Speculation in a two-stage retail supply chain

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One perhaps surprising outcome of E-Commerce has been the emergence of speculators who resell products via the web. These speculators create retail shortages for popular products (e.g., toys) by removing them from store shelves in bulk and then selling them at inflated prices through secondary channels; e.g., on sites such as eBay. This article examines the impact of such speculation on ordering decisions in a two-stage manufacturer–retailer supply chain. The equilibrium results of the proposed model demonstrate a range of outcomes: in some cases both the retailer and manufacturer benefit from speculators, whereas in other cases, both may be hurt by a high number of speculators. The proposed model provides insight on when it is best for the manufacturer to take measures to preclude a high degree of speculation.

Keywords: Dual sales channel, supply chain management, speculation, Stackelberg game

1. Introduction and motivation

The past decade has witnessed an extraordinary growth in E-Commerce, boosted by the widespread use of the Internet, which has drastically changed existing industry structures and fostered new business models. The birth of companies such as Chemdex.com (one of the first online B2B companies) has driven the shift of traditional business-to-business commerce to the Internet. E-Commerce firms “exert enormous influence over the way transactions are carried out, relationships are formed, and profits flow” (Kaplan and Sawhney, 2000, p. 97). Business giants catalyzed by E-Commerce have also arisen in business-to-customer (e.g., Amazon.com), on-line shopping (e.g., ebay.com), and reselling (e.g., Craigslist.com) channels. E-Commerce has also spurred evolutions in data exchanges, transactions, logistics, and management. One perhaps surprising outcome, however, has been the emergence of speculators. This article aims to study the impact of speculators on a two-stage supply chain.

Speculation itself is nothing new. The history of speculation might be traced to earlier stages of trade and commerce. Speculation may be categorized into three classes. The first might be defined as “the purchase (or sale) of goods with a view to resell (or re-purchase) at a later date,” with the motivation being “the expectation of a change in the relevant prices relative to the ruling price and not a gain accruing through their use” (Kaldor, 1939, p. 1). Typical examples can be found in the exchange of financial assets (e.g., futures and other securities) and bulk stocks (e.g., crude oil and raw materials). The second type of speculation appears as a managerial strategy in logistics and supply chain management. It postulates that “changes in form, and the movement of goods to forward inventories, should be made at the earliest possible time to reduce the costs of the supply chain” (Pagh and Cooper, 1998, p. 14). The third type of speculation usually shows up in the context of hoarding, in which suppliers deliberately hold inventories (sometimes life necessities) to create a scarcity of products to stimulate demands and attract higher prices. This strategy was once common in markets without government regulation and has been re-evaluated recently in order to create a sense of “exclusivity” for fashion and luxury items (Sapra et al. 2010).

The speculation studied in this article can be roughly categorized as the first type, despite its context within supply chain management (i.e., we do not consider the case of stimulating demands). Specifically, fashion items or hot sellers with short life cycles are usually sold out quickly in primary sale channels, while showing up in resale channels at inflated prices. The most commonly observed individuals in this line of business include, perhaps, event ticket resellers. E-Commerce no doubt greatly facilitates this kind of reselling; instead of standing outside for hours, such resellers only need a few minutes of clicks on a computer to buy tickets from TicketMaster.com and to subsequently resell them at a much higher price on eBay. Another good example context is in children’s toys. In many cases, a toy

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/uiie.
can suddenly become a very hot item due to some event (e.g., a popular movie) or at some date (e.g., Christmas). It is not uncommon these days for a consumer to look to the Internet when failing to find an item in stock at a retail store and to have to subsequently pay a much higher price. Stock-outs are natural for hot sellers, and speculators intensify this scarcity and subsequently extract a higher margin from customers who are willing to pay higher than retail prices.

Two particular examples illustrate the potential impacts of speculators and the need to explicitly account for it during planning. Prior to Christmas of 2005, the CEO of eBay noted that about 10% of the new Xbox 360 game consoles had been re-sold on eBay for prices that exceeded the retail price by hundreds of dollars (Wingfield and Guth, 2005). In the 2007 Christmas selling season, the popular new Wii game console was sold on eBay for as much as $3000 (compared with Nintendo’s list price of $539.95); see Dewan et al. (2007). Clearly such phenomena have strong implications for consumers, retailers, and manufacturers, as speculators extract a substantial surplus from consumers, while manufacturers and retailers forego a nontrivial amount of the profit generated in product sales. Thus, it is in the manufacturer’s and retailer’s best interest to explicitly account for potential speculation when planning supply quantities, stock levels, and price points. This need provides the motivation for our work, as the model we propose addresses stock planning decisions while explicitly accounting for the impacts of speculation.

The kind of speculation we consider exists for two reasons. The first reason is the short life cycle of the products combined with long supply chain lead times. During the life cycle of the product, it is less likely for the manufacturer to be able to fulfill demand when the product turns out to be a hot item and stocks out at the retailer. The second reason is that the sales agent or retailer has different interests from the supplier or manufacturer. In most cases, the retailer wants to turn inventory into cash as quickly as possible and is not motivated to distinguish speculators from customers. Thus, it is important to understand whether and when a manufacturer and/or retailer might be best served by measures to curb or eliminate speculation, as well as conditions under which it is in their best interest not to interfere with speculators.

It has been well recognized in the economics literature (Kaldor, 1939) that the effects of speculation are twofold. In the supply chain context studied in this article, speculators mitigate some of the retailer’s demand risk and may thus provide benefits to the supply chain. On the other hand, speculators may intensify the level of shortages if the product turns out to be very popular and may negatively impact a manufacturer in terms of market development. Speculation may also have other side effects. For example, it was reported that during the 2008 Beijing Olympic Games, more than AUS$50,000,000 worth of fake tickets had been sold through www.beijingticketing.com (Magnay, 2008).

Our contributions are as follows. We examine the impact of such speculation on supply chain decisions in a two-stage manufacturer–retailer supply chain. We first define a model of the behavior of speculators. Then, we develop a model that can address the competition between a manufacturer and retailer in the presence of speculators and illustrate the impact of speculation on pricing and ordering decisions. We find that the manufacturer can use the dual-sales strategy to regulate speculation by participating in the secondary market and competing with speculators. In some cases, however, it is in the manufacturer’s best interest to not interfere with speculators. Finally, we discuss how a manufacturer can utilize the model to develop decision policies consistent with market strategy.

This paper is organized as follows. In Section 2, we give a brief review of the literature on dual-sales strategies. Sections 3 and 4, respectively, develop the model and analytically characterize the model’s important properties. Section 5 illustrates the impact of speculation through a set of numerical experiments. Section 6 discusses measures that can be taken to regulate speculation. Finally, Section 7 concludes and discusses potential future work.

2. Literature review

This section reviews relevant literature in the area of dual sales channels. This area has seen tremendous research activity in recent years due to the advent of E-Commerce. These papers, which have been written by researchers in both operations and marketing, examine a wide variety of issues, including the impact of a manufacturer’s direct sales channel on retail channel and operational decisions. The literature on dual channels pre-dates E-Commerce, however. Previous research was motivated by other reasons for dual channels, such as franchising and targeting a wider cross-section of customers. For a summary of this research, see Chiang et al. (2003). Here we will only discuss papers that examine dual sales channels such that one channel is direct to customers and the other is via retail stores.

Relevant papers can be broadly classified into three categories. Papers in the first category examine scenarios in which the two channels are owned by separate entities. The focus of these papers is to examine the synergistic and negative effects of the introduction of a direct channel on the retail channel. The introduction of a direct sales channel influences the supply chain in many ways. The most obvious effect is via potential competition between the retailer and the manufacturer for customer demand. By capturing this effect, Chiang et al. (2003) showed that the introduction of a direct channel may improve overall demand, since the retailer is forced to reduce prices due to the threat of competition. As a result, the channel efficiency under a wholesale price contract improves. Arya et al. (2007) considered the same problem context under a variety of structural market assumptions (e.g., when the two sales channels are not
complete substitutes for each other, and when the manufacturer and retailer compete through price).

Cattani et al. (2006) examined a case in which the manufacturer matched the retail price in the direct channel to mitigate channel conflict. They found that this strategy was beneficial for the manufacturer as well as the retailer, provided that the direct channel is not very convenient for the customers. This setup was extended by Dumrongsi et al. (2008). In their model, customers selected a channel based on service quality as well as price. They also developed insights on the viability of the direct channel. Most of the papers mentioned thus far have considered prices in the two channels as the main driver of the relative customer demand. Using an alternative approach, Tsay and Agrawal (2004) considered sales effort exerted by the retailer and the manufacturer as the driver behind the magnitude of demand. In addition to understanding the effect of a direct channel, they proposed and examined two strategies to mitigate any negative effects between the retailer and manufacturer due to the direct channel. Kumar and Ruan (2006) also considered a model in which demand was influenced by sales effort, although this effort was only exerted by the retailer. The demand also depended on the prices in the two channels as well as the relative numbers of brand-loyal and store-loyal customers. Once again, the paper identified conditions for the viability of the direct channel.

The introduction of a second channel may also induce inventory competition between the two channels if customers switch from one channel to another in case of a stock-out. Geng and Mallik (2007) analyzed this issue to determine whether the manufacturer can reduce the quantity shipped to the retailer. The presence of a second channel may also influence the benefits of information sharing between the retailer and the manufacturer. This issue was examined in detail by Yue and Liu (2006).

Papers in the second category examine scenarios in which the retailer has a direct channel that may ship inventory directly from a warehouse. Chiang and Monahan (2005) examined such a supply chain and considered replenishment decisions for the retail location as well as the warehouse. Bernstein et al. (2008) considered an oligopoly in which “bricks-and-mortar” retailers decide whether to open an online channel. They found that opening the online channel is an equilibrium outcome.

The third category of papers studies resale markets for used goods in the presence of strategic buyers. Research on used-good markets is fairly extensive in the marketing science literature (see Nair (2007), Rao et al. (2009), and Yin et al. (2010)). This work emphasizes ways in which the resale of used goods, whose value declines steadily with time, affects the sales of new goods. Thorough analytic work that is closely related to ours was established by Su (2010), in which the author studied the dynamic pricing of a monopolistic seller facing both strategic customers who choose a purchase time in the hope of a lower price and speculators who buy the product for reselling later at an inflated price. Su’s work assumed that the seller reaches customers (including speculators) directly and sets an initial price and stock quantity at time \( t_1 \), at which time myopic customers determine whether or not they will buy the product, speculators determine the quantity they will purchase, and strategic customers decide on whether they will purchase at the initial price or wait until a later time point \( t_2 \) (\( > t_1 \)). At time \( t_2 \), the seller may modify its price to customers, while speculators set their prices based on this modified price, and strategic customers who have waited make their final purchase decisions.

Our model differs from that of Su (2010) in several respects. Like Su we consider two essential time points. However, the entities involved and the decisions made at these time points are quite different in our model. In particular, we consider a manufacturer who sells its product through a retailer, who must determine its stock quantity at time \( t_1 \), based on the manufacturer’s wholesale price and subject to uncertain demand. At the same time, the manufacturer determines the amount it wishes to stock for direct sales to customers at time \( t_2 \). Speculators may remove stock from the retailer’s shelves at time \( t_1 \) for reselling to consumers at time \( t_2 \). The price in the secondary market at time \( t_2 \) then depends on the quantity that both speculators and the manufacturer have managed to accumulate for sales at time \( t_2 \). As a result, our emphasis is on implications of speculators for both a manufacturer and a retailer in a two-level supply chain.

Milner and Kouvelis (2007) considered the impacts of speculators on spot markets and standing contracts for the supply of commodities in the context of business-to-business exchanges. In their paper, speculators take advantage of spot market price gaps over different periods, whereas in our article, speculators are motivated by the price gap in different channels when demand for the item outstrips supply in the primary channel. In a newsvendor setting, Hung et al. (2013) also accounted for the presence of speculators who invest in options for so-called super capacity that can meet demand for a number of retail products at short notice. In this game, retailers have a second ordering opportunity based on a forecast update, at which time they can secure needed super capacity. Another work studying a similar supply chain structure is Kouvelis and Gutierrez (1997), which discussed the decisions of a global newsvendor supplying two distinct markets at successive points in time. In our article, the two channels share the same source of demand and speculators accumulate stock of high-demand items.

In the absence of speculators, our model is similar to that of Lariviere and Porteus (2001), who considered the sale of an item to a newsvendor by a monopolistic manufacturer in a single-period setting. Their work focused on determining an optimal equilibrium wholesale price as well as on the division of channel profits between the two players and mechanisms for coordinating the channel.
As our summary above illustrates, none of the existing papers have examined the impacts of speculation on a manufacturer–retailer chain or the benefits of a manufacturer’s establishment of a direct sales channel to counter speculation. Thus, this article contributes by illustrating how a direct sales channel might be used to manage speculation. An additional contribution of our analysis is an understanding of how speculation may affect manufacturer/retailer decisions. Very little is understood about how speculation in general may affect both manufacturers and retailers. Moreover, existing research has mainly discussed the value of the secondary channel directly competing with the first channel. In this article, the secondary channel is used in a more complementary sense.

3. Model definition and notation

We consider a supply chain consisting of a manufacturer and a retailer with the participation of speculators for a single, short life-cycle product. The product is primarily sold through the retailer (the primary market). In addition to the retail channel, the manufacturer can sell the product through a resale market (the secondary market) if the product becomes popular. The resale market also sees participation of the speculators who purchase inventory from the retailer. We first outline the sequence of events within our model and then analyze the incentives and profits associated with each of the three players in turn.

3.1. Time frame

To precisely describe the relationships among different members of the supply chain, we next outline the sequence of events during the season, see Fig. 1. At time 0, the monopolist manufacturer, who is the Stackelberg game leader, announces a wholesale price $w$ to the retailer. The retailer responds by placing an order of size $Q_1$ given an exogenous retail price $P$. At the same time, the manufacturer may determine a quantity $Q_2$ for selling directly in the resale market, if they choose to participate and compete with speculators via a direct channel. We assume that the manufacturer has unlimited production capacity to avoid any modeling influences that may arise due to capacity. (For convenience, a list of the notation we use in this article can be found in Appendix 1.)

At time 1, the retailer receives its order in full from the manufacturer and begins selling. If the product is perceived to be hot-selling, a portion of the retailer’s inventory, say $Q_s$, is bought by speculators. Assume that the demand, $D$, depends on the price, $P$, and a random variable $\xi$.

At time 2 (a fraction of) customers unsatisfied by the primary market flow to the secondary market. The manufacturer and speculators start selling in the resale market at resale price $P_r$. The size of the resale market depends on $Q_1 - Q_s$, which determines the amount of unsatisfied end customer demand. Also, the retailer salvages unsold products at unit price $v$.

Since speculation causes product shortages in the retail channel, this may lead to a threat of shortages among customers. It is well documented in the existing academic as well as practice literature (e.g., Irwin et al. (2009)) that such a threat makes customers more amenable to paying a higher price. On the other hand, an extremely high level of speculation may lead to angry customers and may thus dampen their enthusiasm.

Speculation affects the performance of a supply chain in several ways, depending on the channel structure and the behavior of speculators. The following section first characterizes the behavior of speculators.

3.2. Assumptions on speculation

Speculators move products from the primary to the secondary market, motivated by an expected price gap between the two markets. The demands of some regular customers in the primary market will not be fulfilled as a result of speculators who remove inventory from the retail shelves. Thus, the presence of speculators’ demands provides an incentive for the retailer to order more than they would otherwise order in the absence of speculators. At the same time, a high availability of the product in the secondary market (as a result of speculators) may drive the resale price down and, therefore, dampen the profit-making opportunity for
speculators. It is thus interesting to study properties of the quantity that speculators will buy in equilibrium.

We are thus interested in whether and when speculators may suffer a loss and whether speculators can collectively maximize their overall profit. With respect to the former question, although speculators may have more knowledge about the market for an individual item than the retailer, empirical research has shown that not all speculation leads to profit, as pointed out by Su (2010). Regarding the latter question, in this article, we focus on speculators who make decisions and take actions independently; it is thus difficult or impossible for them to explicitly coordinate and optimize their overall profit.

Here, we adopt an approach proposed by Su (2010), which assumes that increased speculation may drive down the resale price until $E[P_{r}] = P$. Moreover, speculators may not necessarily be able to buy as much as they would like to because regular customers make purchases as well. We assume without loss of generality that the percentage of the inventory in the retail store that can be purchased by the speculators does not exceed $\gamma \leq 1$, leading to $E[P_{r}] \geq P$. We note that $\gamma$ is an exogenous parameter in our model (in our numerical tests we considered various levels of $\gamma$ in order to characterize how this parameter influences equilibrium solutions).

With $Q_{1}$ moved to the secondary market by speculators, $Q_{1} - Q_{s}$ is the amount available to regular customers in the primary market. The total amount in the secondary market equals $Q_{s} + Q_{2}$. The unsold inventory from the primary market, if any, will not compete in the secondary market but will be salvaged at the per unit price $v$ after the selling season, since whether or not the product will be sold out is not known until the end of this season.

### 3.3. Resale price and demands

Assume that in the primary market, the demand, $D$, is determined by $D = (a - bP)\xi$, where $a$ and $b$ are positive parameters, and $\xi$ is a random variable with range $[\eta_{0}, \eta_{0} + \eta]$ ($\eta_{0}, \eta > 0$). Denote $F$ and $f$ respectively as the cumulative distribution function and the probability density function of $D$.

Next, assume that the resale price in the secondary market is endogenous, determined by Cournot competition. With this assumption, the profit margins of the speculators and the manufacturer vary with the total amount of product moved to the secondary market, $Q = Q_{s} + Q_{2}$ and the size of the secondary market, which in turn depends on $Q_{1} - Q_{s}$. Again, the secondary channel does not coexist with the retail channel simultaneously. It should thus be clear that the separation of the two channels in time and the removal of retail inventory by speculators means that the two channels are not substitutable from the perspective of consumers.

Cournot competition is easily justified when the manufacturer enters the secondary market or when the manufacturer enters an agreement with the retailer not to use its pricing power in the secondary market. Moreover, we assume that the manufacturer agrees not to use its pricing power to sell in the secondary market at a price lower than the retailer’s price. Thus, we assume that if the manufacturer were to use its pricing power in the secondary market, then either (i) it puts out a sufficiently high amount of inventory at the same price as the retailer so as to preclude speculation or (ii) it puts out a limited amount of inventory at a price lower than the prevailing Cournot equilibrium, such that speculators purchase from both the retailer and manufacturer and resell in the secondary market. For model tractability, we ignore these second-order speculation effects and assume that if the manufacturer enters the secondary market, then it accepts the prevailing Cournot equilibrium price.

With these assumptions, in the case of an overstock in the primary market ($D < Q_{1} - Q_{s}$), the maximum size of the secondary market is $a - (a - bP) = bP$, and

$$P_{r} = \max \left\{ 0, P - \frac{Q_{s} + Q_{2}}{ab\xi} \right\}$$

where $\alpha \in (0, 1]$, addressing the fact that not all customers unsatisfied in the primary market go to the secondary market.

In the case of stock-outs in the primary market ($D \geq Q_{1} - Q_{s}$), the maximum size of the secondary market is $a - (Q_{1} - Q_{s})/\xi$, and

$$P_{r} = \max \left\{ 0, \frac{a}{b} - \frac{Q_{1} - Q_{s}}{\xi} - \frac{Q_{s} + Q_{2}}{ab\xi} \right\}$$

In this case, the equilibrium price $P_{r}$ is not strictly required to take a value higher than $P$. Whether or not the manufacturer takes a loss or makes a profit on $Q_{2}$ depends on the equilibrium $P_{r}$ relative to the production cost $c$. On expectation, we have

$$E[P_{r}] = \int_{Q_{1} - Q_{s} < y} \max \left\{ 0, \frac{a}{b} - \frac{\alpha Q_{1} + (1 - \alpha) Q_{s} + Q_{2} a - bP}{y} \right\} dF(y)$$

$$+ \int_{Q_{1} - Q_{s} \geq y} \max \left\{ 0, P - \frac{Q_{s} + Q_{2} a - bP}{y} \right\} dF(y).$$

(1)

Observe that it is possible to have $P_{r} < P$ even when $D > Q_{1} - Q_{s}$ (i.e., when there is a shortage at the retailer) if $Q_{2}$ is sufficiently large, and speculators may still suffer a loss, despite the stock-out at the retailer. Thus, the manufacturer is ultimately able to preclude speculators from being profitable by participating in the secondary market.
if it chooses to do so. Whether and when the manufacturer should do so is one of the central questions of this work.

3.4. Expected profits of the retailer and the manufacturer

In this article, we only consider the situation when the manufacturer and the retailer are not coordinated. We refer to the uncoordinated supply chain as the “decentralized chain.” The profits of the two players are given as follows:

\[ \Pi_R(Q_1) = PE(D + Q_s) + vE[(Q_1 - Q_s) - D]^+ - PE[D - (Q_1 - Q_s)]^+ - wQ_1, \]
\[ \Pi_M(w, Q_2) = (w - c)Q_1 + E[P_1]Q_2 - \kappa c Q_2, \]

where \( \kappa \geq 1 \) reflects a cost factor associated with units sold by the manufacturer in the secondary channel.

Note that unlike the dual sales channels models in the literature, there are actually three players in our problem: the manufacturer, the retailer, and speculators. Speculators determine \( Q_s \) based on \( Q_1, w, \) and \( Q_2 \). The retailer sets \( Q_1 \) based on \( w \) and \( Q_2 \), with the knowledge of how \( Q_s \) affects its revenue. The manufacturer makes the decisions on \( w \) and \( Q_2 \), with knowledge of the response of the retailer and speculators.

4. Equilibrium analysis

In this section, we briefly analyze the decisions of the speculators, the retailer, and the manufacturer, respectively. Here we assume that the relationship among the salvage value, the production cost, and the retail price in such that \( v < c < P \). Moreover, to avoid technical difficulties, we assume that the maximum operator in Equation (1) can be removed, which results in

\[ E[P_1] = \int_{Q_1 - Q_s < y} \left( \frac{a}{b} - \frac{\alpha Q_1 + (1 - \alpha) Q_s + Q_2 a - b P}{ab} \right) - \frac{1}{y} dF(y) \]
\[ + \int_{Q_1 - Q_s \geq y} \left( P - \frac{Q_s + Q_2 a - b P}{ab} \right) - \frac{1}{y} dF(y). \]

This can be done by choosing appropriate values of model parameters; i.e., the parameters are chosen such that no possible realization of demand and decision variables results in a negative price.

4.1. Decision of speculators

Speculation may be viewed as a form of gambling, with the gain and loss depending on the resale price. Compared with normal customers, speculators are highly sensitive to the price gap between retail and resale, which is affected by the order quantity of the retailer, the amount of products that speculators move to the secondary market, and the quantity that the manufacturer allocates to the secondary market.

Lemma 1. In general, the resale price in the secondary market strictly decreases in \( Q_1, Q_s, \) and \( Q_2 \).

Proof. It follows by taking derivatives of Equation (4) with respect to \( Q_1, Q_s, \) and \( Q_2 \), respectively.

First, we study the impact of \( Q_1 \) on \( Q_s \) with a fixed value of \( Q_2 \). With an increasing value of \( Q_1 \), speculators should increase \( Q_s \), subject to the constraint \( Q_s \leq y Q_1 \), as long as speculation is expected to be profitable; i.e., when the expected resale price is higher than the retail price (\( E[P_1] > P \)). As a result, \( E[P_1] \) decreases in \( Q_1 \) and \( Q_s \), according to Lemma 1. Upon reaching the quantity \( Q_s \) such that \( E[P_1] = P \), speculators should reduce their purchase quantity to avoid \( E[P_1] < P \). Denote \( \hat{Q}_1 \) as the turning point (at which \( E[P_1] = P \)), which is determined by the solution of the following system:

\[ E[P_1] = P, \]
\[ Q_s = y \hat{Q}_1. \]

Clearly, \( \hat{Q}_1 \) is a function of \( y \).

This relationship is portrayed in Fig. 2. The slopes of the straight lines in the shaded region where \( E[P_1] > P \) correspond to different values of \( y \), and the bold curve separating the shaded regions is determined by the equation \( E[P_1] = P \). When \( Q_1 \) is small, \( Q_s = y \hat{Q}_1 \) holds, and \( Q_s \) grows proportionally with \( Q_1 \), corresponding to a point moving along a straight line on the left-hand side, with the slope determined by the appropriate value of \( y \). The growth of \( Q_s \) continues until \( E[P_1] = P \), where \( Q_s^* \) starts departing from \( y \hat{Q}_1 \); i.e., \( Q_s^* < y \hat{Q}_1 \) holds, corresponding to a point sliding down the bold curve to the right. Formally, we have the following lemma.

Lemma 2. Given the manufacturer’s decision, \( w \) and \( Q_2 \), the equilibrium quantity that speculators purchase, \( Q_s^* \), is

![Fig. 2. Equilibrium \( Q_s^* \) with fixed \( Q_2 \).](image)
Speculation in a supply chain

not monotone in the order quantity of the retailer, \( Q_1 \). Specifically,

\[
Q^*_s = \begin{cases} 
\gamma Q_1, & \hat{Q}_1(\gamma) < Q_1 < \hat{Q}_1(0), \\
\text{arg } \mathbb{E}[P_1] = P, & \hat{Q}_1(\gamma) < Q_1 \leq \hat{Q}_1(0), \\
0, & \hat{Q}_1(0) < Q_1 \end{cases}
\]

Now, consider the impact of \( Q_2 \) for a fixed value of \( Q_1 \). By Lemma 1 and Equation (4), the bold curve in Fig. 2 rotates counter-clockwise and shifts toward the left as \( Q_2 \) increases, leading to a shrinking margin and opportunity for speculation.

Remark 1: If \( \alpha \) is very small, meaning that little unsatisfied demand of the primary market enters the secondary market, or the manufacturer imposes a large \( Q_2 \) for the secondary market, the expected price in the secondary market is not sufficiently high relative to \( P \) and the opportunity for profitable speculation will become limited.

4.2. Decisions of the retailer

Next, we study the equilibrium decision of the retailer, \( Q^*_1 \), given the decisions of the manufacturer, \( w \) and \( Q_2 \) (regarded as having fixed values), and the equilibrium decision of speculators, \( Q^*_s \). As seen in the previous section, the order quantity of the retailer, \( Q_1 \), affects both the amount of products that speculators can buy and the resale price as well. As a result, \( Q^*_s \) is not monotone in \( Q_1 \), complicating the decision of the retailer. We start from the case without speculation and then discuss the impact of speculation.

Without speculation, the problem is a classic newsvendor problem, with the equilibrium order quantity achieved at \((\partial/\partial Q_1)\Pi_R = 0\), or

\[
Q_1 = \hat{Q}_1(0) = F^{-1}(\frac{P - w}{P - v}).
\]

Now, consider the impact of speculation on the profit of the retailer, \( \Pi_R \). Note that

\[
\frac{\partial \Pi_R}{\partial Q_s} = (P - v)F(Q_1 - Q_s) > 0,
\]

since the retail price is higher than the salvage value \((P > v)\). Put differently, speculation benefits the retailer by sharing the demand risk in the primary market. Thus, in the presence of speculation, all else being equal, the retailer should increase its order quantity.

Formally, if \( \mathbb{E}[P_1] > P \) at \( \hat{Q}_1(0) \) and \( Q_s = 0 \), the retailer should increase \( \hat{Q}_1 \). Then, the question turns to where \( \hat{Q}_1 \) reaches equilibrium. Intuitively, \( Q^*_1 \) may fall into the region corresponding to the straight line or the bold curve in Fig. 2. In the first case, the resulting \( \mathbb{E}[P_1] > P \) and \( Q^*_1 \) satisfies \((\partial \Pi_R/\partial \hat{Q}_1) = 0\). Denote the solution as \( \hat{Q}_1 \), where

\[
\hat{Q}_1(\gamma) = \begin{cases} 
1, & \frac{1}{1 - \gamma} F^{-1} \left[ \frac{P - w}{P - v} \right], \quad P - w \leq (1 - \gamma)(P - v), \\
\infty, & P - w > (1 - \gamma)(P - v)
\end{cases}
\]

with \( Q^*_s = \gamma \hat{Q}_1 \).

However, \( \mathbb{E}[P_1] \) may not always be higher than \( P \) at \( Q^*_1 = \hat{Q}_1 \) and \( Q^*_s = \gamma \hat{Q}_1 \) (otherwise, the retailer can order as much as possible and with guaranteed profit). In this case, \( Q^*_s \) may be located on the bold curve in Fig. 2, defined by \( \mathbb{E}[P_1] = P \). The equilibrium decision in this case results from solving the following optimization problem:

\[
\max : \Pi_R(Q_1),
\]

s.t. : \( \mathbb{E}[P_1] = P \)

\[
0 \leq Q_s \leq \gamma Q_1.
\]

Note that the curve defined by \( \mathbb{E}[P_1] = P \) corresponds to \( \hat{Q}_1 \) for all \( \gamma \in [0, 1] \). In particular, the equilibrium with \( \gamma = 1 \) must satisfy

\[
(P - w) = \left(1 - \frac{d \hat{Q}_1}{d \gamma}\right)(P - v)F(Q_1 - Q_s)
\]

\[
\mathbb{E}[P_1] = P.
\]

Denote \( \gamma^* \) as the corresponding ratio of \( Q^*_s \) and \( Q^*_1 \). In the case of \( \gamma > \gamma^* > 0 \), speculators will only purchase \( \gamma^* \) of \( Q_1 \) and it is optimal for the retailer to order \( Q^*_1 \), such that the resulting expected resale price reaches \( P \). In the case of \( \gamma^* > \gamma > 0 \), the retailer cannot fully reap the benefits of speculation, simply because speculators are not able to obtain as much of the product as they would like.

Finally, note that Equation (7) may not always be feasible; the bold curve defined by \( \mathbb{E}[P_1] = P \) may be flat enough such that \((d/d \hat{Q}_1)\Pi_R(\hat{Q}_1) \) is positive on the curve, which will drive \( Q^*_s \) to zero. Recall the situation discussed in the previous section (Remark 1), in which the retailer does not care about speculation at all. In this case, the area between the straight lines and the bold curve in Fig. 2 is fairly small. Thus, the equilibrium order quantity is still achieved at \( \hat{Q}_1(0) \). We summarize the above analysis in the following lemma.

Lemma 3. Given the manufacturer’s decision, \( w \) and \( Q_2 \), the equilibrium order quantity of the retailer, \( Q^*_1 \), is

\[
Q^*_1 = \begin{cases} 
\hat{Q}_1(\gamma), & \hat{Q}_1(\gamma) < Q_1 < \hat{Q}_1(0), \\
\text{arg } \max \{\Pi_R(Q_1)\}: & \mathbb{E}[P_1] = P, 0 \leq Q_s \leq \gamma Q_1, \quad \hat{Q}_1(\gamma) \geq \hat{Q}_1(0), \quad \hat{Q}_1(0) < \hat{Q}_1(0), \\
\hat{Q}_1(0), & \hat{Q}_1(0) \geq \hat{Q}_1(0)
\end{cases}
\]
In particular, $\Pi_R(Q_1)$ increases in $Q_1$ given $E[P_r] = P$ and $0 \leq Q_s \leq \gamma Q_1$.

**Proof.** See online Appendix 2. ■

In summary, for a given value of $Q_2$ and wholesale price $w$, speculation may benefit the retailer as a result of reducing its demand uncertainty. As a response, the retailer may increase its order quantity, depending on the percentage of stock speculators are able to obtain from the shelves (under the competition with regular customers) and depending on the expected resale price. However, because the manufacturer may anticipate the retailer’s and speculators’ decisions (and adjust the values of $Q_2$ and $w$ accordingly), it is not always the case that the retailer is better off as a result of speculators, as we will see in the next section.

### 4.3. Decision of the manufacturer

Finally, we study the impact of speculation on the decisions of the manufacturer, given the equilibrium decisions of speculators and the retailer, $Q_1^*$ and $Q_2^*$. We first discuss the impact of the wholesale price and the quantity the manufacturer prepares for the secondary market. Then, the situations both with and without the manufacturer’s participation in the secondary market are discussed, referred to as the single-channel chain and dual-channel chain, respectively.

The impact of the wholesale price on the equilibrium decision of the retailer can be intuitively interpreted through Fig. 2. If the wholesale price, $w$, is very low, then this will lead to a high value of $Q_1^*$ in terms of Fig. 2, for sufficiently small $w$, this will lead to a value of $Q_1^*$ to the right of the bold curve in Fig. 2, which implies $Q_2^* = 0$. As $w$ increases, denote the corresponding $(Q_2^*, Q_1^*)$ as a point moving to the left along the $Q_1$ axis, from the right-hand side of the bold curve. With increasing $w$, $(Q_1^*, Q_2^*)$ moves to the left. As a result, it initially moves leftward up the bold curve and then slides down along the appropriate straight line (with positive slope) as the wholesale price continues to increase.

**Theorem 1.** With $\gamma = 1$ and a fixed value of $Q_2$, an increasing wholesale price results in a decreasing retailer order quantity, $Q_1$, and a non-decreasing resale price. However, the aggregate purchase quantity of speculators, $Q_s$, is neither monotonically non-decreasing in $w$ nor monotonically non-increasing in $Q_1$.

**Proof.** See online Appendix 3. ■

Next, consider the impact of $Q_2$, which affects the bold curve in Fig. 2, defined by $E[P_r] = P$. As stated previously, allocating $Q_2$ to the secondary market cannibalizes the margin of speculators and thus may affect $Q_1^*$ and $Q_2^*$. For a given wholesale price, $w$, if $Q_1^* = \hat{Q}_1$, then $E[P_r] > P$, and therefore a slight increase in $Q_2$ does not affect $Q_1^*$ and $Q_2^*$. If $Q_1^* = \hat{Q}_1(0)$, by Lemma 3, $E[P_r] < P$; in this case, the manufacturer cannot sell in the secondary market. Finally, if $Q_1^*$ is achieved on the curve defined by $E[P_r] = P$, increasing $Q_2$ results in a decrease in $Q_1^*$ and thus $Q_1^*$. We summarize these results in the following theorem.

**Theorem 2.** With fixed $w$ and $\gamma = 1$, increasing $Q_2$ dampens speculation and thus the equilibrium order quantity of the retailer.

**Proof.** The conclusion immediately follows from Lemma 3 and Equation (4). ■

Now, consider the equilibrium decision of the manufacturer with the presence of speculation in the case of a single-channel chain; i.e., the manufacturer does not enter the secondary market. For the three scenarios where the equilibrium $Q_1^*$ is achieved (Lemma 3), speculation results in a larger $Q_1^*$ compared with the case without speculation. Therefore, we have the following theorem.

**Theorem 3.** Speculation benefits the manufacturer in a single-channel supply chain; when $\gamma = 1$, it may hurt the retailer.

**Proof.** See online Appendix 4. ■

**Remark 2:** In general, we cannot always guarantee that an equilibrium solution exists. For example, if $\gamma$ is sufficiently high, then cases may exist such that the retailer has an incentive to continue increasing its order quantity, $Q_1$, whereas the optimal action for the monopolistic manufacturer in such cases may result in increasing wholesale price, $w$, until it equals $P$, so that the retailer’s margin is zero (and the retailer no longer has an incentive to participate). As discussed by Lariviere and Porteus (2001), in the absence of speculators, additional assumptions need to be made on the demand distribution and problem parameters in order to identify the conditions required for the existence of an equilibrium solution. This results from the manufacturer’s monopolistic position and an implicit assumption that the retailer does not incur any opportunity cost when carrying the manufacturer’s product. Lariviere and Porteus (2001) consider an explicit opportunity cost for the retailer to mitigate this problem. We take a similar approach in our numerical experiments by requiring $w < w_a < P$ in order to account for the retailer’s opportunity cost.

Speculation may not always benefit the retailer, even when an equilibrium solution exists, even though speculators tend to reduce the retailer’s demand risk. The manufacturer can certainly set the wholesale price by ignoring the impact of speculators; by Lemma 3, the retailer will not order less than the case without speculation. Alternatively, the manufacturer can instead exploit speculation by setting a different wholesale price, potentially earning a higher profit, and this may reduce the profit of the retailer. Although on the surface, the retailer is not motivated to exclude speculators (and may even welcome them), if the retailer only considers speculators as a source of reduced risk, they may be worse off; i.e., they also need to understand how speculators may drive up the wholesale price.

The equilibrium of the dual-channel chain is complicated. On the one hand, speculation may permit the
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manufacturer to increase its margin in the retail channel; however, the profit margin in the secondary channel may be dampened by speculation, since the resale by speculators undercuts the manufacturer's price in the secondary market. Intuitively, consider the equilibrium of the two players reached when the manufacturer does not enter the secondary market. If $Q^*_1$ is achieved on one of the straight lines of Fig. 2 (assuming $\gamma < 1$), $Q^*_s = \gamma Q^*_1$ and thus $E[P_r] > P$. Clearly, the manufacturer can potentially earn an extra profit (depending on the value of $\kappa$) by selling in the secondary market. However, this will press down the bold curve to the left and the new equilibrium may move along the bold curve; in this case, the manufacturer may suffer a loss, since the resale price drops and speculators and the retailer order less. If the price elasticity in the secondary market is high, meaning that $Q^*_s$ has a large impact on the resale price, the manufacturer may not like speculators. If the price elasticity in the secondary market is low, the manufacturer and speculators may share the secondary market.

In the following section, we explore the properties of equilibrium solutions under various parameter values.

5. Numerical results

We now present results of numerical tests on two different models, differentiated by whether or not the manufacturer enters the secondary market. For our numerical tests we assume that $\xi$ follows a beta distribution with both of its parameters equal to $\beta$. Corresponding to the two models to be tested, we selected 32 sets of parameter values as shown in Table 1. Note that for the case without the manufacturer’s entry in the secondary market, $\kappa$ (where $\kappa c$ is the manufacturer’s additional unit cost for selling in the secondary market) does not play a role. For these experiments, as we noted in Remark 2, we imposed an upper bound on the wholesale price, $w \leq w_u$, to account for the retailer’s opportunity cost for carrying the manufacturer’s product.

Recall that the first five parameters characterize the demand curve; $c$, $v$, and $\kappa$ define costs; $\alpha$ describes the percentage of primary market customers who enter the secondary market. In particular, with higher values of $\alpha$, $\beta$, and $b$, the secondary market demand uncertainty is lower.

| Group | $\eta_0$ | $\eta$ | $a$ | $b$ | $P$ | $c$ | $v$ | $\alpha$ | $\beta$ | $\kappa$ | $w_u$ |
|-------|--------|--------|-----|-----|-----|-----|-----|--------|--------|--------|------|
| 1     | 0.3    | 0.7    | 80  | 0.5 | 20  | 5   | 3   | 0.5    | 1      | 2.5    | 17   |
| 2     | 0.3    | 0.7    | 80  | 1.0 | 20  | 5   | 3   | 0.5    | 1      | 2.5    | 17   |
| 3     | 0.1    | 0.9    | 80  | 0.5 | 20  | 5   | 3   | 0.5    | 1      | 2.5    | 17   |
| 4     | 0.1    | 0.9    | 80  | 1.0 | 20  | 5   | 3   | 0.5    | 1      | 2.5    | 17   |
| 5     | 0.3    | 0.7    | 80  | 0.5 | 20  | 5   | 3   | 0.5    | 3      | 2.5    | 17   |
| 6     | 0.3    | 0.7    | 80  | 1.0 | 20  | 5   | 3   | 0.5    | 3      | 2.5    | 17   |
| 7     | 0.1    | 0.9    | 80  | 0.5 | 20  | 5   | 3   | 0.5    | 3      | 2.5    | 17   |
| 8     | 0.1    | 0.9    | 80  | 1.0 | 20  | 5   | 3   | 0.5    | 3      | 2.5    | 17   |
| 9     | 0.3    | 0.7    | 80  | 0.5 | 20  | 9   | 3   | 0.5    | 1      | 2.5    | 17   |
| 10    | 0.3    | 0.7    | 80  | 1.0 | 20  | 9   | 3   | 0.5    | 1      | 2.5    | 17   |
| 11    | 0.1    | 0.9    | 80  | 0.5 | 20  | 9   | 3   | 0.5    | 1      | 2.5    | 17   |
| 12    | 0.1    | 0.9    | 80  | 1.0 | 20  | 9   | 3   | 0.5    | 1      | 2.5    | 17   |
| 13    | 0.3    | 0.7    | 80  | 0.5 | 20  | 9   | 3   | 0.5    | 1      | 2.5    | 17   |
| 14    | 0.3    | 0.7    | 80  | 1.0 | 20  | 9   | 3   | 0.5    | 1      | 2.5    | 17   |
| 15    | 0.1    | 0.9    | 80  | 0.5 | 20  | 9   | 3   | 0.5    | 3      | 2.5    | 17   |
| 16    | 0.1    | 0.9    | 80  | 1.0 | 20  | 9   | 3   | 0.5    | 3      | 2.5    | 17   |
| 17    | 0.3    | 0.7    | 80  | 0.5 | 20  | 5   | 3   | 0.5    | 1      | 2.5    | 18   |
| 18    | 0.3    | 0.7    | 80  | 1.0 | 20  | 5   | 3   | 0.5    | 1      | 2.5    | 18   |
| 19    | 0.1    | 0.9    | 80  | 0.5 | 20  | 5   | 3   | 0.5    | 1      | 2.5    | 18   |
| 20    | 0.1    | 0.9    | 80  | 1.0 | 20  | 5   | 3   | 0.5    | 1      | 2.5    | 18   |
| 21    | 0.3    | 0.7    | 80  | 0.5 | 20  | 5   | 3   | 0.5    | 3      | 2.5    | 18   |
| 22    | 0.3    | 0.7    | 80  | 1.0 | 20  | 5   | 3   | 0.5    | 3      | 2.5    | 18   |
| 23    | 0.1    | 0.9    | 80  | 0.5 | 20  | 5   | 3   | 0.5    | 3      | 2.5    | 18   |
| 24    | 0.1    | 0.9    | 80  | 1.0 | 20  | 5   | 3   | 0.5    | 3      | 2.5    | 18   |
| 25    | 0.3    | 0.7    | 80  | 0.5 | 20  | 9   | 3   | 0.5    | 1      | 2.5    | 18   |
| 26    | 0.3    | 0.7    | 80  | 1.0 | 20  | 9   | 3   | 0.5    | 1      | 2.5    | 18   |
| 27    | 0.1    | 0.9    | 80  | 0.5 | 20  | 9   | 3   | 0.5    | 1      | 2.5    | 18   |
| 28    | 0.1    | 0.9    | 80  | 1.0 | 20  | 9   | 3   | 0.5    | 1      | 2.5    | 18   |
| 29    | 0.3    | 0.7    | 80  | 0.5 | 20  | 9   | 3   | 0.5    | 3      | 2.5    | 18   |
| 30    | 0.3    | 0.7    | 80  | 1.0 | 20  | 9   | 3   | 0.5    | 3      | 2.5    | 18   |
| 31    | 0.1    | 0.9    | 80  | 0.5 | 20  | 9   | 3   | 0.5    | 3      | 2.5    | 18   |
| 32    | 0.1    | 0.9    | 80  | 1.0 | 20  | 9   | 3   | 0.5    | 3      | 2.5    | 18   |
but the resale price is more elastic in supply. Put differently, for higher values of these parameters, speculation produces lower risk-sharing benefits for the retailer, but it also undercuts the secondary market resale price, and therefore the manufacturer’s profit margin, in the secondary market.

5.1. Single-channel chain

Our goal in this section is to understand how the (maximum) level of speculation affects various equilibrium values. Figures 3 to 5 show the average value of retailer order quantity ($Q_1^*$), wholesale price ($w$), speculators’ acquisition quantity ($Q_s^*$), the expected secondary market price ($P_r$, where we omit the expectation operator for notational convenience), and profit levels as a function of the maximum speculation level $\gamma$. The figures labeled (a) show the average values among the first 16 problem sets for which $w_u = 17$, whereas those labeled (b) show the same measures averaged among the second set of 16 problems, where $w_u = 18$. Recall that the value of $w_u$ represents the maximum wholesale price that the manufacturer may charge; thus, it can be viewed as a proxy for the retailer’s relative channel power; i.e., a lower value of $w_u$ implies greater relative channel power for the retailer. As can be seen (Fig. 4), $Q_s^*$ increases in $\gamma$, the upper bound of the inventory share that speculators are capable of obtaining in the primary market, although speculators obtain a shrinking margin. Note that speculators choose to purchase $Q_s^* < \gamma Q_1^*$ for $\gamma \geq 0.2$, although they are not constrained and are able to buy more, since the expected resale price for $\gamma \geq 0.2$ is equal to the retail price, and the expected margin of speculators is thus zero.

Similar to the case of $Q_s^*$, the values of $Q_1^*$, $P_r$, and $w^*$ also demonstrate two different trends in $\gamma$. In particular, the equilibrium wholesale price, $w^*$, experiences an initial drop, followed by growth later, which is exactly the opposite of the trend for the retailer’s equilibrium order quantity, $Q_1^*$. Meanwhile, the decreasing wholesale price and the increasing order quantity at low values of $\gamma$ in Fig. 3 lead to the profit growth for the retailer in Fig. 5; later, the trends
reverse and the profit drops. However, the manufacturer tends to uniformly benefit from speculation.

In summary, an increasing share of the retailer’s inventory does not necessarily lead to an increasing profit margin for speculators, as they are not coordinated and thus do not maximize their overall profit. The manufacturer can take advantage of this trait of speculators by increasing its wholesale price (if speculators can buy as much as they want), since the speculators purchases mitigate the impact of an increasing wholesale price imposed on the retailer. As a result, the gap between the wholesale price and the resale price narrows, and the retailer, whose margin is sandwiched in between, may suffer a loss. Although speculation may appear to be an extra source of demand for the retailer, it might be worse off in equilibrium, depending on how much speculators are capable of buying. In these examples, the retailer’s profit is negatively impacted when speculators can obtain a large percentage of their stock. Note that by comparing Figs. 5(a) and 5(b), we see that the more powerful retailer ($w_u = 17$) is more effective at mitigating the impact of speculators on their expected profit.

5.2. Dual-channel chain

Next, consider the case of the dual-channel chain (where the manufacturer enters the secondary market), which is more complicated, as seen in Figs. 6 to 8. As these figures show, the equilibrium wholesale price is more likely to equal (or be close to) its upper bound, $w_u$. As $\gamma$ increases, $Q^*_s$ also increases (as in the previous section), whereas $Q^*_2$ and $P_r$ both drop. Note that the resale price is always greater than or equal to the retail price for all values of $\gamma$; that is, the manufacturer does not use a lower price in the secondary market to push out speculators, nor does it undercut the retailer’s primary market price.

The story on the retailer’s side is different from that of the single-channel chain case; increasing speculation may benefit the profit of the retailer (compared with the case of no speculation), although the magnitude of the retailer’s profit is smaller than in the single-channel chain case. Also, as shown in Fig. 7, the manufacturer and speculators may co-exist in the secondary market, which is similar to the results for the case of a monopolistic direct seller with speculators, as discussed in Su (2008).
Fig. 7. Dual-channel chain equilibrium $Q^*_s$ and $P_r$: (a) $w_u = 17$ and (b) $w_u = 18$.

However, speculation may not always benefit the manufacturer (see Fig. 8); although speculation leads the retailer to order more, the competition with speculators in the secondary market undercuts the secondary market price and thus may cannibalize the profit opportunity for the manufacturer.

6. Implications for supply chain management

Based on our numerical results, we first make the following observations:

1. By comparing Fig. 5 with Fig. 8, we see that the retailer is never better off, and is generally much worse off, as a result of the manufacturer’s participation in the secondary channel. However, when the manufacturer does participate, the retailer’s position is always improved by the participation of speculators. Thus, it is in the retailer’s interest to try to keep the manufacturer out of the secondary market; if it cannot, it should not limit speculators.

2. By comparing Fig. 5 with Fig. 8, we see that the manufacturer is never worse off from participating in the secondary market.

3. If the manufacturer does not participate in the secondary market, then its position is improved by the participation of speculators, whereas the retailer’s position is often worse. This, coupled with point 1, implies that the retailer is best off when neither speculators nor the manufacturer create a secondary market.

4. Channel profit is universally improved by increased speculator participation when the manufacturer does not participate in the secondary market. However, channel profit can decrease as speculation increases when the manufacturer participates in the secondary market.

5. Channel profit may decrease solely at the retailer’s expense from the manufacturer’s participation in the secondary market.

We thus argue that compelling reasons exist for countering speculation. Although speculation raises the expected profits of both the retailer and the manufacturer in some

Fig. 8. Dual-channel chain profit: (a) $w_u = 17$ and (b) $w_u = 18$. 
cases, the improvement in expected short-term profit may hurt the manufacturer in terms of the long-term benefits. As stated in Section 1, speculation causes scarcity of the product in the primary channel. Some customers therefore cannot gain access to the product simply because they do not move as fast as speculators and other customers. Moreover, customers entering the resale market face a substantially higher price. Finally, as we have shown in Section 5, speculation may hurt both supply chain players. Note that γ may not necessarily be an exogenous bound on the inventory share for speculators; it is possible to restrict γ within a range that is beneficial to the supply chain players.

We next discuss several means of controlling speculation. First, the retailer can limit the number of units that can be purchased each time and the number of purchases per customer or household. Second, the manufacturer can also allocate a large quantity of products for sale in the secondary market, undercutting or even cutting off the margin of speculators.

Finally, for products with short life cycles, the value of the product hoarded by speculators quickly decreases. The effective resale period is the duration between the moment when the primary channel runs out of inventory and the end of the product’s life cycle. Therefore, the manufacturer can allocate $Q_2$ to agents to sell the product at multiple sequential time points after retail shelves go empty. Note that speculators can obtain the product simply because they respond to the release of the product faster and go to the retail store earlier than the average customer. The sequential selling strategy can effectively restrain speculators.

7. Conclusions and future extensions

This article studied the impact of speculation in a manufacturer–retailer two-stage supply chain. The behavior of speculators was analyzed and a model that considers speculation was developed to optimize supply chain decisions. Extensive experiments on the model were also conducted to illustrate the impacts of speculation on supply chain decisions. The impact of speculation on supply chain decisions and expected profit were shown to be nontrivial.

Specifically, speculation may improve supply chain profitability through a reduction in the retailer’s demand uncertainty in the case of a low degree of speculation. However, this benefit comes at a cost to customers. Moreover, speculation may intensify the conflict between the manufacturer and the retailer in the case of a high degree of speculation. In this case, supply chain players are motivated to control speculation and better coordinate with each other.

Finally, we suggested several measures to regulate speculators when they are harmful to the supply chain. To our knowledge, this is the first study on the operations cost impacts of speculation in retail sales channel management.

We believe that there are several possible research extensions of this topic. First, measures for controlling speculators could serve as a selling point for the retailer when negotiating with the manufacturer. It will be interesting to consider this issue when there is more than one retailer. Second, it will be interesting to extend our model to the case with an endogenous retail price. For example, the retailer can consider decreasing the retail price in the case of a high degree of speculation, such that speculation remains in the range that provides benefits. Finally, it will be valuable to study strategies for the manufacturer in hiring selling agents for the secondary market. In particular, it would be interesting to study the pricing strategy for multiple, sequential time points for selling in the secondary market (e.g., the time points to release the product and the amount of product released at each time point).

Another interesting problem might be controlling speculation for multiple products that are not fully differentiated. For example, Monsanto has developed several types of gene-engineered seeds with certain traits (e.g., rootworm resistance, drought tolerance), with each type of seed possessing a different utility value for farmers in different areas. As a result, Monsanto has several pricing zones in the United States. However, price differentiation creates the potential for profits based on speculation. In this case, speculators may consider transporting seeds from a pricing zone charging less to a higher-price zone in order to make additional profit. Seeds obviously have a life cycle (depending on the sowing season), and farmers in a pricing zone may have several types of seed options to consider. It would be interesting to study the strategies of the supplier (Monsanto), the retailers, speculators, and farmers, and any resulting equilibria and to develop managerial strategies for the supplier to counter the negative impacts of speculation.

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Supplemental material

Supplemental data for this article can be accessed on the publisher’s website.

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**Appendix 1**

**Notation**

| Notation | Meaning |
|----------|---------|
| $D$      | Customer demand level |
| $\xi$    | Random variable defining demand/price relationship |
| $\eta_0, \eta$ | Bounding parameters for $\xi$ |
| $P$      | Retail price |
| $a, b$   | Parameters defining the demand curve |
| $Q_1$    | Order quantity of the retailer |
| $Q_s$    | Quantity purchased by speculators |
| $Q_2$    | Quantity allocated to the secondary market by the manufacturer |
| $w$      | Wholesale price |
| $\alpha$ | Proportion of the unsatisfied demand entering the secondary market |
| $\beta$  | Parameter of beta distribution |
| $\gamma$ | Maximum proportion of $Q_1$ purchased by speculators |
| $c$      | Unit production cost |
| $v$      | Retailer’s unit salvage value |

**Biographies**

Tianke Feng is a Decision Science Consultant at The Walt Disney Company. He holds a Ph.D. in Operations Research from the University of Florida. His research focuses on dynamic optimization, supply chain management, and revenue management.

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