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Strategic Inventories Under Supply Chain Competition

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Abstract. ***Problem definition***: We consider the effects of strategic inventory (SI) in the presence of chain-to-chain competition in a two-period model. ***Academic/practical relevance***: Established findings suggest that SI may alleviate double marginalization and improve the efficiency of a decentralized distribution channel. However, no studies consider the role of SI under chain-to-chain competition. ***Methodology***: We build a two-period model consisting of two competing supply chains, each with an upstream manufacturer and an exclusive retailer. The retailers compete on either price or quantity. We characterize the firms' strategies under the concept of perfect Bayesian equilibrium. We consider cases where contracts are either observable or unobservable across supply chains. ***Results***: (1) SI still exists under chain-to-chain competition. Retailers may carry more inventory when the competition becomes fiercer, which further intensifies the supply chain competition. (2) Different from the existing findings, SI may backfire and hurt all firms. Interestingly, firms may benefit from a higher inventory holding cost. (3) Under supply chain competition, the prisoner's dilemma can arise if competition intensity is intermediate; in other words, manufacturers are better off without strategic inventory, and yet they cannot help allowing strategic inventory, which is the unique equilibrium. ***Managerial implications***: Despite its appeal among firms of a single supply chain, the role of SI is altered or even reversed by chain-to-chain competition. Conventional wisdom on SI should be applied with caution.

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1. Introduction

1.1. Background and Motivation

Forward buying refers to retailers' activity of purchasing units during a particular period, holding some of them in inventory, and then selling them in subsequent periods (Desai et al. 2010). It has been a long-time business practice. The empirical literature provides evidence of forward buying in various categories, including bathroom tissue, coffee, detergents, and paper towels (Bell et al. 1999). Likewise, Armstrong (1991) also finds empirical support of forward buying in such product categories as disposable diapers and ground caffeinated coffee.

Anand et al. (2008) first identify the strategic role of such inventory held by retailer in coordinating supply chains. They find that in a two-period dyadic supply chain, the retailer may build up strategic inventory (SI) at the end of the first period to limit the manufacturer's market power in the second period. Interestingly, this strategic use of inventory alleviates double marginalization and improves both the manufacturer's and the retailer's profit. Under different settings, a number of subsequent studies (Desai et al. 2010, Arya and Mittendorf 2013, Hartwig et al. 2015) have all confirmed the similar role of SI in a decentralized supply chain. In particular, Hartwig et al. (2015) conducted an experimental study to show that decision makers indeed use inventory strategically, as the theory prescribes.

Although these findings are insightful, one missing feature among all existing research on SI is supply chain competition, which appears to be prevalent in this modern economy. As a matter of fact, the product categories (e.g., detergents, coffee, paper towels, and diapers) of the earlier-cited empirical literature on forward buying are all rather competitive with many brands and retailers. As Taylor (2003), Barnes (2006), and Ha and Tong (2008) thoroughly discuss, nowadays business competition is all about supply chain versus supply chain. The financial performance of a firm, be it a manufacturer or a retailer, hinges on the performance of the supply chain to which it belongs. Examples of chain-to-chain competition abound. A canonical example of this can be seen when competing car manufacturers distribute their cars through exclusive dealers. Another example can be seen in the relationship between electronics manufacturers and exclusive distributors/retailers; for example, customers frequently purchase through Panasonic and Samsung shops that operate independently from the original manufacturers (e.g., Panasonic in Japan and Samsung in Korea). Sanitaryware brands such as Toto and Jacob Delafon typically sell their products through regional distributors, and likewise many garment brands sell their products through third-party exclusive retailers.

To fill the gap between the academic literature and business practice, we attempt in this paper to study the role of SI in the presence of chain-to-chain competition. In addition to the fact that chain-to-chain competition is ubiquitous and should be factored into the picture, this paper follows a natural rationale: conventional wisdom on SI should be applied with caution. SI primarily facilitates internal coordination within a supply chain, but it is not a priori clear whether this internal coordination is overwhelmingly beneficial when facing external competition.

In compliance with Anand et al. (2008), we consider a two-period model in which two retailers sell (imperfect) substitutes that are sourced from their exclusive manufacturers. The retailers can purchase excessive goods in the first period and carry them through to the second period. In the basic model, we consider a situation where the supply contracts and transaction details within a supply chain are not observable to the rival supply chain and where the retailers compete on price. Unobservable contracts are typical in practice. Consider two competing automotive manufacturers and their exclusive dealers in a region. Contract terms such as wholesale prices and order quantities are often not observable to the rival firms, although they are mostly known within the chain. As robustness checks, we also study the scenario where contracts are observable across chains and the scenario where the retailers engage in quantity competition.

1.2. Summary of Our Findings

Based on these model characteristics, we make a number of observations. First, we replicate the existing wisdom by showing that the retailers still hold SI under supply chain competition. SI could lead to lower wholesale prices in the second period, thereby alleviating double marginalization. This establishes the close connection between the existing literature and our setup. However, in addition to double marginalization alleviation, SI also has a competition intensification effect. By stocking excessive inventory in the first period, a retailer faces a lower wholesale price in the second period, which intensifies the competition between the two retailers. Note that when competition is not fierce, SI could alleviate the first-period competition. However, this effect is immaterial compared with the competition intensification effect in the second period.

Along this line, the more substitutable the goods are, the more SI the retailers will carry and the fiercer will be the competition between the supply chains. When competition is mild, the double marginalization alleviation effect overweighs the competition intensification effect; consequently, SI improves the firms' profits. However, when competition is fierce, the competition intensification effect starts to take over, which leads to lower equilibrium profits for all firms.

Second, we compare the results with those in the no-inventory (NI) case, which refers to the scenario in which the retailer cannot carry inventory. In Anand et al. (2008), the manufacturers always prefer to operate with strategic inventories. This insight is further confirmed by Desai et al. (2010), Arya and Mittendorf (2013), and Roy et al. (2019) in different contexts. However, in the presence of supply chain competition, we show that manufacturers can strictly prefer to eliminate strategic inventories. This occurs when competition is relatively fierce because the competition intensification effect now overshadows double marginalization alleviation. and SI backfires on both retailers and manufacturers. It is also worth mentioning that although firms benefit from SI only when competition is mild, SI always improves social welfare.

Third, we consider the case where manufacturers can choose whether to allow retailers to carry strategic inventories. For example, a manufacturer can eliminate SI by implementing a vendor-managed inventory (VMI) system and delivering to its retailer only the needed amount for the current period. In e-commerce, drop shipping is a common arrangement between manufacturers and retailers. Similarly, with drop shipping, the retailer does not physically handle the products or carry inventory. The manufacturers' choices of eliminating SI are long-term decisions and, once made, cannot be changed in the short run. We find that in equilibrium, manufacturers choose to eliminate SI when competition is fierce. This happens because NI could help the retailers shield themselves from the fierce competition caused by strategic inventory, which, in turn, also benefits manufacturers. However, holding SI remains a pure-strategy equilibrium when competition is less fierce, even though it may hurt the manufacturers' profits. This constitutes a form of the prisoner's dilemma: when the competition is intermediate, it is difficult for either manufacturer to escape from this unfortunate outcome.

Finally, to check the robustness of our findings, we extend the basic model in two directions. We consider a case in which the contract terms between a manufacturer and its downstream retailer are observed by the other supply chain and find that our results continue to hold. We also investigate a scenario in which retailers compete on quantity (as opposed to price). We find that the main insights remain qualitatively unchanged under quantity competition.

Taken together, these results help us build an understanding of SI in competitive markets.

1.3. Related Literature

Our paper contributes to the growing literature concerning the strategic use of inventories. The idea of SI was originally proposed by Anand et al. (2008). In their seminal work, these authors consider a decentralized distribution channel in which a retailer may opt to carry additional inventory after the first period to convince the manufacturer to lower its wholesale price in the second period. There are no uncertainties in the model, and the use of inventories is purely strategic. The authors show that SI could alleviate double marginalization and improve both the manufacturer's and the retailer's profits. Moreover, the manufacturers always prefer to operate with strategic inventories.

Following Anand et al. (2008), Desai et al. (2010) use SI to explain the practice of forward buying. They consider competition at either the upstream or the downstream but not chain-to-chain competition, and their focus is on channel configuration. Therefore, their insights are different. In their two-retailers, one-manufacturer model, a retailer could free ride on the rival retailer's strategic inventory, and as competition becomes fiercer, SI level decreases. This is in direct contrast to our finding. Moreover, these authors assume that the contract between one retailer and the manufacturer is observed by the rival retailer, whereas we assume that contracts are not observable across supply chains. In their two-manufacturers, one-retailer model, the retailer is always better off with strategic inventory, which intensifies the competition between the upstream manufacturers. In our model, SI can backfire on the retailers' profit when competition is fierce. Arya and Mittendorf (2013) show that manufacturer-to-consumer rebates can further improve the performance of strategic inventory. In particular, they find that with consumer rebates, carrying strategic inventories is preferred to the elimination of inventories (i.e., NI) by the manufacturer, retailer, and consumers alike. Arya et al. (2014) demonstrate that in the presence of strategic inventory, a firm's decision to cede procurement choices to its individual divisions can help moderate inventory levels and provide a natural salve on supply chain frictions. Recently, Roy et al. (2019) consider the case where the manufacturer cannot observe the retailer's level of strategic inventory. They show that this can lead to more or less strategic inventory depending on the level of holding cost. They also find that the manufacturer would prefer not to have visibility into the retailer's operations, which would permit it to observe the inventory, whereas the retailer would prefer for the manufacturer to have observability only when the holding cost is sufficiently low. Guan et al. (2019) show that a retailer could carry SI to limit the encroachment of its upstream manufacturer and that both firms may benefit from the coexistence of SI and supplier encroachment.

It is worth noting that excess inventory may arise as a result of other strategic concerns. For example, Lai et al. (2011) and Lai et al. (2012) show that in the presence of short-term valuation concerns, firms (or firm managers) may have an incentive to overstock to signal their market value to the capital market.

This paper is also closely related to the literature on chain-to-chain competition. Beginning with McGuire and Staelin (1983), this classical problem has been extensively studied in operations management, marketing, and economics (e.g., Carr and Karmarkar 2005, Villas-Boas 2007, Ha and Tong 2008). Whereas McGuire and Staelin (1983) implicitly assume that all contracts are public information in the market, Coughlan and Wernerfelt (1989) show that the channel equilibrium is completely different when such contracts are not observed by rival firms. Corbett and Karmarkar (2001) consider entry decisions and postentry decisions in a multitier serial supply chain. Ha and Tong (2008), Ha et al. (2011), and Ha et al. (2017) focus on the value of information sharing within a supply chain under chain-to-chain competition. In particular, they assume that contract types are observable but that contract terms are not observable to firms in the rival supply chain. In this connection, Shin and Tunca (2010) study the effect of observability in supply chains. They show that forecast observability (i.e., the observability of forecast investments) amplifies both the overinvestment in forecasting and the ensuing supply chain efficiency.

Finally, there is a large body of literature on inventory competition (e.g., see Cachon 2001, Netessine and Rudi 2003, Gaur and Park 2007, Zhao and Atkins 2008, Nagarajan and Rajagopalan 2009). However, this literature largely studies the competition of two firms and focuses on the operational role of inventory, that is, to prevent stock-outs. In contrast, we consider the strategic role of inventory under chain-to-chain competition.

1.4. Organization of This Paper

The rest of this paper is organized as follows. Section 2 presents the model, which is analyzed and discussed in Section 3. Section 4 considers the equilibrium strategies when the manufacturers could choose between SI operations and NI operations. Section 5 extends the model to consider observable contracts and quantity competition. The paper is concluded in Section 6. All the proofs are relegated to the online appendix.

2. Model

Our model consists of two competing supply chains, indexed by $i \in \{1, 2\}$ and $j = 3 - i$, each with an upstream manufacturer and a downstream retailer. The two retailers sell imperfect substitutes and compete on price, each sourcing from an exclusive manufacturer, which does not supply the other retailer.

2.1. Market Demand

There are two periods in the model, $t = 1, 2$. In period t, the retail demand for product i is[1]

$$D_{it} = 1 - p_{it} + \theta(p_{jt} - p_{it}), \tag{1}$$

where $\theta > 0$ reflects the extent of competition between the two supply chains. This parameter captures the degree of substitutability both between the products and between the retailers. When θ is larger, competition will be fiercer. Throughout this paper, as in (1), we use the first subscript to represent supply chain indices and the second subscript to represent period indices. This demand structure has been used in the literature (e.g., Desai et al. 2010). The manufacturers' marginal production costs are symmetric, constant, and normalized to zero.

It is noteworthy that some literature (e.g., McGuire and Staelin 1983) uses a different demand function to model supply chain competition, that is, $D_{it} = 1 - p_{it} + tp_{jt}$, where $t \in [0, 1)$ captures the intensity of competition. This model is equivalent to our model in the sense that

$$D_{it} = 1 - (1 - t)p_{it} + t\left(p_{jt} - p_{it}\right).$$

Let $\hat{p} = (1 - t)p$ and $\theta = t/(1 - t)$. We have $D_{it} = 1 - \hat{p}_{it} + \theta(\hat{p}_{jt} - \hat{p}_{it})$, where θ can be any positive number. For example, $t = 0.8$ corresponds to $\theta = 4$.

2.2. Inventory Carryover

So far the model is standard and is commonly used in the literature (cf. McGuire and Staelin 1983). We assume, à la Anand et al. (2008), that the retailers could purchase excessive goods during period $t = 1$, carry the goods in their retail inventory, and sell them during period $t = 2$. The unit inventory holding cost is h per period.

2.3. Timing and Decisions

We analyze a four-stage game, with two stages in each period. In the first stage, the two manufacturers simultaneously decide their first-period wholesale prices w_{i1} and w_{j1}. In the second stage, the two retailers simultaneously decide their retail prices p_{i1} and p_{j1}. They also decide Q_{i1} and Q_{j1}, the quantities that they order from their upstream manufacturers. Note that the order Q_{i1} may exceed the actual demand D_{i1}. If so, the excessive goods $I_i = (Q_{i1} - D_{i1})^+$ are carried forward to the second period by retailer i.

In the third stage, the two manufacturers simultaneously decide their second-period wholesale prices w_{i2} and w_{j2}. In the fourth stage, the retailers decide their retail prices p_{i2} and p_{j2}, and then they decide Q_{i2}, Q_{j2}, the quantities they order from their upstream manufacturers. Retailer i uses both I_i, its inventory carryover, and Q_{i2}, the new orders the retailer places in period 2, to satisfy the demand.

2.4. Information Structure

Our model slightly differs from the traditional literature on supply chain competition (cf. McGuire and Staelin 1983) in its information structure. We assume that the contract terms and transaction details within a supply chain are not observed by firms of the rival supply chain. In other words, firms of supply chain j do not observe w_{it} or Q_{it}, and subsequently, they do not observe I_i either. We make this assumption of unobservability for the following reasons. First, as pointed out in the literature, unobservable contracts are more realistic because contract terms within a supply chain are typically not observed by rival firms (see Coughlan and Wernerfelt 1989, Hart et al. 1990, McAfee and Schwartz 1994, Segal 1999, Rey and Tirole 2007, Gavazza and Lizzeri 2009, Ha et al. 2011, Li and Liu 2020, for example). Second, our main findings remain qualitatively unchanged under observable contracts (see Section 5.1). Third, the analysis of unobservable contracts is cleaner and more tractable. As such, we choose to study unobservable contracts in the main model.

As in Anand et al. (2008), there is no demand uncertainty in our model. As these authors noted, this assumption helps isolate the strategic interactions between the manufacturers and the retailers via inventories without muddying the waters through other effects that are not the focus of this paper. Anand et al. (2008) suggest that SI could alleviate double marginalization in a supply chain and therefore could improve the profits of both the upstream and downstream firms. As we will show in this paper, in the presence of supply chain competition, SI not only alleviates double marginalization but also intensifies the competition between the two supply chains. The exact implication of SI hinges on the magnitudes of these two effects.

3. Analysis

In this section, we will analyze the channel equilibrium in the basic model. Given that contract terms are not observed by firms of the rival supply chain, we characterize the firms' strategies under the concept of perfect Bayesian equilibrium (PBE). It is noteworthy that PBE does not impose restrictions on beliefs off the equilibrium path. This gives rise to multiple equilibria. Here we assume *passive beliefs*—that is, beliefs are not updated upon observing a deviance, an assumption commonly made in the literature (Hart et al. 1990, McAfee and Schwartz 1994, Segal 1999, Rey and Tirole 2007, Gavazza and Lizzeri 2009, Ha et al. 2011, Li and Liu 2020). For example, when observing an unexpected wholesale price w_{i1}, retailer i does not change its belief of w_{j1}. Similarly, when observing an unexpected retail price p_{j1}, retailer i does not change its belief of w_{j1}. It is worth mentioning that there are other beliefs, such as symmetric beliefs and wary beliefs, that are used when studying unobservable contracts in a supply chain (McAfee and Schwartz 1994). These beliefs are less appealing in our model because (1) our model consists of two independent manufacturers, whereas the existing literature focuses on a single upstream manufacturer, and (2) in our model, a deviation in retail price can result from the off-equilibrium behavior by either the manufacturer or the retailer, which is indistinguishable to the rival supply chain. Given these issues, we adopt passive beliefs for our analysis.

3.1. Equilibrium Characterization

Detailed analysis has been relegated to the online appendix. The equilibrium strategies are described in Table 1. We also compare the results with those in an NI system, where a manufacturer only delivers whatever its downstream retailer can sell.

3.1.1. Strategic Inventory. From the results in Table 1, we observe that the firms still hold SI under supply chain competition. Moreover, we have the following proposition.

Proposition 1. *Under chain-to-chain competition, we have the following:*

a. *If and only if $h < 1/(4+\theta)$, SI exists in equilibrium.*

b. *When $\theta < \hat{\theta}$, SI increases the intensity of competition; otherwise, SI decreases the intensity of competition, where $\hat{\theta}$ solves*[2]

$$h = \frac{1{,}552 + 1{,}144\hat{\theta} + 229\hat{\theta}^2}{8{,}928 + 11{,}920\hat{\theta} + 6{,}254\hat{\theta}^2 + 1{,}484\hat{\theta}^3 + 133\hat{\theta}^4}.$$

The rationale for a retailer to hold SI under chain-to-chain competition remains the same: it induces the upstream manufacturer to reduce the second-period wholesale price, which leaves more room for the retailer's profit margin. In the presence of market competition, it also provides the retailer with more pricing flexibility to compete. Collectively, incorporating supply chain competition does not eliminate SI. Nevertheless, the retailer will hold SI only if holding inventory is not too costly.

A similar logic applies to understanding the impact of competition on SI. When competition becomes fiercer (i.e., θ increases), the second-period demand D_{i2} becomes more sensitive to the selling price p_{i2}. Because the selling price is influenced by the wholesale price w_{i2}, the retailer has a stronger incentive to induce a lower wholesale price in order to remain competitive in the market. Mathematically, this arises because

$$\frac{\partial D_{i2}}{\partial w_{i2}} = \frac{\partial D_{i2}}{\partial p_{i2}} \cdot \frac{\partial p_{i2}}{\partial w_{i2}} = -\frac{1}{2}(1+\theta) < 0.$$

Holding SI turns out to be an effective way to lower the wholesale price and boost demand, and it is more effective when θ is large. By contrast, when θ is large, the fierce competition erodes the retailer's second-period margin $p_{i2} - w_{i2}$, and the retailer is less interested in carrying SI. When θ is low, the former effect dominates, and SI is increasing in θ, whereas when θ

Table 1. Equilibrium Strategies

Decisions	SI ($h \leq 1/(4+\theta)$)	SI ($h > 1/(4+\theta)$) or NI
w_{i1}	$\frac{36-2h(4-\theta)}{68+19\theta}$	$\frac{2}{4+\theta}$
p_{i1}	$\frac{104+55\theta-2h(1+\theta)(4-\theta)}{(2+\theta)(68+19\theta)}$	$\frac{3}{4+\theta}$
D_{i1}	$\frac{(1+\theta)(32+19\theta+2h(4-\theta))}{(2+\theta)(68+19\theta)}$	$\frac{1+\theta}{4+\theta}$
I_i	$\frac{(1+\theta)(20+7\theta)(1-h(4+\theta))}{(2+\theta)(68+19\theta)}$	0
w_{i2}	$\frac{24+40h+14h\theta}{68+19\theta}$	$\frac{2}{4+\theta}$
p_{i2}	$\frac{92+43\theta+2h(1+\theta)(20+7\theta)}{(2+\theta)(68+19\theta)}$	$\frac{3}{4+\theta}$
D_{i2}	$\frac{(1+\theta)(44+19\theta-2h(20+7\theta))}{(2+\theta)(68+19\theta)}$	$\frac{1+\theta}{4+\theta}$
Π_i	$\frac{4(1+\theta)(306-34h(4-\theta)+h^2(272+\theta(136+21\theta)))}{(68+19\theta)^2}$	$\frac{4(1+\theta)}{(4+\theta)^2}$
π_i	See the online appendix.	$\frac{2(1+\theta)}{(4+\theta)^2}$

is high, the latter effect dominates, and SI is decreasing in θ.

3.2. Comparison with NI

Proposition 1 indicates the essence of SI. However, one question remains unaddressed: is SI profitable in competitive markets? To answer this question, we compare our results with the benchmark in which SI is absent. We derive the firms' equilibrium profits in the absence of SI and summarize the equilibrium results in column "NI" of Table 1.

3.2.1. Price Competition. Does SI intensify or alleviate the price competition between the two supply chains? To address this issue, we compare the equilibrium prices under SI and under NI. The results are summarized in the following corollary.

Corollary 1. *Compared with the case of NI, we have that in equilibrium:*

a. *The first-period wholesale and retail prices are higher under SI when $\theta < 4$ and lower otherwise.*

b. *The second-period wholesale and retail prices are always lower under SI.*

Corollary 1 illustrates that SI always intensifies the second-period competition. Because both retailers carry SI, the manufacturers will charge lower wholesale prices in the second period to motivate the retailers to buy. As a result, the second-period retail prices go down, and competition becomes fiercer than under NI.

Now consider the effect of SI on first-period price competition. Here two forces play against each other. On the one hand, as discussed by Anand et al. (2008), the manufacturers have an incentive to raise the first-period wholesale prices to discourage their own retailers from carrying inventories. On the other hand, both manufacturers have a tendency to encourage the retailers to carry inventory to gain a competitive advantage in the second period over the competing chain. Consequently, when θ is small, the first force dominates, and retailers face higher wholesale prices and thus charge higher retail prices, which reduces the intensity of first-period competition. When θ is large (i.e., the competition between the two supply chains is fierce), the second force prevails. As a result, the manufacturers charge lower prices, and in turn, the competition is fiercer in both periods than under NI.

In Figures 1 and 2, we show the effect of SI on the equilibrium prices. From the figures, we can see that when θ is small, the first-period prices are higher under SI, thereby reflecting the softening of competition. However, this effect quickly diminishes as θ increases. When θ is large, competition is fiercer in both periods. It is worth noting that relative to the NI setting, the first-period wholesale price decreases faster in θ. As θ increases, the competition between the two supply chains becomes fiercer. Each individual supply chain would benefit more from holding SI on its own side to be competitive in the second period. As such, a manufacturer is more willing to lower its first-period wholesale price (relative to its wholesale price in the NI setting) to encourage its downstream retailer to stock more. As such, the first-period wholesale price in the SI setting decreases faster in θ.

Figure 1. Strategic Inventory and Wholesale Prices ($h = 0$)

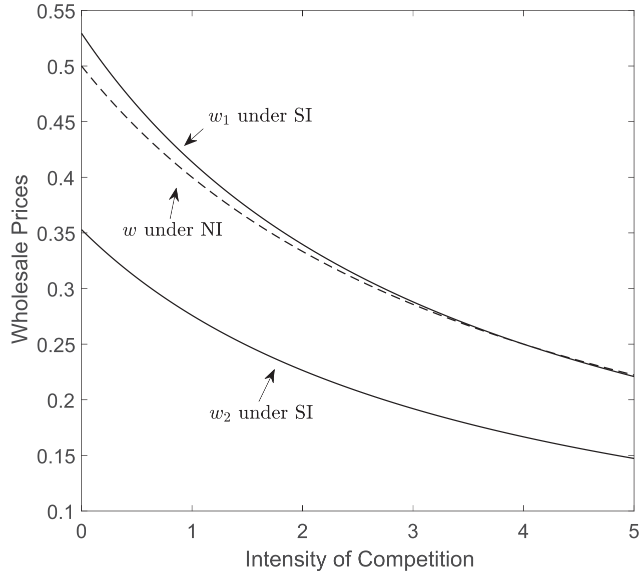
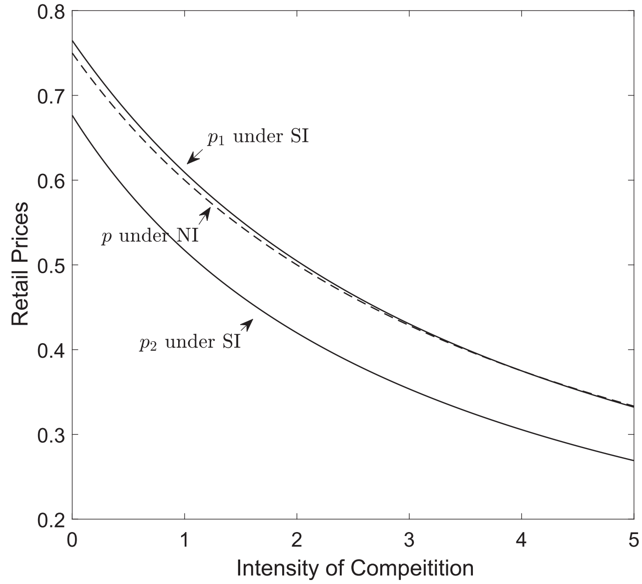


Figure 2. Strategic Inventory and Retail Prices ($h = 0$)



3.2.2. Profit Comparisons. Comparing the firms' profits under different strategies yields the following proposition.

Proposition 2. *Suppose that $h < 1/4$. Under chain-to-chain competition, there exists $0 \le \theta_0 < 1/h - 4$ such that SIs leave all firms strictly worse off when $\theta_0 < \theta < 1/h - 4$. (When $h \ge 1/4$ or $\theta \ge 1/h - 4$, SIs are not carried in equilibrium.)*

We now consider the case of $h = 0$, which allows us to characterize the conditions more succinctly. We have the following corollary.

Corollary 2. *Suppose that $h = 0$; then we have the following results:*

a. *When $\theta \ge 1.308$, SIs always leave the manufacturers worse off.*

b. *When $\theta \ge 2.021$, SIs always leave the retailers worse off.*

c. *When $\theta \ge 1.505$, SIs always leave the supply chain profits worse off.*

Proposition 2 indicates that unlike the monopoly case ($\theta = 0$), in a competitive market, SI may reduce both the retailers' and manufacturers' profits. To visualize this, in Figures 3 and 4, we supplement Proposition 2 by plotting the manufacturers' and retailers' profits under the SI and NI settings (setting $h = 0$). When $\theta = 0$, the model degenerates to the familiar Anand et al. (2008) model of monopoly markets, where SI leads to 5.9% and 7.3% profit improvement for the manufacturer and retailer, respectively. However, when θ is large, SI leads to substantial profit losses. For example, when $\theta \to \infty$, the two products are perfect substitutes, and SI can lead to 15.2% and 11.6% profit losses for the manufacturers and retailers, respectively.[3] Clearly, the profit advantage of SI hinges on the intensity of the competition.

Why does fierce competition reduce the profitability of SI? To answer this question, note first that in the absence of competition, SI has the sole effect of alleviating double marginalization. This double marginalization alleviation effect is unambiguously positive.

Figure 3. Benefit of Strategic Inventory to Manufacturers ($h = 0$)

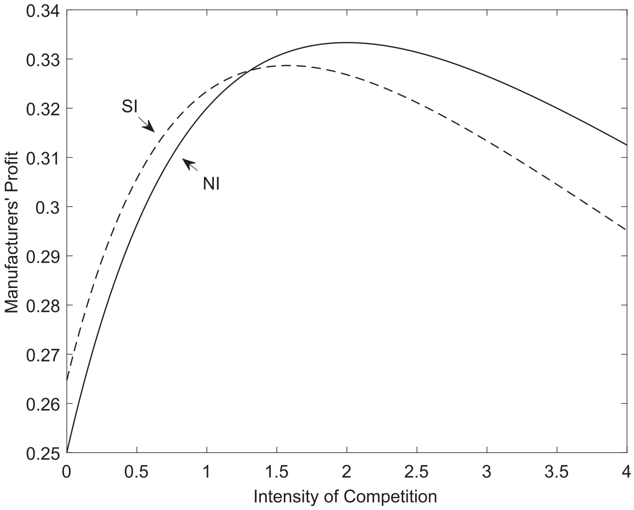
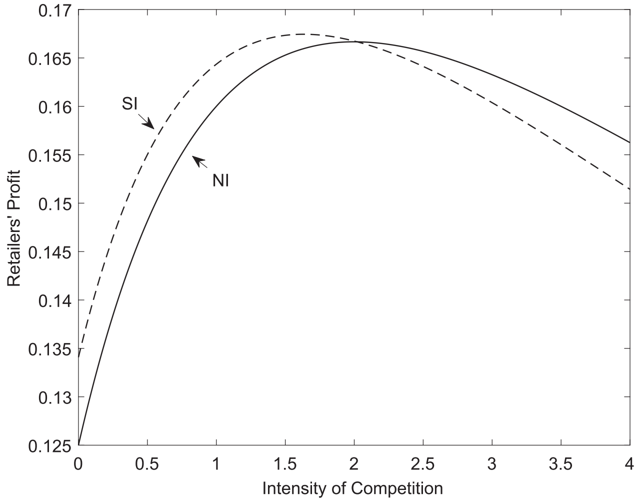


Figure 4. Benefit of Strategic Inventory to Retailers ($h = 0$)



The presence of competition brings a second effect to SI: it reduces (intensifies) the first-period chain-to-chain competition when θ is small (large) and also intensifies second-period chain-to-chain com-petition, as shown in Figures 1 and 2. Competition is so fierce in the second period that SI has an overall competition intensification effect.[4] This competition intensification effect backfires on both the retailers' and manufacturers' profits.

Therefore, when competition is weak, the double marginalization alleviation effect dominates, and overall SI improves the profits of both manufacturers and retailers. As θ grows, the competition intensification effect starts to take over and eventually dominates the double marginalization alleviation effect. Therefore, SI can either benefit or hurt firms depending on the magnitudes of these two effects. In a similar vein, the effect of SI on total channel profit hinges on the intensity of competition between the two chains. Whereas the previous literature has suggested that SI alleviates the issue of double marginalization and that firm profits decrease with market competition, our results find an interaction between these two effects, namely SI intensifies market competition and leaves the firms worse off when competition is fierce enough. Such an interaction effect is new and has not been covered in the literature. It is noteworthy that although both manufacturers and retailers prefer SI (NI) to NI (SI) when competition is low (high), their interests toward SI are not perfectly aligned. For example, when $h = 0$, manufacturers (retailers) are worse off (better off) with SIs when $1.308 \le \theta \le 2.021$. This is because the benefit of double marginalization alleviation is not created equal for the supply chain members—retailers benefit more from the double marginalization alleviation effect. Moreover, when $h > 0$, the cost of carrying SI is borne by the retailers alone, which makes SI less profitable for the retailers.

3.2.3. Welfare Implication. Finally, in regard to social welfare, we have the following corollary.

Corollary 3. (a) *When* $\theta < 1.512$*, SI always improves social welfare.* (b) *When* $\theta > 1.512$*, SI improves social welfare when h is small enough.*

The intuition for Corollary 3 is as follows. SI has two effects on social welfare. First, SI alleviates double marginalization and improves supply chain efficiency. This effect benefits social welfare because prices are lower and demand is higher. Second, SI brings about a dynamic inefficiency into the system because inventory holding cost is incurred. This effect hurts social welfare. When competition is less fierce or inventory holding cost is not too high, the former effect dominates the latter, and social welfare is higher. When competition is fierce and inventory holding cost is high, however, substantial cost is incurred in carrying SI. As a result, the latter effect dominates, and social welfare is worse off.

3.3. Inventory Holding Cost

Anand et al. (2008) show that in a monopoly supply chain, the manufacturer's profit is always decreasing in the inventory holding cost h. The rationale is that a higher inventory holding cost reduces the SI and the benefit of double marginalization alleviation. Does the same result hold under supply chain competition? We analyze the effect of an increase in h on manufacturers' and retailers' profits and summarize the results in the following proposition.

Proposition 3. (a) *In equilibrium, the manufacturers' profit is strictly increasing in h when*

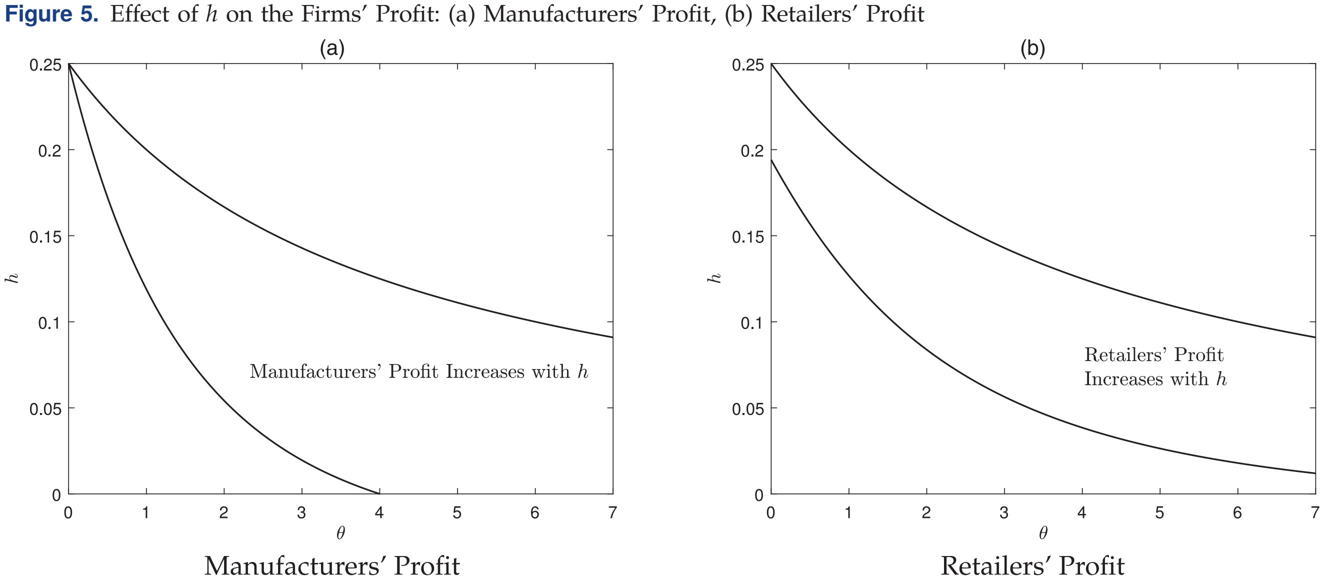
$$\frac{17(4-\theta)}{272+136\theta+21\theta^2} \le h \le \frac{1}{4+\theta}.$$

(b) *In equilibrium, the retailers' profit is strictly increasing in h when*

$$\frac{1{,}888+1{,}424\theta+242\theta^2-35\theta^3}{9{,}728+11{,}456\theta+5{,}344\theta^2+1{,}148\theta^3+98\theta^4} \le h \le \frac{1}{4+\theta}.$$

Proposition 3 suggests that in contrast to the monopoly case, under supply chain competition, both manufacturers' and retailers' profits can increase in h. The rationale is the following. When h is high, an increase in h reduces SI, which consequentially alleviates the competition between the two chains. Moreover, increasing h can also save the costs associated with carrying SIs (i.e., $I_i \cdot h$ decreases in h when h is high). As a result, both manufacturers and retailers may benefit from a higher inventory holding cost. The regions in which the firms' profits increase with h are illustrated in Figure 5. It is worth mentioning that we assume that supply chain i observes h_j, the inventory holding cost of supply chain j. This assumption is reasonable when the two retailers use similar facilities and technologies to store the products. Nonetheless, it may be possible that supply chain i does not observe h_j, and vice versa. Although we are not able to solve a model with unobserved inventory holding cost, we expect our insights to continue to hold: under supply chain competition, the role of SI is twofold. On the upside, it improves the internal coordination within a supply chain. On the downside, it intensifies the competition between the two supply chains. When the competition is fierce enough, the latter effect can dominate the former effect and leave competing firms worse off.

Figure 5. Effect of h on the Firms' Profit: (a) Manufacturers' Profit, (b) Retailers' Profit



4. Endogenizing the Choice Between SI and NI

So far in our model both retailers are left to decide whether to carry SI from period to period. However, as we have seen, when the competition is fierce, SI backfires and hurts all the firms. Therefore, the firms may have incentives to disallow SI in their supply chains. To prevent retailers from holding SI, manufacturers may adopt a VMI system. As Anand et al. (2008) point out, under VMI, the manufacturers manage the retailer's inventories, and it virtually eliminates SIs in vertical contracts. Notably, VMI is a long-term decision and requires a sizable investment and commitment. Therefore, once made, such an arrangement often becomes known to the firms of the rival supply chain. In e-commerce, drop shipping remains a common arrangement between manufacturers and retailers (Lofgren 2020). With drop shipping, the retailer simply forwards customer orders to the manufacturer, who delivers the orders directly to customers and is paid a predetermined price by the retailer (Khouja 2001). Because the retailer does not handle the products physically, drop shipping eliminates SI as well. Notably, the choice of drop shipping is a long-term decision and can also be easily observed by other firms. Based on the preceding discussion, the manufacturers can credibly commit to eliminating SIs in the first place.

In this section, we consider whether the manufacturers will choose to eliminate SI. For ease of exposition, we will use the term NI to refer to the elimination of inventories and SI to refer to the use of strategic inventory. As we have seen, manufacturers benefit from SI when competition is less fierce and may be hurt otherwise. Would a manufacturer then choose to commit to NI when a pure NI system is more beneficial?

To answer this question, we cannot directly compare the two systems (SI versus NI) because we must allow each manufacturer to determine whether to adopt NI or SI. In the game-theoretic setting, we add a stage zero to the basic model in which the manufacturers simultaneously choose between NI and SI. If a manufacturer chooses NI, then its downstream retailer will carry zero SI in the subsequent stages. Alternatively, if the manufacturer chooses SI, then its downstream retailer is free to carry any amount of SI. We assume that as discussed earlier, once made, the manufacturers' choices become public knowledge in the market. Moreover, to focus on strategic incentives, we assume that there is no cost difference between the SI and NI strategies.

We solve the model when the two supply chains adopt asymmetric inventory strategies and summarize the results in Table 2 of the online appendix. The case in which both supply chains adopt SI or NI is presented in Table 1. When the inventory holding cost $h = 0$, we have the following proposition.

Proposition 4. *Suppose that $h = 0$. When the manufacturers can choose between NI and SI, the following equilibria are identified:*

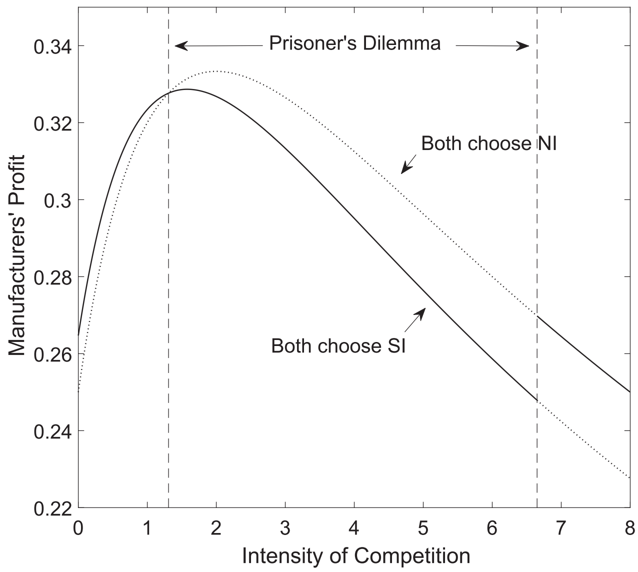
a. *When $\theta \leq 6.867$, there is a pure-strategy equilibrium where both manufacturers choose SI.*

b. *When $\theta \geq 6.650$, there is a pure-strategy equilibrium where both manufacturers choose NI.*

We have previously shown that for $\theta \geq 1.308$, a pure NI system dominates a pure SI system. However, from Proposition 4, for $\theta \leq 6.650$, a manufacturer can make greater profits through SI as long as its rival chooses an NI operation. Thus, for $\theta \leq 6.650$, the pure NI system is not an equilibrium. The problem of choosing between NI and SI operations when $1.308 \leq \theta \leq 6.650$ is a classical prisoner's dilemma game. This suggests that when the competition is at the intermediate level, it is very difficult for either party to escape from this unfortunate outcome. In essence, the fact that SI is prevalent does not mean that it benefits everyone. It could be an undesirable situation that firms cannot help falling into.

For a relatively high intensity of competition ($6.650 \leq \theta \leq 6.867$), both the pure NI system and the pure SI system can be sustained as equilibrium strategies, and the former is a preferred equilibrium (by both manufacturers and retailers) in that it Pareto dominates the latter. This dominant equilibrium is appealing and therefore is a natural equilibrium to select. In Figure 6, we plot their equilibrium profits.

Figure 6. Manufacturers' Profits When They Freely Choose Between NI and SI



Note. Solid lines denote the equilibrium profits.

We can see that there is a discontinuity in the manufacturers' profit at $\theta = 6.650$, where they switch from (SI, SI) to (NI, NI). This regime switch showcases the manufacturers' strategic concerns about the retailers' inventory carryover.

Interestingly, Figure 6 also shows that manufacturers may benefit from an increase in the intensity of competition. This phenomenon occurs around the regime switch, that is, when θ is slightly below the threshold 6.650.[5] As competition becomes fiercer, the manufacturers are induced to choose NI instead of SI. This eliminates the retailers' flexibility (of using SI) and may substantially alleviate the downside of enhanced competition intensity. Consequently, the manufacturers can benefit.

Finally, we conducted numerical analysis for positive h and found out that the prisoner's dilemma also appears. This result is illustrated in Figure 7. In the area labeled "Prisoner's dilemma," the manufacturers are better off when they both choose NI, yet they cannot help choosing SI in equilibrium.

5. Extensions

In this section, we examine two extensions of the basic model. First, we consider a case where the contracts within a chain are observable to the other chain. We then consider the scenario where the retailers compete on quantity instead of on price.

5.1. Observable Contracts

So far our model assumes that the contract terms and transactions of a supply chain are not observed by firms in the other supply chain. Although unobserved contracts are more realistic, in certain cases, this information may be observed.

5.1.1. Motivation for Cross-Chain Observability. For example, the warehouse of a retailer may be monitored, observed, or spied on by the retailer's rivals. On certain online platforms, retailers are required to disclose their inventory levels, and hence, inventory levels become public information. In addition, policy discussions in the European Union and the United States have led to legislation to mandate intermediaries to disclose their private information (see Inderst and Ottaviani 2012, Janssen and Shelegia 2015). There is also a large body of literature, including both analytical and empirical studies, that implicitly assumes that supply chain contracts are public information in the market (McGuire and Staelin 1983, Tsay and Agrawal 2000, Corbett and Karmarkar 2001, Carr and Karmarkar 2005, Villas-Boas 2007).

This motivates us to consider the observed case in this section. We revisit the basic model by assuming that all the contracts are public information in the market. Because the game features perfect information, we simply use backward induction to find out the subgame perfect equilibrium. To obtain tractable results, we assume that $h = 0$, which corresponds to the case where the inventory holding cost is negligible.[6] The following proposition says that SI still exists in the observable case.

Proposition 5. *In the observable case, SI exists in equilibrium. Moreover, compared with the unobserved case, in the observed case:*

a. *Retailers stock less inventory.*
b. *Both manufacturers and retailers make higher profits.*

We again use a figure to visualize the findings on the effect of inventory observability. In Figure 8, we compare the equilibrium inventory levels in the observed case with the unobserved case. Proposition 5 suggests that SI again arises when the contract terms are observed by rival firms. The rationale is similar: SI facilitates the internal coordination of a supply chain.

Figure 7. Prisoner's Dilemma and Inventory Holding Cost.

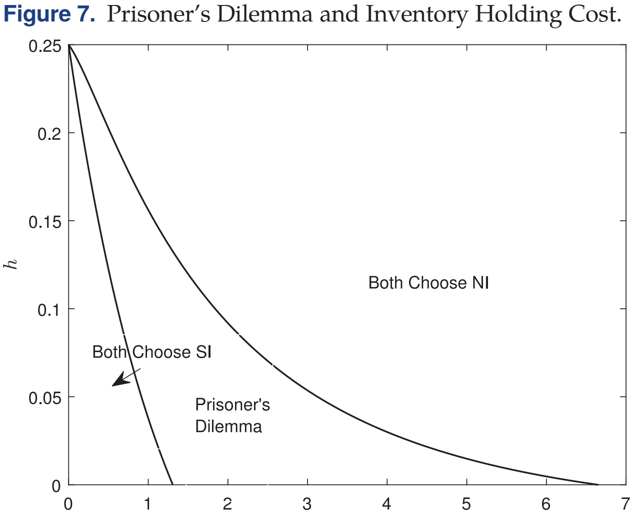
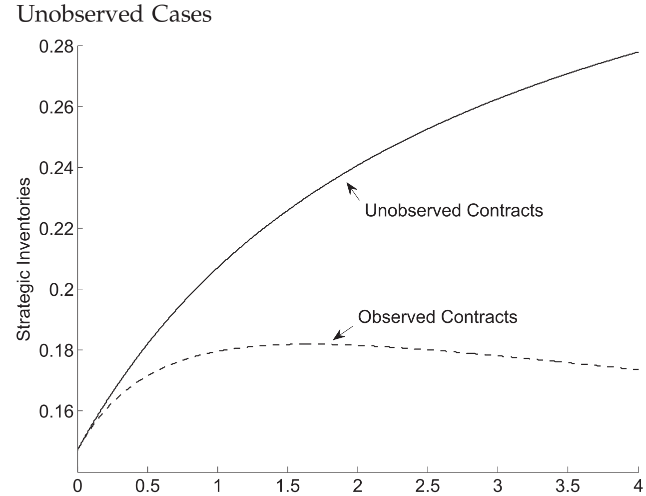


Figure 8. Strategic Inventory in the Observed and Unobserved Cases



Interestingly, retailers stock less inventory when the contract terms are observable. This result arises because in the observed case, when retailer i stocks more inventory (i.e., $\hat{I}_i$ increases, where we use a hat to represent the observed case), the rival manufacturer j, facing a competitive disadvantage, will respond by undercutting its second-period price $\hat{w}_{j2}$, which intensifies supply chain competition; that is, $\frac{\partial \hat{w}_{j2}}{\partial \hat{I}_i} < 0$. In anticipation of this, retailer i stocks less inventory in the observed case to avoid such retaliation from the rival chain.[7] Because both retailers carry less inventory, the supply chain competition becomes less fierce, resulting in higher profits.

Do the firms benefit from SI? Again, we compare the firms' profits to the NI case and summarize the results in the following proposition.

Proposition 6. *Under chain-to-chain competition, when the contracts are observable, we have the following:*

a. *The manufacturers benefit from SI if and only if $\theta \le 1.466$.*
b. *The retailers benefit from SI if and only if $\theta \le 2.865$.*
c. *The total supply chains benefit from SI if and only if $\theta \le 1.773$.*

Proposition 6 replicates the main finding of the basic model that under supply chain competition, both manufacturers and retailers are worse off with SI when the competition between the supply chains is fierce enough. The results are illustrated in Figures 9 and 10. Again, these results arise because as competition becomes fiercer, the double marginalization alleviation effect of SI is dominated and overshadowed by the effect of competition intensification, which finally backfires on the firms' profits.

Figure 9. Benefit of SI to Manufacturers (Observed Case)

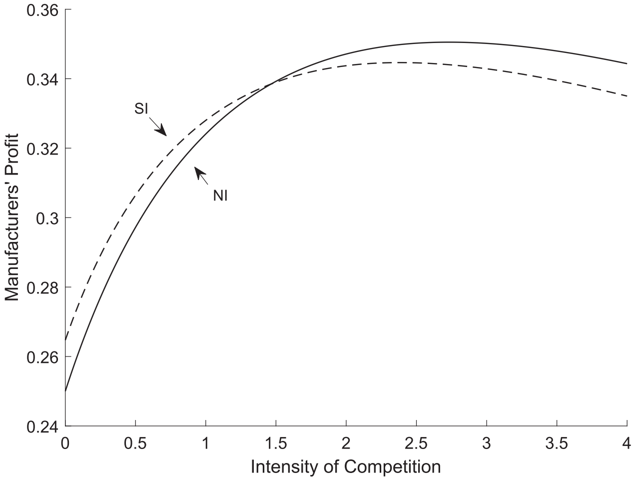
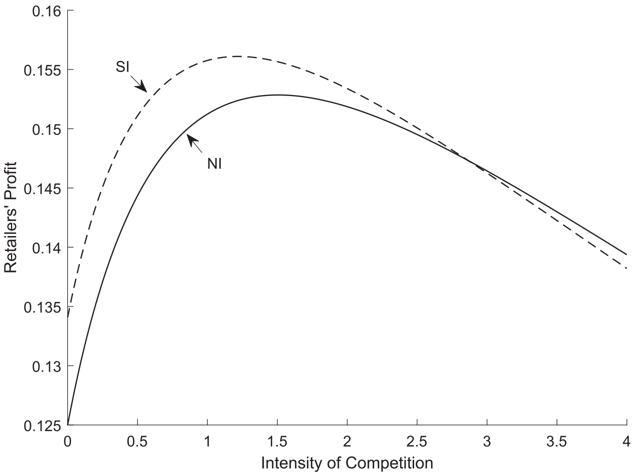


Figure 10. Benefit of SI to Retailers (Observed Case)



5.2. Quantity Competition

The basic model assumes that the two supply chains compete on price. In certain cases, the supply chains can also compete on quantity. In this subsection, we consider the case in which the supply chains compete on quantity.

To model quantity competition, we assume that the inverse demand function takes the following specification, which is commonly assumed in the literature:

$$p_{it} = 1 - Q_{it} - \gamma Q_{jt}, \tag{2}$$

where $0 \le \gamma \le 1$ reflects the extent of competition between the two supply chains. When $\gamma \to 0$, the demands for the two products are unrelated, and there is no competition between the two products, whereas when $\gamma \to 1$, the two products are perfect substitutes. We maintain the setup of the basic model except that retailer i now chooses the quantity to offer to the market in period t, Q_{it} (as opposed to the price p_{it} studied in the basic model).

We relegate the analysis to the online appendix and present the result in Table 2. From Table 2, we can see that SI arises under quantity competition. In the basic model, we find that under price competition, SI always leaves firms worse off when the competition is fierce enough (see Proposition 2). Does the same results hold under quantity competition? The following proposition summarizes the result.

Proposition 7. *Consider the case of quantity competition. When h is small, that is, $h \le 0.0378$, no matter how fierce the competition is, SIs always leave both manufacturers and retailers better off.*

Table 2. Equilibrium Strategies for Quantity Competition

Decisions	SI ($h \leq 1/(4+\gamma)$)	SI ($h > 1/(4+\gamma)$) or NI
w_{i1}	$\frac{36-2h(4-\gamma)}{68+19\gamma}$	$\frac{2}{4+\gamma}$
Q_{i1}	$\frac{32+19\gamma-2h(4-\gamma)}{(2+\gamma)(68+19\gamma)}$	$\frac{1}{4+\gamma}$
p_{i1}	$\frac{104+55\theta-2h(4-\gamma)(1+\gamma)}{(2+\gamma)(68+19\gamma)}$	$\frac{3}{4+\gamma}$
I_i	$\frac{(1-h(4+\gamma))(20+7\gamma)}{(2+\gamma)(68+19\gamma)}$	0
w_{i2}	$\frac{24+40h+14h\gamma}{68+19\gamma}$	$\frac{2}{4+\gamma}$
Q_{i2}	$\frac{44+19\gamma-2h(20+7\gamma)}{(2+\gamma)(68+19\gamma)}$	$\frac{1}{4+\gamma}$
p_{i2}	$\frac{92+43\gamma+2h(1+\gamma)(20+7\gamma)}{(2+\gamma)(68+19\gamma)}$	$\frac{3}{4+\gamma}$
Π_i	$\frac{4(306-34h(4-\gamma)+h^2(272+136\gamma+21\gamma^2))}{(68+19\gamma)^2}$	$\frac{4}{(4+\gamma)^2}$
π_i	See the online appendix.	$\frac{2}{(4+\gamma)^2}$

Note that Proposition 7 says that no matter how fierce the competition is, the firms are better off with SI when $h \leq 0.0378$. The threshold for the firms to benefit from SI is higher when competition is less fierce. For example, when $\gamma = 0.5$, both firms are better off with SI as long as $h \leq 0.0913$.[8]

Proposition 7 is in stark contrast to Proposition 2, which says that for all h, strategic inventories leave both manufacturers and retailers worse off when the competition is fierce enough. Notably, in both observed and unobserved cases, the role of SI is twofold. First, it has a double marginalization alleviation effect, which benefits the firms. Second, it has a competition intensification effect, which hurts the firms. However, as well established in the literature, competition is less fierce under quantity competition than under price competition (Singh and Vives 1984), which means that the competition intensification effect is less salient under quantity competition. As such, under quantity competition, the double marginalization alleviation effect always dominates the competition intensification effect, and therefore, the firms are always better off under SI.

It is worth noting that the preceding results only hold in the case of two competing chains. When there are three or more supply chains that compete on quantity, SI can make the manufacturers and retailers worse off. For example, consider the case with four competing supply chains, with $h = 0$ and $\gamma = 1$. Straightforward analysis shows that SI leads to a 4.03% profit loss to the manufacturers and a 1.77% profit loss to the retailers. This is in line with our previous analysis: as the number of supply chains increases, the competition between the supply chains becomes fiercer. Accordingly, SI plays a more important role in intensifying market competition, which overshadows its effect in alleviating double marginalization. As a result, the firms can get hurt by SIs.

Next, we examine how the firms' profits change with h. The following proposition summarizes the result.

Proposition 8. *Consider the case of quantity competition:*

a. *In equilibrium, the manufacturers' profit is strictly increasing in h when*

$$\frac{17(4-\gamma)}{272+136\gamma+21\gamma^2} \leq h \leq \frac{1}{4+\gamma}.$$

b. *In equilibrium, the retailers' profit is strictly increasing in h when*

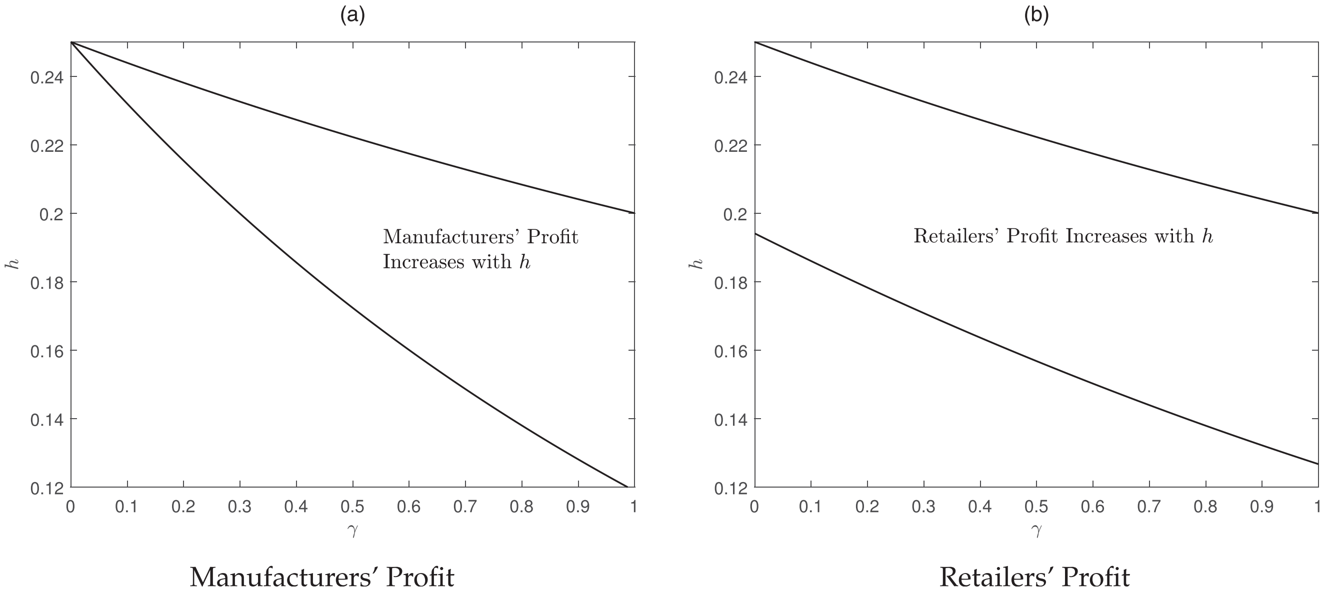
$$\frac{1{,}888+1{,}424\gamma+242\gamma^2-35\gamma^3}{9{,}728+11{,}456\gamma+5{,}344\gamma^2+1{,}148\gamma^3+98\theta^4} \leq h \leq \frac{1}{4+\gamma}.$$

Proposition 8 replicates Proposition 3, suggesting that under quantity competition, a higher inventory holding cost can leave both manufacturers and retailers better off. Again, this finding occurs because as h increases, less SI will be carried by the retailers, which can reduce the competition between the supply chains, working to the benefits of all firms. This result is illustrated in Figure 11.

6. Concluding Remarks

This paper analyzes the role of SI in competitive markets. We have found that in addition to the double marginalization alleviation effect, SI also has a competition intensification effect. By and large, retailers not only consider SI to be a tool to secure lower wholesale prices but also a way to commit to a competitive pricing strategy. We relate the relative strength of these two effects to the extent of the competition. We find that when supply chain competition is fierce, SI intensifies the competition and hurts all the firms. Importantly, this implies that manufacturers can strictly prefer to not carrying SIs. This is in stark contrast to the existing literature,

Figure 11. Effect of h on the Firms' Profit Under Quantity Competition: (a) Manufacturers' Profit, (b) Retailers' Profit



including Anand et al. (2008), Desai et al. (2010), Arya and Mittendorf (2013), and Roy et al. (2019).

We further allow manufacturers to commit to the elimination of SI. Essentially both manufacturers and retailers prefer to have SI in the supply chains when the competition is less fierce and prefer NI otherwise. However, for firms, a sort of prisoner's dilemma can take place: they commit to SI because of competition, even though an NI system is more profitable to all the firms. Finally, we extend our analysis to the cases of observable contracts and quantity competition and show that all our insights in the basic model continue to hold.

Our results underline the importance of supply chain competition on the effects of SI. However, our model can be extended in a number of directions. In our model, there is no demand uncertainty, and inventory only plays a strategic role. One may consider the role of SI in the competitive market in the presence of demand uncertainty. Although the main implications from this study are expected to hold in the presence of demand uncertainty, it would be of interest to explore whether additional insights may arise. In addition, in our model, the observability of vertical contracts is exogenously given. One may endogenize the process and examine the incentives for a supply chain to disclose its contract terms in a credible way.

Acknowledgments
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Endnotes

[1] Although we chose such a simplified linear demand form to make the results easier to understand, the whole analysis holds for a general linear demand function. That is, given $D_{it} = a - bp_{it} + cp_{jt}(c < b)$, we can rewrite it as $\hat{D}_{it} = 1 - \hat{p}_{it} + \theta(\hat{p}_{jt} - \hat{p}_{it})$ by rescaling $\hat{D} = \frac{D}{a}, \hat{p} = \frac{b-c}{a}p$, and $\theta = \frac{c}{b-c}$.

[2] Note that for given h, there is a unique $\hat{\theta}$ because the right side of the equation is monotonically decreasing in $\hat{\theta}$. In particular, $h = 0$ implies $\hat{\theta} = \infty$; that is, SI always increases in the intensity of competition.

[3] When $\theta \to \infty$, all firms make zero profits with or without SI, but the relative profit improvement is still positive.

[4] That is, the second-period prices are much lower under SI. The first-period prices are only slightly higher under SI when θ is small.

[5] The manufacturers' profit also increases in θ when $\theta < 1.579$. Within this regime, competition alleviates double marginalization and improves the manufacturers' profit.

[6] Numerical studies suggest that all our results go through under a small inventory holding cost.

[7] In contrast, in the unobserved case, we have $\frac{\partial w_{j2}}{\partial I_i} = 0$ because I_i is not observed by manufacturer j.

[8] Similar results also hold when contracts are observable. We can show that under quantity competition, when contracts are unobservable, both firms are better off with SI as long as $h \leq 0.2042$.

References

Anand K, Anupindi R, Bassok Y (2008) Strategic inventories in vertical contracts. *Management Sci.* 54(10):1792–1804.

Armstrong M (1991) Retail response to trade promotion: An incremental analysis of forward buying and retail promotion. Unpublished doctoral dissertation, University of Texas at Dallas.

Arya A, Mittendorf B (2013) Managing strategic inventories via manufacturer-to-consumer rebates. *Management Sci.* 59(4):813–818.

Arya A, Frimor H, Mittendorf B (2014) Decentralized procurement in light of strategic inventories. *Management Sci.* 61(3):578–585.

Barnes D (2006) Competing supply chains are the future. *Financial Times* (November 8).

Bell DR, Chiang J, Padmanabhan V (1999) The decomposition of promotional response: An empirical generalization. *Marketing Sci.* 18(4):504–526.

Cachon GP (2001) Stock wars: Inventory competition in a two-echelon supply chain with multiple retailers. *Oper. Res.* 49(5):658–674.

Carr SM, Karmarkar US (2005) Competition in multiechelon assembly supply chains. *Management Sci.* 51(1):45–59.

Corbett CJ, Karmarkar US (2001) Competition and structure in serial supply chains with deterministic demand. *Management Sci.* 47(7):966–978.

Coughlan AT, Wernerfelt B (1989) On credible delegation by oligopolists: A discussion of distribution channel management. *Management Sci.* 35(2):226–239.

Desai PSO, Koenigsberg D, Purohit D (2010) Forward buying by retailers. *J. Marketing Res.* 47(1):90–102.

Gaur V, Park YH (2007) Asymmetric consumer learning and inventory competition. *Management Sci.* 53(2):227–240.

Gavazza A, Lizzeri A (2009) Transparency and economic policy. *Rev. Econom. Stud.* 76(3):1023–1048.

Guan H, Gurnani H, Geng X, Luo Y (2019) Strategic inventory and supplier encroachment. *Manufacturing Service Oper. Management* 21(3):536–555.

Ha AY, Tong S (2008) Contracting and information sharing under supply chain competition. *Management Sci.* 54(4):701–715.

Ha AYQ, Tian S, Tong S (2017) Information sharing in competing supply chains with production cost reduction. *Manufacturing Service Oper. Management* 19(2):246–262.

Ha AY, Tong S, Zhang H (2011) Sharing demand information in competing supply chains with production diseconomies. *Management Sci.* 57(3):566–581.

Hart O, Tirole J, Carlton D, Williamson O (1990) Vertical integration and market foreclosure. *Brookings Papers Econom. Activity* 1990: 205–286.

Hartwig R, Inderfurth K, Sadrieh A, Voigt G (2015) Strategic inventory and supply chain behavior. *Production Oper. Management* 24(8):1329–1345.

Inderst R, Ottaviani M (2012) Competition through commissions and kickbacks. *Amer. Econom. Rev.* 102(2):780–809.

Janssen M, Shelegia S (2015) Consumer search and double marginalization. *Amer. Econom. Rev.* 105(6):1683–1710.

Khouja M (2001) The evaluation of drop shipping option for e-commerce retailers. *Comput. Indust. Engrg.* 41(2):109–126.

Lai G, Debo L, Nan L (2011) Channel stuffing with short-term interest in market value. *Management Sci.* 57(2):332–346.

Lai G, Xiao W, Yang J (2012) Supply chain performance under market valuation: An operational approach to restore efficiency. *Management Sci.* 58(10):1933–1951.

Li X, Liu Q (2020) Contract unobservability and downstream competition. *Manufacturing Service Oper. Management*, ePub ahead of print October 5, https://doi.org/10.1287/msom.2020.0905.

Lofgren L (2020) The best dropshipping companies. Quicksprout (September 28), https://www.quicksprout.com/best-dropshipping-companies.

McAfee RP, Schwartz M (1994) Opportunism in multilateral vertical contracting: Nondiscrimination, exclusivity, and uniformity. *Amer. Econom. Rev.* 84(1):210–230.

McGuire TW, Staelin R (1983) An industry equilibrium analysis of downstream vertical integration. *Marketing Sci.* 2(2):161–191.

Nagarajan M, Rajagopalan S (2009) A multiperiod model of inventory competition. *Oper. Res.* 57(3):785–790.

Netessine S, Rudi N (2003) Centralized and competitive inventory models with demand substitution. *Oper. Res.* 51(2):329–335.

Rey P, Tirole J (2007) A primer on foreclosure. Armstrong M, Porter R, eds. *Handbook of Industrial Organization*, vol. 3 (Elsevier, Amsterdam), 2145–2220.

Roy A, Gilbert S, Lai G (2019) The implications of visibility on the use of strategic inventory in a supply chain. *Management Sci.* 65(4): 1752–1767.

Segal I (1999) Contracting with externalities. *Quart. J. Econom.* 114(2):337–388.

Shin H, Tunca T (2010) Do firms invest in forecasting efficiently? The effect of competition on demand forecast investments and supply chain coordination. *Oper. Res.* 58(6):1592–1610.

Singh N, Vives X (1984) Price and quantity competition in a differentiated duopoly. *RAND J. Econom.* 15(4):546–554.

Taylor D (2003) Supply chain vs. supply chain. *Computerworld* (November 10), https://www.computerworld.com/article/2573872/supply-chain-vs--supply-chain.html.

Tsay AA, Agrawal N (2000) Channel dynamics under price and service competition. *Manufacturing Service Oper. Management* 2(4):372–391.

Villas-Boas SB (2007) Vertical relationships between manufacturers and retailers: Inference with limited data. *Rev. Econom. Stud.* 74(2):625–652.

Zhao X, Atkins DR (2008) Newsvendors under simultaneous price and inventory competition. *Manufacturing Service Oper. Management* 10(3):539–546.