

We first consider the benchmark case of nonstorable goods that neither the retailer nor consumers can stockpile. In this case, the two periods are completely separate, and the two-period game reduces to a repetition of a static game. In each period, the retailer's profit function is $\pi_t = (p_t - w_t)(1 - p_t)$ and the manufacturer's profit function is $\Pi_t = w_t(1 - p_t)$. We solve for the equilibrium prices and obtain $p_t = \frac{1+w_t}{2}$ and $w_t = \frac{1}{2}$. Thus, in equilibrium, the manufacturer charges the static wholesale price $w_t = \frac{1}{2}$, and the retailer charges the static retail price $p_t = \frac{3}{4}$. The manufacturer's total profit over two periods is $\Pi = \frac{1}{4}$, and the retailer's total profit is $\pi = \frac{1}{8}$. Because the manufacturer and the retailer maximize their own profit, the retail price in this decentralized channel is higher than the optimal level (i.e., $\frac{1}{2}$) in a centralized channel. The high retail price depresses demand and reduces channel profit and consumer surplus, which is the double-marginalization problem of the decentralized channel. In the following sections, we show that stockpiling can improve channel coordination and increase the manufacturer's profit.

## 3 With Restriction of Retailer Stockpiling

Now, we consider a case in which the manufacturer restricts the retailer's ability to stockpile the product. As a result, only consumers can stockpile. We solve the game backward.

### 3.1 The second period

The second-period equilibrium depends on consumers' storage level $S \geq 0$. Consumers use up their products in storage before purchasing additional products from the retailer to satisfy their second-period demand. Thus, the quantity of products that consumers purchase from the retailer is the second-period demand minus the storage level; that is, $Q_2(p_2) = D_2(p_2) - S = 1 - p_2 - S$. The retailer chooses $p_2$ to maximize its second-period profit $\pi_2 = Q_2(p_2)(p_2 - w_2)$, and we obtain $p_2 = \frac{1-S+w_2}{2}$. The manufacturer chooses $w_2$ to maximize its second-period profit $\Pi_2 = Q_2(p_2)w_2$, which gives $w_2 = \frac{1-S}{2}$. Thus, in the second-period equilibrium, the retailer charges $p_2 = \frac{3(1-S)}{4}$, its profit is $\pi_2 = \frac{(1-S)^2}{16}$, and the manufacturer's profit is $\Pi_2 = \frac{(1-S)^2}{8}$. Note that the second-period equilibrium outcome does not depend on the value of $w_1$.

### 3.2 The first period

In the first period, consumers make their stockpiling decisions. Lemma 1 describes the relationship among consumers' storage level, retail prices, and the storage cost.

**Lemma 1** *In equilibrium, retail prices and consumers' storage satisfy the following:*

$$\begin{cases} p_1 + h \geq p_2 & \text{if } S = 0, \\ p_1 + h = p_2 & \text{if } S > 0. \end{cases}$$

Lemma 1 suggests that, in equilibrium, whenever consumer stockpiling occurs (i.e., $S > 0$), consumers are indifferent about whether to stockpile (i.e., $p_1 + h = p_2$). The intuition is that, when there are strictly positive arbitrage gains from stockpiling (i.e., $p_1 + h < p_2$), consumers will stockpile more. As they do so, the second-period price will decrease (i.e., $\frac{\partial p_2}{\partial S} < 0$), which reduces the arbitrage gains. Eventually, the option to stockpile completely eliminates positive arbitrage gains, leaving consumers indifferent.[2] Using the no-arbitrage condition and the second-period equilibrium outcome, we solve for consumers' storage decisions:

$$S = \begin{cases} \frac{3-4h-4p_1}{3} & \text{if } p_1 \leq \hat{p}_1 = \frac{3}{4} - h, \\ 0 & \text{otherwise.} \end{cases} \tag{1}$$

Therefore, when the first-period retail price is sufficiently low (i.e., $p_1 \leq \hat{p}_1$), consumers anticipate a price increase in the second period and stockpile the product. Otherwise, if the first-period price is too high (i.e., $p_1 > \hat{p}_1$), consumers find it unprofitable to stockpile. In the first period, consumers purchase from the retailer to satisfy their first-period consumption demand and the stockpiling needs; that is, $Q_1(p_1) = D_1(p_1) + S(p_1)$. Using Equation (1), we have the following:

$$Q_1(p_1) = \begin{cases} \frac{6-4h-7p_1}{3} & \text{if } p_1 \leq \hat{p}_1, \\ 1 - p_1 & \text{otherwise.} \end{cases} \tag{2}$$

[2] Given that consumers are indifferent about stockpiling or not in equilibrium, it is plausible that they may mix in their stockpiling decisions, but this does not affect the equilibrium outcome. For example, suppose that there exists an equilibrium in which every consumer stockpiles $S = 2$ units. It is possible that there exists another equilibrium in which a consumer stockpiles $S_1 = 1.5$ units with probability half and $S_2 = 2.5$ units with probability half. When we summarize over all consumers, the average inventory level must still be $\bar{S} = 2$ units, and the equilibrium strategies will not be affected.

As Equation (2) illustrates, the first-period purchase quantity has a kink: At prices above $\hat{p}_1 = \frac{3}{4} - h$, consumers do not stockpile the product because the second-period price will be low compared with the first-period price. At prices below $\hat{p}_1$, consumers stockpile the product (see Figure 1).

It is worth mentioning that consumers' storage decision does not depend on $w_1$ either. As long as consumers observe $p_1$, they are not concerned about the realization of $w_1$.

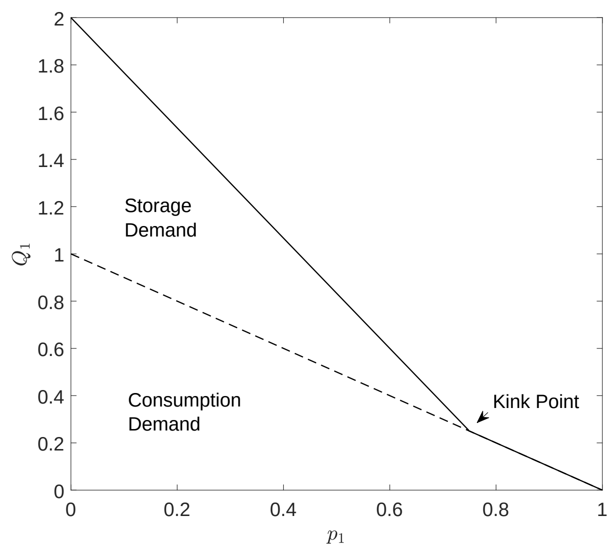


Figure 1: First-period consumer purchase ($h = 0$)

Now, we consider the retailer's first-period pricing decisions. Given $w_1$, the retailer chooses $p_1$ that maximizes its total profit $\pi = Q_1(p_1)(p_1 - w_1) + \pi_2$ from both periods. Just as $Q_1$ has a kink at $\hat{p}_1 = \frac{3}{4} - h$, the retailer's profit function also has a kink. The retailer may either charge a low price (i.e., $p_1 \leq \hat{p}_1$) to trigger consumer stockpiling or charge a high price (i.e., $p_1 > \hat{p}_1$) so that consumers do not stockpile.[3] This decision depends on the first-period wholesale price as follows:

$$p_1 = \begin{cases} \frac{18-10h+21w_1}{40} & \text{if } w_1 \leq \hat{w}_1 = \frac{18-30h-\sqrt{5}(1+8h)}{29}, \\ \frac{1+w_1}{2} & \text{otherwise.} \end{cases} \tag{3}$$

Equation (3) reveals that if the manufacturer offers a low wholesale price (i.e., $w_1 \leq \hat{w}_1$), the retailer charges a price lower than the static retail price (i.e., $p_1 < \frac{1+w_1}{2}$) and adds a smaller margin

[3]To break ties, we assume that the retailer behaves in favor of the manufacturer. That is, when it is indifferent about whether to induce consumer stockpiling, it always induces consumer stockpiling. This is because the manufacturer can always decrease the price slightly to obtain the desired outcome. Similarly, we assume that when the manufacturer is indifferent about whether to induce consumer stockpiling, it always induces consumer stockpiling, which works in favor of the retailer.

to the wholesale price to induce consumer stockpiling. Otherwise, if the wholesale price is high (i.e., $w_1 > \hat{w}_1$), the retailer charges the static price for nonstorable goods (i.e., $p_1 = \frac{1+w_1}{2}$) that does not induce consumer stockpiling.

Anticipating the retailer's pricing incentives, the manufacturer chooses $w_1$ to maximize its total profits from both periods, $\Pi = Q_1 \cdot w_1 + \Pi_2$. The manufacturer can charge a lower wholesale price $w_1 \leq \hat{w}_1$, anticipating that the retailer will partially pass the wholesale price discount to consumers, thereby triggering consumer stockpiling. Alternatively, the manufacturer can charge a high price that does not induce consumer stockpiling. We solve for the equilibrium first-period wholesale price and obtain the following:

$$w_1 = \begin{cases} \frac{422-230h}{931} & \text{if } h < h_1 \approx 0.0643, \\ \frac{18-30h-\sqrt{5}(1+8h)}{29} & \text{if } h_1 \leq h \leq h_2 \approx 0.1608, \\ \frac{1}{2} & \text{otherwise.} \end{cases} \tag{4}$$

When the storage cost is low (i.e., $h < h_1$), the manufacturer charges a low price to induce consumer stockpiling. The resulting wholesale price is an interior solution ($w_1 < \hat{w}_1$). When $h_1 \leq h \leq h_2$, the storage cost is higher, and the manufacturer's optimal wholesale price is a corner solution ($w_1 = \hat{w}_1$), at which the retailer is indifferent about whether or not to induce consumer stockpiling. Finally, when $h > h_2$, the manufacturer forgoes inducing consumer stockpiling and charges the static price. We summarize the equilibrium outcome in Table 2 and the findings in Proposition 1.

**Proposition 1** *With restriction of retailer stockpiling:*

*a. When the storage cost is low (i.e., $h < h_2 \approx 0.1608$), the manufacturer reduces first-period wholesale price (from the static price) to induce consumer stockpiling.*

*b. When the storage cost is high (i.e., $h \geq h_2$), the manufacturer charges the high static price and consumers do not stockpile.*

*c. The manufacturer's profit is higher with than without consumer stockpiling.*

Proposition 1 gives conditions under which the manufacturer should offer trade promotions by reducing the wholesale price from the static price without stockpiling. When the retailer cannot

Table 2: Equilibrium results with restriction of retailer stockpiling

| | $h < h_1$ | $h_1 \leq h \leq h_2$ | $h_2 < h$ |
|---|---|---|---|
| $w_1$ | $\frac{422-230h}{931}$ | $\frac{18-30h-\sqrt{5}(1+8h)}{29}$ | $\frac{1}{2}$ |
| $Q_1$ | $\frac{15-17h}{38}$ | $\frac{220+600h+49\sqrt{5}(1+8h)}{1160}$ | $\frac{1}{4}$ |
| $S$ | $\frac{11(1-10h)}{133}$ | $\frac{7\sqrt{5}(1+8h)-10-80h}{290}$ | $0$ |
| $p_1$ | $\frac{183-101h}{266}$ | $\frac{900-920h-21\sqrt{5}(1+8h)}{1160}$ | $\frac{3}{4}$ |
| $w_2$ | $\frac{61+55h}{133}$ | $\frac{300+80h-7\sqrt{5}(1+8h)}{580}$ | $\frac{1}{2}$ |
| $Q_2$ | $\frac{61+55h}{266}$ | $\frac{300+80h-7\sqrt{5}(1+8h)}{1160}$ | $\frac{1}{4}$ |
| $p_2$ | $\frac{3(61+55h)}{266}$ | $\frac{3(300+80h-7\sqrt{5}(1+8h))}{1160}$ | $\frac{3}{4}$ |
| $\Pi$ | $\frac{529-206h+365h^2}{1862}$ | $\frac{32909+1808\sqrt{5}+11504h+5960\sqrt{5}h-130304h^2-68032\sqrt{5}h^2}{134560}$ | $\frac{1}{4}$ |
| $\pi$ | $\frac{367-158h+258h^2}{2527}$ | $\frac{1345+88\sqrt{5}+2960h+944\sqrt{5}h+4880h^2+1920\sqrt{5}h^2}{13456}$ | $\frac{1}{8}$ |

stockpile and the storage cost is low, offering a trade promotion is an equilibrium outcome. This is because when consumers stockpile, they can buy from the current retailer and stockpile or wait to buy from the future retailer to fulfill future demand. This option value of stockpiling induces the retailer to compete with itself intertemporally. Therefore, consumer stockpiling squeezes the retailer's margin and benefits the manufacturer. Anticipating this benefit, the manufacturer is willing to sacrifice its own margin by offering a trade promotion to induce consumer stockpiling. As a result, both the manufacturer's and retailer's margins decline, which alleviates the double-marginalization problem and improves channel coordination, benefiting the manufacturer, the retailer, and consumers.

We elaborate on the above *margin-squeezing effect* of consumer stockpiling using our two-period model. Specifically, if the manufacturer issues a trade promotion by reducing its first-period wholesale price $w_1$, the retailer's cost of procuring the product from the manufacturer is lower. The retailer reduces its first-period retail price $p_1$ as well. As long as the storage cost is low, consumers respond to the first-period retail price reduction by stockpiling for second-period consumption. As a result, consumers will consume their storage to fulfill their second-period demand before buying from the second-period retailer, and consumers' second-period purchase declines, which puts downward pressure on the retailer's second-period margin ($p_2 - w_2$): Even if the second-period wholesale price $w_2$ does not change, the retailer needs to reduce the second-period retail price (i.e., $p_2$) to respond to the decreased purchase from consumers. As a result, the retailer's second-period margin declines with consumers' stockpiling, which benefits the manufacturer. Anticipating the future benefit, the manufacturer is willing to reduce its first-period wholesale price (i.e., offer a trade promotion).

When the manufacturer offers a trade promotion, the retailer is better off reducing the retail price to partially pass the discount to consumers rather than retaining the discount. The reason is that by reducing the retail price $p_1$, the retailer can expand the first-period demand and induce consumer stockpiling. Both factors allow the retailer to sell more products in the first period to leverage the wholesale price discount.

Consumer stockpiling improves the manufacturer's profit by squeezing the retailer's margin, which results in lower channel prices, alleviates the double-marginalization problem, and improves channel coordination. Specifically, the manufacturer offers a trade promotion in the first period to induce consumer stockpiling and also reduces the second-period wholesale price to respond to the decreased purchase from consumers (i.e., $w_2$ decreases with consumer storage). Thus, the wholesale price declines in both periods. The retailer passes trade promotions to consumers by reducing its first-period retail price. The retailer also reduces its second-period price to respond to the decreased purchase. Thus, the retail price also declines in both periods. When $h = 0$, the weighted average wholesale price over two periods declines from 0.5 in the static model without stockpiling to 0.455 with consumer stockpiling and the weighted average retail price declines from 0.75 without stockpiling to 0.688 with consumer stockpiling (see Table 3). Reductions in wholesale and retail prices expand consumer demand and alleviate the double-marginalization problem, benefiting the manufacturer, the retailer, and consumers (see Table 3). Therefore, consumer stockpiling results in a win-win-win outcome.

Empowered with the option of stockpiling, consumers gain a larger share (18.4% vs. 14.4%) of the social welfare while the firms gain smaller shares (retailer's share decreases from 28.5% to 27.5%; manufacturer's share decreases from 57.1% to 54.1%) than the benchmark case without stockpiling. However, the social welfare improves (from 0.438 to 0.527) with consumers' stockpiling, benefiting not only consumers, who gain a larger share of the social welfare, but also the manufacturer and the retailer, whose share of the social welfare shrinks.

Consumer stockpiling takes place as long as the storage cost is low. Part (b) of Proposition 1 shows that, if the storage cost is sufficiently high, the manufacturer no longer offers price discounts to induce consumer stockpiling. This is because, with a high storage cost, the manufacturer and the retailer need to reduce prices substantially to compensate consumers for expending the high storage cost when stockpiling; they would be better off charging the high static price and forgo inducing consumer stockpiling.

Table 3: Equilibrium weighted average prices and channel surplus ($h = 0$), share of social welfare in parentheses

| | Nonstorable | Restrict Retailer Stockpiling |
|---|---|---|
| Consumer Stockpiling | No | Yes |
| Retailer Stockpiling | No | No |
| Weighted average wholesale price ($\bar{w}$) | 0.5 | 0.455 |
| Weighted average retail price ($\bar{p}$) | 0.75 | 0.688 |
| Manufacturer's profit ($\Pi$) | 0.250(57.1%) | 0.285(54.1%) |
| Retailer's profit ($\pi$) | 0.125(28.5%) | 0.145(27.5%) |
| Consumer surplus ($CS$) | 0.063 (14.4%) | 0.097 (18.4%) |
| Social welfare ($SW$) | 0.438 (100%) | 0.527 (100%) |

## 4 With Permission of Retailer Stockpiling

Now, we investigate the scenario in which the manufacturer allows the retailer to stockpile the product so that both the retailer and consumers can stockpile. This case differs from the previous case in the first-period decisions. Given wholesale price $w_1$, the retailer chooses its first-period price $p_1$. Then, after observing $p_1$, the retailer and consumers decide on their respective storage level $I$ and $S$ simultaneously.[4]

Because consumers do not observe $w_1$, let $\tilde{w}_1$ represent their belief about $w_1$. Likewise, let $\tilde{I}$ be consumers' belief about $I$ (note that in the current model, $I$ can hinge on $w_1$). Because a perfect Bayesian equilibrium does not place any restrictions on beliefs off the equilibrium path, a consumer is free to change her beliefs upon receiving an off-equilibrium first-period price $p_1 \neq p_1^*$. To pin down the equilibrium outcome, we follow the literature and consider *passive beliefs* (Hart and Tirole, 1990; McAfee and Schwartz, 1994; De Fontenay and Gans, 2005; Janssen and Shelegia, 2015): Under passive beliefs, consumers do not change their belief about $w_1$ upon receiving an off-equilibrium $p_1$. Subsequently, their beliefs about $I$ do not change as well. In this sense, we can

[4]Our results continue to hold if $I$ and $S$ are determined sequentially.

treat $\tilde{w}_1$ and $\tilde{I}$ as constants in the following analysis.

One interpretation for the passive beliefs is that, upon receiving a price $p_1 \neq p_1^*$, consumers believe that the manufacturer has followed its equilibrium strategy $w_1 = \tilde{w}_1$ while the retailer has unilaterally deviated. In other words, they interpret $p_1$ as the retailer's tremble. Passive beliefs are commonly used in the vertical contracting literature and it allows us to obtain tractable solutions to the equilibrium outcome (Hart and Tirole, 1990; McAfee and Schwartz, 1994; De Fontenay and Gans, 2005; Janssen and Shelegia, 2015).

### 4.1 The Second Period

The second-period equilibrium depends on consumers' storage level $S \geq 0$ and the retailer's storage level $I \geq 0$. At $t = 2$, given consumer storage $S$, the quantity of products that consumers purchase from the retailer is $Q_2(p_2) = D_2(p_2) - S = 1 - p_2 - S$. The quantity of products that the retailer purchases from the manufacturer is $Q_2(p_2) - I$. The retailer chooses $p_2$ to maximize its second-period profit $\pi_2 = Q_2(p_2)p_2 - (Q_2(p_2) - I)w_2$. Solving the retailer's problem yields the second-period retail price $p_2 = \frac{1-S+w_2}{2}$.

We now consider the manufacturer, which chooses wholesale price $w_2$ to maximize its second-period profit $\Pi_2 = (Q_2(p_2) - I)w_2$. We obtain the second-period equilibrium:

$$w_2 = \frac{1-2I-S}{2},\ p_2 = \frac{3-3S-2I}{4},\ \Pi_2 = \frac{(1-S-2I)^2}{8},\ \pi_2 = \frac{1+S^2+12(1-I)I-2S(1+6I)}{16}. \quad (5)$$

The retailer's second-period margin is $p_2 - w_2 = \frac{1+2I-S}{4}$ which increases with the retailer's own storage level $I$ but decreases with the consumers' storage level $S$. These opposing results suggest that the retailer can improve its second-period margin by stockpiling whereas consumer stockpiling squeezes the retailer's second-period margin.

Because $I$ may hinge on $w_1$, which is not observed by consumers, consumers act according to $\tilde{I}$, their belief of $I$. Following the above analysis, the consistency of beliefs requires that

$$\tilde{p}_2 = \frac{3-3S-2\tilde{I}}{4}, \quad (6)$$

and they refer to $\tilde{p}_2$ when making their first-period storage decisions.

## 4.2 The First Period

In the first period, consumers respond to the current period price $p_1$ when making their stockpiling decisions. Similar to Lemma 1, we can show that consumers' storage satisfies the following no-arbitrage condition:

$$\begin{cases} p_1 + h \geq \tilde{p}_2 & \text{if } S = 0, \\ p_1 + h = \tilde{p}_2 & \text{if } S > 0. \end{cases} \tag{7}$$

Note that now $p_2$ is replaced by $\tilde{p}_2$ as consumers do not know the actual value of $p_2$: It is equal to $\tilde{p}_2$ along the equilibrium path but not necessarily so off the equilibrium path. Using Equations (6) and (7), we derive that

$$S = \begin{cases} \frac{3-4h-4p_1-2\tilde{I}}{3} & \text{if } p_1 \leq \frac{3-2\tilde{I}-4h}{4}, \\ 0 & \text{otherwise.} \end{cases} \tag{8}$$

Note that now, $S$ is a function of $\tilde{I}$, consumers' belief of the retailer's storage (the realization of $I$ is not observed by consumers). For the retailer, after choosing $p_1$, it chooses $I$ to maximize its residual profit:

$$\pi' = -(w_1 + h) \cdot I + \pi_2, \tag{9}$$

where the first term on the right-hand side is the cost of purchasing and carrying inventory $I$, and the second term is the retailer's second-period profit. Optimizing the retailer's residual profit over $I$, we have

$$I = \begin{cases} \frac{1}{3}(2p_1 - 2w_1 + \tilde{I})^+ & \text{if } p_1 \leq \frac{3-2\tilde{I}-4h}{4}, \\ \frac{1}{6}(3 - 4h - 4w_1)^+ & \text{otherwise.} \end{cases} \tag{10}$$

For consumers, the consistency of beliefs requires that

$$\tilde{I} = \begin{cases} \frac{1}{3}(2p_1 - 2\tilde{w}_1 + \tilde{I})^+ & \text{if } p_1 \leq \frac{3-2\tilde{I}-4h}{4}, \\ \frac{1}{6}(3 - 4h - 4\tilde{w}_1)^+ & \text{otherwise.} \end{cases} \tag{11}$$

The retailer's total profit from the two periods is

$$\pi = (1 - p_1 + S)(p_1 - w_1) + \pi', \tag{12}$$

where $1 - p_1 + S$ is the quantity of products that consumers purchase in the first period to meet their needs for consumption and stockpiling, $p_1 - w_1$ is the retailer's first-period margin, and $\pi'$ is the retailer's residual profit in Equation (9). Solving the retailer's problem, we derive

$$p_1 = \begin{cases} \frac{18-2\tilde{I}-10h+15w_1}{34} & \text{if } w_1 \leq \frac{1}{2} - \tilde{I} - \frac{3+\sqrt{17}}{4}h, \\ \frac{1+w_1}{2} & \text{otherwise.} \end{cases} \tag{13}$$

In Equation (13), when $w_1 \leq \frac{1}{2} - \tilde{I} - \frac{3+\sqrt{17}}{4}h$, the retailer charges a low first-period price that induces consumer stockpiling; otherwise, the retailer charges a high first-period price that does not induce consumer stockpiling.

Meanwhile, the manufacturer chooses $w_1$ to maximize its own profit over two periods

$$\Pi = (1 - p_1 + S + I)w_1 + \Pi_2. \tag{14}$$

The manufacturer either chooses a low $w_1 \leq \frac{1}{2} - \tilde{I} - \frac{3+\sqrt{17}}{4}h$ to induce consumer stockpiling, or chooses a high $w_1 > \frac{1}{2} - \tilde{I} - \frac{3+\sqrt{17}}{4}h$ that forgoes consumer stockpiling. In the former case, the manufacturer's profit is maximized at $w_1 = \min\left(\frac{171-36\tilde{I}-61h}{361}, \frac{1}{2} - \tilde{I} - \frac{3+\sqrt{17}}{4}h\right)$. In the latter case, the manufacturer's profit is maximized at $w_1 = \max\left(\frac{9-2h}{17}, \frac{1}{2}\right)$. Comparing the above two cases and using the consistency of beliefs (Equation 11 and $w_1 = \tilde{w}_1$ in equilibrium), we find that the manufacturer always charges a high $w_1$ that forgoes consumer stockpiling. We state the results in Proposition 2 and summarize the equilibrium outcome in Table 4.

**Proposition 2** *With permission of retailer stockpiling:*

a. *When the storage cost is low (i.e., $h < \frac{1}{4}$), the manufacturer raises first-period wholesale price (from the static price of nonstorable goods), and the retailer stockpiles but consumers do not.*

b. *When the storage cost is high (i.e., $h \geq \frac{1}{4}$), the manufacturer charges the static price, and neither the retailer nor consumers stockpile.*

Table 4: Equilibrium results with permission of retailer stockpiling

| | $h < \frac{1}{4}$ | $h \geq \frac{1}{4}$ |
|---|---|---|
| $w_1$ | $\frac{9-2h}{17}$ | $\frac{1}{2}$ |
| $Q_1$ | $\frac{13-18h}{34}$ | $\frac{1}{4}$ |
| $S$ | $0$ | $0$ |
| $I$ | $\frac{5(1-4h)}{34}$ | $0$ |
| $p_1$ | $\frac{13-h}{17}$ | $\frac{3}{4}$ |
| $w_2$ | $\frac{2(3+5h)}{17}$ | $\frac{1}{2}$ |
| $Q_2$ | $\frac{3+5h}{17}$ | $\frac{1}{4}$ |
| $p_2$ | $\frac{23+10h}{34}$ | $\frac{3}{4}$ |
| $\Pi$ | $\frac{9-4h+8h^2}{34}$ | $\frac{1}{4}$ |
| $\pi$ | $\frac{155-118h+304h^2}{1156}$ | $\frac{1}{8}$ |

*c. The manufacturer's profit is higher with retailer stockpiling than its static profit without stockpiling.*

Proposition 1 has shown that the manufacturer offers trade promotions when the retailer cannot stockpile products and the storage cost is low. By contrast, Proposition 2 shows that even when the storage cost is low, if the retailer can stockpile the product, the manufacturer should not offer trade promotions. Instead, the manufacturer should charge a higher price than that in the static model without stockpiling to respond to the retailer's stockpiling ability. Therefore, the manufacturer should adjust prices in opposite directions depending on *who* can stockpile products. Let us understand the manufacturer's incentive to raise the wholesale price.

When the retailer can stockpile products and the storage cost is low, it can buy from the current manufacturer and stockpile or wait to buy from the future manufacturer for selling to future consumers. This option value of retailer stockpiling induces the manufacturer to compete with itself intertemporally and squeezes the manufacturer's margin. This *margin-squeezing effect* of retailer stockpiling hurts the manufacturer but benefits the retailer. Anticipating this negative consequence, the manufacturer raises its current wholesale price to discourage retailer stockpiling.

Despite the increase in the current wholesale price, as long as the storage cost is low, the retailer is still willing to stockpile for its future benefit, which improves the manufacturer's current profit. Essentially, the manufacturer expands its contract space from linear pricing in the static case to a nonlinear pricing with retailer stockpiling; it sells to the retailer at two different prices: a high price to fulfill current demand and retailer stockpiling, and a low price to fulfill residual purchase in the future. The contract-space expansion enables the manufacturer to improve channel coordination and make a higher profit. In other words, the manufacturer's gain from raising its current wholesale price offsets its loss from a lower future wholesale price. The manufacturer's total profit is higher with retailer stockpiling than its static level without stockpiling.

The retailer's stockpiling ability reduces the manufacturer's channel power by squeezing the wholesale margin. This effect of retailer stockpiling is reflected by the reduction in the weighted average wholesale price and the manufacturer's share of the social welfare. In our two-period model, the wholesale price increases in the first period and decreases in the second period, and the weighted average wholesale price over two periods decreases with retailer stockpiling. When $h = 0$, the weighted average wholesale price declines from 0.5 in the static model without stockpiling to 0.474 with retailer stockpiling (see Table 5). Although the manufacturer's share of the social welfare declines with retailer stockpiling (from 28.5% in the static model to 28.0% when $h = 0$ in Table 5), the social welfare increases with retailer stockpiling (from 0.438 to 0.479 when $h = 0$ in Table 5). The manufacturer receives a smaller share of the enlarged social welfare, and its profit ends up higher (i.e., increases from 0.25 to 0.265 when $h = 0$).

Given a wholesale price, the retailer prefers own stockpiling to inducing consumer stockpiling. This is because consumer stockpiling squeezes the retailer's second-period margin, whereas retailer stockpiling squeezes the manufacturer's second-period margin. Therefore, compared to consumer stockpiling, retailer stockpiling leads to a higher profit for the retailer in the second period. Moreover, when the retailer stockpiles products itself, it does not need to cut current retail price and sacrifice retail margin as is required when inducing consumer stockpiling. As the first-period wholesale price increases, it becomes more costly for the retailer to procure products from the manufacturer. The retailer raises its first-period retail price as well.

With a high retail price, consumers are unwilling to stockpile products. Therefore, retailer stockpiling crowds out consumer stockpiling and the manufacturer cannot benefit from both types of stockpiling. Instead, the manufacturer can choose whether to activate consumer stockpiling by restricting retailer stockpiling or allowing for retailer stockpiling which crowds out consumer stockpiling.

After discussing the separate cases in which the manufacturer restricts retailer stockpiling and permits retailer stockpiling, we compare the manufacturer's and the retailer's equilibrium profits

Table 5: Equilibrium channel surplus distribution ($h = 0$), share of social welfare in parentheses

| | Nonstorable | Permit Retailer Stockpiling |
|---|---|---|
| Consumer Stockpiling | No | Yes[a] |
| Retailer Stockpiling | No | Yes |
| Weighted average wholesale price ($\bar{w}$) | 0.5 | 0.474 |
| Weighted average retail price ($\bar{p}$) | 0.75 | 0.714 |
| Manufacturer's profit ($\Pi$) | 0.250(57.1%) | 0.265(55.3%) |
| Retailer's profit ($\pi$) | 0.125(28.5%) | 0.134(28.0%) |
| Consumer surplus ($CS$) | 0.063 (14.4%) | 0.08(16.7%) |
| Social welfare ($SW$) | 0.438 (100%) | 0.479(100%) |

[a] Consumers can stockpile products, but consumer stockpiling does not arise in equilibrium.

in these two cases. We examine conditions under which the manufacturer should restrict retailer stockpiling and how the restriction affects the retailer.

**Proposition 3** *The manufacturer should restrict the retailer from stockpiling if and only if the storage cost is low (i.e., $h \leq h_3 \approx 0.157$).*

When the storage cost is low, both the retailer and consumers bear a low cost to stockpile the product. In this case, if the manufacturer restricts retailer stockpiling, it reduces the first-period wholesale price to induce consumer stockpiling (see Proposition 1). If the manufacturer allows retailer stockpiling, it raises the first-period wholesale price, and only the retailer stockpiles products (see Proposition 2). Both consumer stockpiling and retailer stockpiling benefit the manufacturer. However, retailer stockpiling crowds out consumer stockpiling and the manufacturer cannot benefit from both types of stockpiling. By controlling the retailer's stockpiling ability, the manufacturer can choose whether to allow the retailer or consumers to stockpile products.

The manufacturer prefers to have consumers instead of the retailer stockpile products, as consumer stockpiling squeezes the retailer's future margin whereas retailer stockpiling squeezes the manufacturer's future margin. The former reduces the retailer's pricing power in relation to the manufacturer but the latter reduces the manufacturer's pricing power. Therefore, when $h$ is low, the manufacturer should restrict retailer stockpiling to induce consumer stockpiling. When $h$ is high, it becomes too costly to induce consumer stockpiling. The manufacturer permits retailer stockpiling to improve its profit. Figure 2 illustrates the results.[5]

[5] Note that when $h \in (0.157, 0.1608)$, although the manufacturer can induce consumer stockpiling, consumers' storage is sufficiently low and its benefit is lower than the benefit of retailer stockpiling.

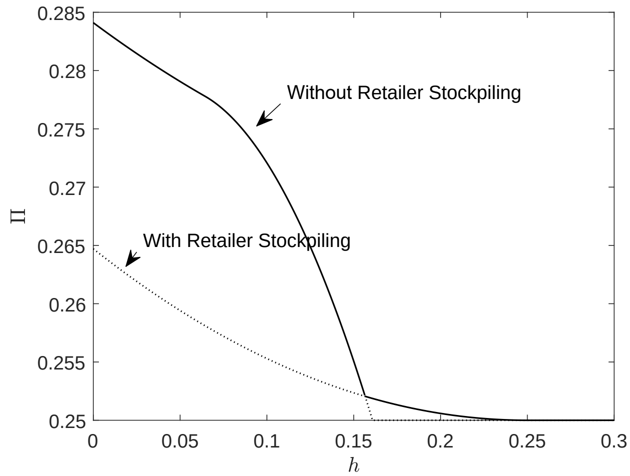


Figure 2: Manufacturer's profit

**Proposition 4** *The retailer's profit is weakly higher when the manufacturer restricts its stockpiling ability.*

Proposition 4 presents the comparison of the retailer's equilibrium total profits over two periods between the scenarios when the retailer can (in Section 4) and cannot (in Section 3) stockpile products. On the surface, it seems that retailers always benefit from their ability to stockpile products at low prices, while scan-backs or other contractual agreements that eliminate retailers' ability to stockpile products appear to hurt retailers. However, Proposition 4 suggests that this intuition may not hold. The retailer is instead better off when the manufacturer restricts its ability to stockpile products.

The intuition is that without the ability to stockpile, the retailer credibly commits to working with the manufacturer to induce consumer stockpiling. In this case, the manufacturer is willing to offer a trade promotion (see Proposition 1) to help the retailer induce consumer stockpiling. Alternatively, if the retailer has the ability to stockpile products, the manufacturer rationally anticipates that the retailer prefers to stockpile products itself instead of inducing consumer stockpiling. In this case, the manufacturer raises the wholesale price (see Proposition 2). Ex ante, the retailer is better off without its stockpiling ability to enjoy the trade promotion, and its profit is higher as a result.

We can also understand the result from the channel efficiency perspective. By restricting retailer stockpiling, the manufacturer allows consumer stockpiling to squeeze the retail margin.

By permitting retailer stockpiling, the retailer's stockpiling squeezes the manufacturer's margin without reducing its own margin. The former reduces retail prices and alleviates the double-marginalization problem to a greater degree than the latter does. The channel is more efficient with consumer stockpiling than retailer stockpiling. Although the retailer can gain a larger share of the social welfare with own stockpiling instead of consumer stockpiling (28.0% in Table 3 vs. 27.5% in Table 5), the overall social welfare is much higher with consumer stockpiling than retailer stockpiling (0.527 vs. 0.479). As a result, the retailer's profit ends up higher with consumer stockpiling instead of own stockpiling.

**Proposition 5** *A manufacturer's profit increases as its product's storage cost $h$ decreases.*

Propositions 1 and 2 show that either consumer stockpiling or retailer stockpiling improves channel coordination and increases the manufacturer's profit from the level without stockpiling. Proposition 5 further illustrates that as the product becomes more storable or less costly to stockpile (i.e., $h$ decreases), the manufacturer's profit increases.

The intuition follows from the benefits of stockpiling. Either consumer stockpiling or retailer stockpiling empowers consumers or the retailer vis-à-vis their upstream channel member. Stockpiling squeezes channel margins, which leads to lower weighted average prices. Thus, stockpiling alleviates the issue of double marginalization and improves channel efficiency and the manufacturer's profit. As the product becomes easier to stockpile (i.e., $h$ decreases), it is less costly for consumers or the retailer to stockpile products to improve channel coordination. The manufacturer's profit increases accordingly. This result implies that manufacturers should design the packaging or ingredients of products to make them more storable.

# 5 Conclusion

Manufacturers of consumer packaged goods invest heavily in trade promotions but find the majority of trade promotions unprofitable. A main issue is that retailers and consumers take advantage of temporary price discounts to stockpile products for future sales or consumption, respectively. Therefore, a manufacturer of storable goods should take retailer and consumer stockpiling into account when contracting with the retailer. In this paper, we show that stockpiling exerts the margin-squeezing effect by inducing an intertemporal price competition between the upstream supplier and its future self. The margin-squeezing effect of consumer stockpiling exists because the manufacturer is willing to offer a trade promotion to induce consumer stockpiling, which constraints the retailer's channel power. The margin-squeezing effect of retailer stockpiling exists because the retailer strategically stockpiles to constrain the manufacturer's channel power. Our results answer our research questions on when a manufacturer should restrict its retailer's stockpiling ability and when it should issue trade promotions to leverage retailer stockpiling and consumer stockpiling for channel coordination.

*When should a manufacturer restrict its retailer's ability to stockpile its product?* Our analysis reveals that a manufacturer should restrict retailer stockpiling when the storage cost is *low* to induce consumer stockpiling. Therefore, manufacturers should adopt this restriction strategy selectively across product categories depending on storage costs.

*Why should a retailer accept restrictive channel contracts that forfeit its stockpiling ability?* Our analysis suggests that restriction of retailer stockpiling weakly improves the retailer's profit. Therefore, retailers are willing to accept seemingly harmful restrictive channel contracts, such as scan-backs, that prevent their stockpiling ability. These contractual agreements can lead to win-win outcomes for both the manufacturer and the retailer.

*When should the manufacturer issue trade promotions?* We find that the manufacturer should issue trade promotions when the retailer cannot stockpile products and the storage cost is low. However, if the retailer can stockpile products, the manufacturer should not only avoid issuing trade promotions but also raise the wholesale price to deter and exploit the retailer's stockpiling incentives.

*How does the storability of products change a manufacturer's profit?* Our research shows that the storability of products increases the manufacturer's profit. Therefore, manufacturers should strive to design products to be more storable.

Future research could extend this work in several directions. For example, future research can allow the retailer and consumers to incur different storage costs and also discuss whether the retailer wants to restrict consumer stockpiling. Future research can also consider situations in which consumers exhibit mixing stockpiling behaviors, storage costs are nonlinear, consumers incur heterogeneous storage costs, demand changes over time, storage costs are continuous, channel members compete on price or quantity, and a model with longer horizons. In the main model, we also assume away demand uncertainty to focus on how channel interactions induce stockpiling with certain and fixed demand. However, retailers' and consumers' stockpiling incentives are likely to change when they are uncertain about future demand. Therefore, considering the equilibrium outcome in the presence of demand uncertainty would be worthwhile. In addition, we focus on a channel contracted through dynamic linear pricing. If the manufacturer can commit to its future price, stockpiling does not squeeze the manufacturer's margin and its benefit for improving channel coordination may decline. With two-part tariffs, the manufacturer can extract the retailer's entire surplus to coordinate channel efficiently. Retailer stockpiling results in a storage cost that is passed on to the manufacturer and consumer stockpiling results in retail price distortion, both of which can reduce channel efficiency. Therefore, the benefits of stockpiling may not apply to channels contracted with two-part tariffs. Future research can further examine price commitment and nonlinear pricing contracts for storable goods.

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