Lead Time, Uncertainty, and Channel Decision-Making

Eyal Biyalogorsky
Graduate School of Management
University of California at Davis, Davis, CA 95616
eyalog@ucdavis.edu

Oded Koenigsberg
Columbia Business School
Columbia University, New York, NY 10027
ok2018@columbia.edu

April 2006
Lead Time, Uncertainty, and Channel Decision-Making

Abstract

Production lead time forces companies to make production decisions before the realization of demand. These decisions thereafter constrain the firms’ reactions to changes in demand. Channel members’ decisions depend on the initial production decisions made by manufacturers and on stocking decisions by retailers. In this study, we analyzed how production lead time affects decisions in a channel of distribution facing uncertain demand. Our demand formulation is derived from micro-modeling of consumer utility functions and captures demand uncertainty regarding two parameters, market size and price sensitivity. We considered which channel member, the retailer or the manufacturer, should keep ownership of the units in the channel and how lead time affects prices in the channel. We find that, in most cases, the channel, the retailer, and the manufacturer all benefit when the manufacturer maintains ownership over the units in the channel. However, when there is uncertainty about market size and the difference between the possible demand states is large, the channel and the retailer are better off if the retailer retains ownership of the units but the manufacturer will still prefer to maintain ownership. Thus, there is potential for channel conflict erupting under these conditions. In addition, we find that the pass-through rate varies with the type of demand uncertainty. The pass-through is greater than 100% when there is price-sensitivity uncertainty and less than 100% when there is market-size uncertainty.

Key words: Channels of distribution; Demand uncertainty; Lead time; Pricing; Pass-through.
1. Introduction

In a perfect world, everyone would have a replicator—one of those amazing gadgets depicted in the Star Trek television shows and movies that can instantly produce any item you want, just in time and to your exact specifications. In our world, it takes time to manufacture products, move them through the supply chain, and deliver them to customers. Many industries operate supply chains that involve long lead times. Fisher and Raman (1996) reported that the time between ordering and shipment of fashion merchandise can be as long as 12 months; in the toy industry the gap between ordering and delivery can be as long as 18 months. One result of long lead times is that channel members—manufacturers, retailers, wholesalers, distributors—must make production and possibly ordering decisions long before they know the actual demand for a product. Once made, these decisions constrain the range of strategic and tactical reactions available to participants as they respond to changes in demand. For example, retail pricing and promotion decisions can be made closer to the time a product appears in the market, but such decisions are constrained by the quantities already ordered and produced and the inventories already in place.

In a distribution channel, the need to make production decisions before uncertainty is resolved raises the issue of which channel member, the retailer or the manufacturer, should retain ownership of the units in the channel until the demand uncertainty is resolved. Grossman and Hart (1986) have shown that ownership can be beneficial because it confers to the owner the residual right to respond to changes in the

---

1 As reported by a number of industry sources, for example The Toy and Game Inventor’s Handbook (Levy and Weigartner 2003), and the Industry Insights FAQ at http://www.toysngames.com/Inventors/insight4.html.

2 We consider only made-to-stock systems in this paper. Made-to-order systems face a different set of issues.
market. A manufacturer can change wholesale prices in response to demand conditions as long as it owns the goods, but once title to the units is transferred to the retailer, the manufacturer can no longer change the wholesale price. However, ownership is potentially costly if demand turns out to be low. The owner (whether the manufacturer or the retailer) may end up stuck with units that cannot be sold. This risk may cause each channel member to prefer that the other member take ownership of the units (Cachon 2004; Netessine and Rudi 2004). Thus, it is not clear a priori what sort of ownership arrangement is in the best interest of the retailer, the manufacturer, and the channel and under what conditions.

Different ownership arrangements and structures are common in practice and the potential costs and benefits of ownership are substantial. Here are some examples:

- L.L. Bean, a direct catalog retailer, takes ownership of its merchandise fairly early and makes final, firm commitments to its vendors 12 weeks before a catalog reaches consumers. These commitments create inflexibility that costs the retailer $20 million annually due to stockouts or liquidations (Schliefer 1993).

- Wal-Mart attempts to minimize the amount of time it actually owns merchandise, sometimes to as little time as is required to electronically scan a bar code at checkout (Clement 1995).

- For products such as furniture and specialty chemicals, it is common for retailers to operate without any inventory at all. Retailers essentially operate as catalogs and order-takers while the manufacturer maintains ownership and keeps inventories in a central warehouse and ships products directly to customers upon order receipt (Kandel 1996).
Johnson (2001) reported that in the toy industry there is a trend of shifting ownership of units in the channel from retailers to manufacturers.

Apple Computer, in the span of little more than a year, faced both shortages of its popular iPod Mini players (Gibson 2004) and overstocks of its new iPod Shuffle player (CNNMoney 2005). In response to the iPod Mini shortages, Apple increased European prices for the iPod Mini before launching them there in July 2004, prompting consumer complaints about the difference in prices between Europe and the U.S.

When Toyota Motor Corp. faced supply shortages of the Prius in the U.S. in late 2004, it raised the Prius’ price by $580 (Bloomberg.com 2004).

As these examples clearly demonstrate, ownership can be a double-edged sword. Firms need to understand the strategic implications of ownership in terms of both potential costs (e.g., L.L. Bean’s $20 million loss) and potential benefits (e.g., the ability of Apple Computer and Toyota to raise prices in response to demand conditions). Interestingly, these strategic considerations become more prominent with the emergence of more flexible contracting arrangements between channel members that separate ownership of the units from the actual physical location of the units in the channel. Many internet retailers use drop-shipping, whereby the retailer takes ownership but not physical possession and units are shipped directly from the manufacturer to the final consumer (Wall Street Journal 2003; Netessine and Rudi 2003). Valentini and Zavanella (2003) described a “consignment stock” arrangement in which a supplier keeps an agreed-upon number of units at the customer’s warehouse. The customer can draw from that inventory according to prices set by the supplier (which can be changed on a daily basis). Thus, even though the units are stored on the customer’s premises,
they are still owned by the supplier. Such consignment-like arrangements (Rubinstein and Wolinsky 1987; Wang, Jiang, and Shen 2004), as well as certain forms of vendor-managed inventory (VMI) arrangements (Yang, Ruben, and Webster 2003), make it much easier to shift ownership of the units between members of a channel.

The main purpose of this paper is to examine ownership issues in the context of a simple manufacturer-retailer channel when demand is uncertain. Specifically, we focus on who should retain ownership of the units in the channel—the manufacturer or the retailer. We develop a single-period model in which a manufacturer sells its products to a retailer that then sells them to consumers. Our demand formulation is derived from micro-modeling of consumer utility functions and captures demand uncertainty regarding market size and price sensitivity. We find that the manufacturer always prefers to retain ownership, but that the retailer under some conditions prefer the manufacturer to retain ownership, and under other conditions prefer to assume ownership himself. The incentives for retaining ownership depend on the nature of the demand uncertainty (i.e., market size or price sensitivity) and on the amount of demand uncertainty faced by the channel. When there is uncertainty regarding market size and the possible difference in size is large, the manufacturer and the retailer will disagree about who should have ownership rights, potentially leading to conflict in the channel. In addition, we find that ownership has important implications for firms’ pricing decisions and for consumer surplus and social welfare.

**Related Literature**

The literature on firm behavior under demand uncertainty distinguishes four possible modes of behavior that depend on whether decisions are made before or after uncertainty about demand is resolved (Leland 1973): (1) All decisions are made *ex*
post—after demand is known. (2) Quantity is set ex ante—before demand is known—and price is set ex post. (3) Price is set ex ante and quantity is set ex post. (4) Both price and quantity are set ex ante. Until recently, the literature on channels under uncertainty focused on modes 1 and 4. Thus, Gerstner and Hess (1991, 1995) assumed that both price and quantity can be adjusted in investigating how a channel of distribution should use push and pull promotions when demand turns out to be unexpectedly low. On the other hand, the literature on optimal production/inventory-replenishment plans under uncertainty commonly assumes that all decisions must be made before observing actual demand conditions (Lariviere and Porteus 2001).

We, on the other hand, consider the case when quantity is set ex ante and price ex post (mode 2), which is a reasonable description of decision-making in channels with relatively long production lead times. Note that the difference between this case and the literature cited previously is not just that some decisions are made before demand is known and some after; in addition, the optimization problem is no longer a simultaneous decision on both price and quantity. Many industries are characterized as having long production lead times and accompanying uncertainty about demand conditions. These include cars, consumer electronics, and seasonal products like clothing and toys, (Fisher and Raman 1996). Even sophisticated demand forecasting systems many times cannot mitigate the problems these conditions cause. For example, Sport Obermeyer, a producer of ski apparel that is highly touted for its innovative use of demand forecasting, still has to produce 50% of its merchandise early in the season before demand is known (Fisher et al. 1994).

Intuitively under such conditions, the ability to wait and make decisions after demand is known should be valuable, hence the interest in designing processes that
allow decision postponement (Van Meighem and Dada 1999). Most of that research concentrated on product-design strategies (see, for example, Lee and Tang 1996), but there has been some work on the effect of different ordering arrangements between a retailer and a manufacturer. Ferguson (2003) looked at how a retailer’s postponing the ordering decision (without changing the retail price, which is exogenous) affects the manufacturer’s production decision. Cachon (2004) showed that offering advance-purchase discounts and allowing the retailer to place some orders before and some orders after demand is known can help in coordinating the channel when demand is uncertain. Netessine and Rudi (2003, 2004) investigated how demand uncertainty affects the use of drop-shipping, in which the manufacturer/wholesaler owns and stocks the inventory and ships units directly to customers at the retailer’s direction. A common theme in these papers is that prices are exogenous and only the production decision is considered. In contrast, our focus is on the effect that the ability to change prices ex post (while production decisions must be taken ex ante) has on channel members.

The postponement literature points to the benefits of the ability to delay decisions until demand is known, but there are indications that in some cases these benefits may not be sufficient to justify delaying the decisions. Iyer and Padmanabhan (2000) asked when a manufacturer should offer flexible terms of trade to a retailer facing demand uncertainty and showed that there are times when a manufacturer will offer rigid rather than flexible terms. In a setting of a single manufacturer and multiple competing retailers, Iyer, Narasimhan, and Niraj (2003) investigated how improved information affects the manufacturer’s preference regarding where to keep the
inventory. They found that, with more reliable information, the manufacturer prefers to hold the inventory only if the retail market is very competitive.\footnote{This may be partly due to an increase in manufacturer power as the retail market becomes more competitive. Iyer and Villas-Boas (2003) showed in a channel bargaining model that only a powerful}

The work most closely related to the current study is a working paper by Taylor (2005). Taylor, independent of us, studied a setting that is similar to our model. Among the questions posed by Taylor was when should a manufacturer sell to a retailer—early or late in the selling season? He showed that the manufacturer always (weakly) prefers to sell late rather than early. One can interpret the sale-timing decision in Taylor as a decision about when to transfer ownership of the units in the channel from the manufacturer to the retailer. Thus, Taylor’s result is equivalent to our Part C of Proposition 1 in Section 4, which describes manufacturer preferences regarding ownership of units in the channel. Unlike Taylor’s work, our model captures demand uncertainty regarding both market size and price sensitivity. We later show that the nature of the demand uncertainty affects the results in important ways. We also differ from Taylor in viewing the ownership decision as a strategic choice for the channel rather than just for the manufacturer. Thus, we consider issues affecting incentives for the retailer while Taylor’s model includes a constraint that the retailer has to be no worse off under manufacturer ownership than under retailer ownership. This enables us to show that there are situations in which channel members can agree that the retailer should retain ownership even if the incentives to the manufacturer (considered in isolation) are such that the manufacturer strictly prefers to retain ownership. This explains when and why we see ownership rights given to retailers. In addition, we explore how the presence of lead time affects pricing and promotion decisions and how the nature of the demand uncertainty affects these issues.
Shifting ownership of units in the channel from the retailer to the manufacturer and vice versa also means shifting the risk from one to another. This bears some similarity to mechanisms such as return policies (Mantrala and Raman 1999; Marvel and Peck 1995; Padmanabhan and Png 1997) and guaranteed profit margins (Mantrala, Basuroy, and Gajanan 2005) that provide risk-sharing between retailers and manufacturers. These mechanisms, however, provide for risk-sharing without shifting a participant’s right to make decisions about the units in the channel. In contrast, changing ownership shifts both risks and decision rights, and it is the question of who should hold those decision rights that is central to this study.

2. Model

We consider a bilateral channel in which a risk-neutral manufacturer sells its product to a risk-neutral retailer that sells to consumers. In order to have the units ready and on store shelves in time, the firms must make many decisions well in advance of the selling time. In particular, firms in many industries must commit to the production quantity very early in the planning cycle. For example the lead-time between the start of unit production and availability of those units for sale reaches as much as 18 months in the toy industry (Eckert 2001), and 12 months in the fashion industry (Fisher and Raman 1996). Other decisions, like pricing, can be made much closer to the selling season or during the selling season.4

Channel members are uncertain about demand conditions. They take steps like market research by which they try to learn about the true demand conditions. As a result, the amount of uncertainty they have about demand is reduced over time. Thus, manufacturer will voluntarily offer a return policy.

4 Even in the case of direct catalog retailers like L.L. Bean, pricing decisions are finalized much closer to the shipping of catalogs than are production decisions.
the firms have less uncertainty when making the pricing decisions than when making the production decisions. The earlier production decisions must be made, the more uncertain firms will be about demand. This is because of the potential for changes in economic conditions and consumer tastes and because consumers are notoriously bad at predicting their future behavior (Morwitz 1997).

Given these conditions, it is natural to ask who in the channel, the manufacturer or the retailer, should have ownership over the units produced until the pricing decisions have to be made. If the manufacturer retains ownership, it can adjust the wholesale price in response to the lower demand uncertainty but also risks being stuck with units that cannot be sold or can be sold only at deeply discounted prices. The retailer can always adjust the retail price as it learns more about demand. If the retailer takes ownership over the units, that locks in the wholesale price charged by the manufacturer and the retailer reaps most of the windfall if demand turns out to be high, at the cost of getting stuck with unwanted units if demand turns out to be low.

To capture this situation and the forces involved, we used a simple model in which there are two states of firms’ knowledge about demand: In the beginning, the manufacturer and retailer each have some symmetrical and exogenous uncertainty about demand. Then, at a later point, they learn the true demand in the market. Production decisions must be made before the firms learn the true demand state. Pricing decisions can be made after the firms learn about demand.

The assumption that there are only two possible states of knowledge about demand is clearly a simplification of the real-world process in which participants’ knowledge of demand develops over time, allowing them to adjust production and marketing accordingly. However, this model captures the primary aspects operating in
this situation: (1) production decisions are made under conditions of more severe uncertainty than are pricing decisions, and (2) at a certain point, the channel must commit to a production plan. Changing the production plan at a later point in time is very costly when possible at all (see, for example, Caruana and Einav 2005; Fisher and Raman 1996; Johnson 2001; and Schleifer 1993).

We further assume that there is a constant marginal cost of production, $c$ per unit, and that the retailer’s marginal costs are zero. Unit-holding costs are zero and unsold units are scrapped with no cost or value to either the manufacturer or the retailer.

We distinguish between two possible cases. In the first case (Figure 1A), the retailer takes delivery of ordered units when demand is still unknown and assumes ownership upon delivery. The time line in this case is as follows: The manufacturer sets the wholesale price (while there is still uncertainty regarding demand), and the retailer orders products. The units are produced and delivered to the retailer. After the firms learn the true demand conditions, the retailer sets the retail price. Any unsold units are scrapped. Under this scenario, the retailer bears the cost of unsold inventory.

In the second case, the retailer places orders with the manufacturer only after learning what the true demand in the market is. However, the lead time needed for production forces the manufacturer to produce units in anticipation of retail orders and actual production takes place while there is still uncertainty about demand. In this case, the time line is as follows (see Figure 1B): The manufacturer decides how many units to produce. After the firms learn the true demand conditions, the manufacturer sets the wholesale price and the retailer places orders with the manufacturer and sets the retail price.

---

5 All the results directly extend to the case of a positive symmetric holding cost, $h>0$. Details are available from the authors upon request.

6 Delivery and ownership transfer do not have to happen at the same time. The critical assumption here is that ownership is transferred to the retailer before demand is known.
price. The manufacturer ships the requested units to the retailer and scraps any leftover units. Under this scenario, the manufacturer bears the cost of unsold inventory.

Insert Figure 1

Demand Uncertainty

We model demand and demand uncertainty in the following manner: Let $\phi$ be consumers’ valuation of the service provided by the product. We assume that $\phi$ is distributed uniformly in the interval $[0, \frac{1}{\beta}]$; that there are $\alpha$ consumers in the market, each independently drawn from the distribution of $\phi$; and that each consumer uses at most one product.\(^7\) From these assumptions, the quantity demanded as a function of price, $p$, is:

$$q = \alpha \Pr[\phi \geq p] = \alpha[1 - \Pr[\phi \leq p]] = \alpha(1 - \frac{p}{1/\beta}) = \alpha(1 - \beta p).$$

Thus, the market demand function $q$ is given by:

$$q = \alpha(1 - \beta p),$$

(1)

where $\alpha$ represents market size and $\beta$ represents consumers’ price sensitivity.

There are two possible sources of uncertainty: (1) the firm may be uncertain about the exact number of consumers in the market, $\alpha$; and/or (2) the firm may be uncertain about consumers’ valuation of the product, which in this case means uncertainty regarding the upper bound of the valuation distribution. Uncertainty regarding consumer valuation is reflected as uncertainty regarding the price sensitivity in the market, $\beta$.

\(^7\) These assumptions lead to a linear demand function formulation. We also conducted an analysis using an exponential demand formulation. All the results of the linear case hold for the exponential case as well. Details are available from the authors upon request.
Note that, in contrast to the usual linear demand function formulation, in Equation 1 we keep $\alpha$ as a multiplicative term outside the parentheses. This is done to avoid confounding the effects of potential market size (number of consumers) and price sensitivity. It is common to write the preceding demand function in reduced form as $q = \alpha - \beta' p$ with $\beta' = \alpha \beta$ and to model uncertainty as an additive linear error term on $\alpha$ while keeping $\beta'$ fixed. Such an approach confounds uncertainty regarding the number of consumers and their valuation of the product because keeping $\beta'$ fixed requires that $\beta$ must change in negative correlation to $\alpha$. This confounding causes problems in interpretation of the mathematical results. To avoid this, we use the demand formulation in Equation 1.

We model uncertainty in demand as a discrete two-state distribution. Demand can be either high with probability $\theta$ or low with probability $1-\theta$ where $\theta$ is known. We denote parameters related to the high-demand state with a subscript $h$ and parameters related to the low-demand state with a subscript $l$. In one case, we assume that channel members are uncertain about consumers’ price sensitivity and know for certain the market size. Price sensitivity can be strong ($\beta_l$) or weak ($\beta_h$) with $\beta_l > \beta_h$. In a second case, we assume that channel members are uncertain about the number of potential consumers in the market but know for certain their price sensitivity. Market size can be large ($\alpha_h$) or small ($\alpha_l$) with $\alpha_h > \alpha_l$. The third case we consider is when firms have substantial uncertainty regarding both market size and price sensitivity.

---

*See Marvel and Peck (1995) for a similar approach for modeling uncertainty.*
3. Analysis

In this section, we analyze a game between a manufacturer and a retailer in a distribution channel where the manufacturer acts as the Stackelberg leader and the retailer as the follower. We consider in this analysis only linear per-unit wholesale arrangements. This is a reasonable starting point in view of the wide use of such arrangements in practice (Lariviere and Porteus 2001) and since it is the optimal outcome expected of bargaining in channels under uncertainty (Iyer and Villas-Boas 2003). In addition, understanding firms’ incentives under linear contracts is a necessary first step in figuring out whether more complex arrangements such as side payments and nonlinear prices are called for. Within this channel structure, we examine two scenarios—one in which the retailer owns the units and bears the cost of unsold inventory and a second in which the manufacturer owns the units. In all cases we apply the proper parameter restrictions to ensure that demand is strictly positive and both the retailer and the manufacturer have non-negative expected profits.

3.1 Market-Size Uncertainty

In this section, we analyze the case where channel members do not know the exact market size, \(\alpha\). With probability \(\theta\), demand is high (\(\alpha_h\)); with probability \(1-\theta\), demand is low (\(\alpha_l\)). The price sensitivity, \(\beta\), is known and fixed.

Table 1 reports the equilibrium outcomes for the three possible regimes: the retailer owns the units and \(\alpha_i < \frac{\alpha_h(\theta - \beta c)}{2\theta}\), the manufacturer owns the units and \(\alpha_i \leq \frac{\alpha_h(\theta - \beta c)}{\theta}\), and either the manufacturer or the retailer owns the units and
\( \alpha_i > \frac{\alpha_h(\theta - \beta c)}{\theta} \). Table 1 also shows as a benchmark the outcomes when the channel does not face lead time. We next describe how the equilibrium outcomes were derived.

### 3.1.1 Retailer Owns the Units

When the retailer assumes ownership of the units (Figure 1A), the manufacturer determines the wholesale price based on currently available (uncertain) information regarding demand conditions. The retailer orders units from the manufacturer based on the same demand information and the quoted wholesale price. After demand is revealed, the retailer sets the retail price.

To find the subgame perfect equilibrium, we solve this game backward and start with the retail price decision. At that point, the retailer already knows the exact market size \( \alpha_i(i=l, h) \) and thus faces the following demand function:

\[
q = \alpha_i (1 - \beta p).
\]

Remember that the retailer holds units that it already ordered and cannot receive any additional units in time (because of production lead time). Obviously, the retailer cannot sell more than the \( Q \) units it already holds. Therefore, the retailer’s maximization problem is

\[
\begin{align*}
\text{Max} & \quad p(q(\alpha_i, p), \\
\text{s.t.} & \quad q(\alpha_i, p, q) \leq Q.
\end{align*}
\]

There are two possibilities; the optimal price may imply either that the constraint in Equation 3 is binding and all \( Q \) units are sold or that the constraint is not binding and only some of the units are sold and the rest are scrapped (recall that we assumed that scrapping is costless). We show in the Appendix that the solution for this optimization problem leads to two possible cases. First, if \( \alpha_i \) is sufficiently large, the optimal retail
price is set at a level such that all units are sold regardless of the demand condition. Otherwise, the optimal price is set at a level such that all units are sold if demand is high but only some of the units are sold if demand is low. The equilibrium outcomes are given in Table 1 and the derivation of the solutions can be found in the Appendix. Here, for the sake of brevity, we describe fully only the latter case in which the retailer’s policy is to sell all units when demand is high but only some when demand is low. In this case, the retailer’s optimal pricing decision is given by:

\[
p_i = \begin{cases} 
\frac{\alpha_h - Q}{\beta \alpha_h} & \text{if } \alpha_i = \alpha_h, \\
\frac{1}{2\beta} & \alpha_i = \alpha_l.
\end{cases}
\] (4)

Next, we consider the retailer’s ordering decision. The retailer makes the ordering decision before knowing the exact demand state. Therefore, the retailer determines the order quantity, \(Q\), that solves the following optimization problem:

\[
Max \quad E[\Pi] = wQ + \theta \pi_H + (1-\theta)\pi_L,
\] (5)

where \(\pi_L\) (\(\pi_H\)) is the profit if the market size is small (large) and is given by

\[
\pi_L = \frac{1}{2\beta} [\alpha_i (1 - \beta \frac{1}{2\beta})], \quad \text{and}
\]
\[
\pi_H = \frac{\alpha_h - Q}{\beta \alpha_h} [\alpha_h (1 - \beta \frac{\alpha_h - Q}{\beta \alpha_h})].
\] (6)

This optimization problem yields:

\[
Q = \frac{\alpha_h (\theta - \beta w)}{2\theta}.
\] (7)

We now turn to the manufacturer’s wholesale pricing decision. We assume that the manufacturer is a Stackelberg leader and correctly incorporates the retailer’s optimal
reaction function. Therefore, the manufacturer determines the wholesale price that solves the following optimization problem:

$$\max_w \Pi_M = (w - c)Q.$$  \hfill (8)

The first-order condition with respect to \( w \) yields:

$$w = \frac{c}{2} + \frac{\theta}{2\beta}. \quad (9)$$

Comparing the retailer’s profits under this policy with its profits from the policy of selling all the units in both demand conditions, we find that this policy is optimal when \( \alpha_i < \frac{\alpha_i(\theta - \beta c)}{2\theta} \).

### 3.1.2 Manufacturer Owns the Units

In this scenario, the manufacturer makes the production decision before demand is revealed and before receiving orders from the retailer. After demand is revealed, the manufacturer sets the wholesale price, the retailer places its orders, the units are delivered to the retailer, and the retailer sets the retail price. We find that there are two different regimes. First, for values of \( \alpha_i > \frac{\alpha_i(\theta - \beta c)}{\theta} \), the entire production quantity is sold independent of actual market size. For values of \( \alpha_i \leq \frac{\alpha_i(\theta - \beta c)}{\theta} \), the manufacturer’s optimal policy is to sell all of the units produced when market size is large and sell only a portion of the available units when market size is small. Note that in this case it is the manufacturer (not the retailer) who decides what portion to sell since the manufacturer owns the units and can adjust the wholesale price in response to demand conditions. The equilibrium outcomes are given in Table 1 and the derivation can be found in the Appendix.
3.2 Price-Sensitivity Uncertainty

In this section, we analyze the case where channel members are uncertain about price sensitivity in the market. With probability $\theta$, consumers are not very price sensitive ($\beta_h$) and therefore demand is high. With probability $(1-\theta)$, consumers are more price sensitive ($\beta_l$), so demand is low. The potential market size, $\alpha$, is known and fixed. Such a setup corresponds well, for example, to the effect of economic conditions on demand. If the economy turns south, aggregate price sensitivity in the automobile market should increase. The potential market size, on the other hand, should not be affected. Demand for free cars, then, would be the same regardless of economic conditions.

As before, we analyze and compare two possible scenarios. In one, the retailer owns the units. The retailer places orders with the manufacturer before the uncertainty is resolved and the manufacturer produces only the amount ordered by the retailer. In the second, the manufacturer owns the units and decides how much to produce before the uncertainty is resolved while the retailer places orders only after the uncertainty is resolved.

We find the optimal decisions for the manufacturer and retailer by working backward, as we did for the case of market-size uncertainty (see Section 3.1), and derive the subgame perfect equilibrium for each of the scenarios. Table 2 reports the equilibrium outcomes for three different cases: the retailer owns the units, the manufacturer owns the units, and a benchmark of the results when the channel does not face production lead time (see the Appendix for the details of deriving these results). This case turned out to be somewhat simpler than the one for market-size uncertainty.
because the full production quantity is sold under all scenarios due to the fixed market size.

**INSERT TABLE 2**

### 3.3 Combined Market-Size and Price-Sensitivity Uncertainty

The analysis for combined market-size and price-sensitivity uncertainty is very similar to the analysis described in Section 3.1. In the interest of brevity, we have omitted the details here, but they are available from the authors.

## 4. Results

### 4.1. Who Should Own the Units in a Channel?

Retaining ownership over the units in a channel exposes a firm to the risk of not being able to sell all the units. If the optimal sale quantity turns out to be smaller than the available units by \( \Delta \), then the firm wastes money (\( c\Delta \) for a manufacturer that retains ownership and \( w\Delta \) for a retailer that retains ownership). On the other hand, owning the units provides a firm with another degree of freedom in responding to eventual demand conditions. For example, a manufacturer that owns the units can adjust the wholesale price according to revealed demand. If, on the other hand, ownership is transferred to the retailer, the manufacturer has to fix the wholesale price before demand is revealed and cannot adjust it later according to the revealed demand. The added flexibility is useful if the firm finds it profitable not to sell all the available units when demand is low. The firm can then restrict the quantity sold by setting a higher price. For example, the manufacturer can set a higher wholesale price that results in the retailer ordering (and selling) fewer than the number of units available in inventory.

These two forces affect the manufacturer and the retailer differently. The costs of wasting a unit are smaller for the manufacturer than for the retailer since \( c < w \). The
manufacturer also cares more about the flexibility afforded by ownership since that is the only way the manufacturer can respond to revealed demand, while the retailer can always change the retail price. Intuitively, these differences lead to different decisions by the manufacturer and the retailer regarding when and how much to restrict sales in the low-demand state. Therefore, it matters who owns the units in a channel. Next we present the results describing how demand uncertainty affects the manufacturer and retailer decisions regarding ownership of the units in the channel.

4.1.1 Market-Size Uncertainty

We define $k = \frac{\theta - \beta c}{\theta}$ as a threshold level such that for any values of $k < \frac{\alpha_i}{\alpha_h}$ neither the manufacturer nor the retailer find it optimal to hold inventory. When market size is uncertain, we find that there are three different regimes depending on the size of the uncertainty. Then,

**Proposition 1:** When market size is uncertain,

(A) Total channel profits are greater under retailer ownership if the difference in market size is large ($\frac{\alpha_i}{\alpha_h} < \frac{k}{2}$) and under manufacturer ownership if the difference is intermediate ($\frac{k}{2} < \frac{\alpha_i}{\alpha_h} < k$). Channel profits are the same regardless of ownership if the difference in market size is small ($k < \frac{\alpha_i}{\alpha_h}$).

(B) Retailer profits are greater under retailer ownership if the difference in market size is large ($\frac{\alpha_i}{\alpha_h} < \frac{k}{2}$) and under manufacturer ownership if the difference is intermediate
$\left(\frac{k}{2} < \frac{\alpha_l}{\alpha_h} < k \right)$. Retailer profits are the same regardless of ownership if the difference in market size is small ($k < \frac{\alpha_l}{\alpha_h}$).

(C) Manufacturer profits are greater under manufacturer ownership if the difference in market size is not too small ($\frac{\alpha_l}{\alpha_h} < k$). Manufacturer profits are the same regardless of ownership if the difference in market size is small ($k < \frac{\alpha_l}{\alpha_h}$).

**INSERT FIGURE 2**

There are several important implications stemming from Proposition 1. First, it does matter who owns the units in a channel. Specifically, it matters when there is uncertainty about market size and the potential difference in market size is large enough (see Figure 2). For intermediate differences in market size, the manufacturer should retain ownership over the units, and since this is also in the interest of the retailer, it is reasonable to expect that the manufacturer and retailer can reach an arrangement that keeps ownership with the manufacturer. For large differences in market size, the retailer would like to have ownership of the units. However, in this case the manufacturer’s interest differs from the retailer’s interest in that the manufacturer prefers to retain ownership. Since total channel profits are greater under retailer ownership, there are potential arrangements that would make everyone better off and let the retailer assume ownership of the units. This may explain cases where we observe retailer ownership in practice. Of course, the fact that an agreement is possible does not mean that the parties

---

*Note that when $\theta < \beta k$ then $k < 0 < \frac{\alpha_l}{\alpha_h}$ and both firms would never carry units in inventory.*
will reach one, and therefore there is potential for channel conflict to arise under these conditions.

To illustrate the importance of these results, consider one possible set of parameters where $\beta=0.04$, $\theta=0.5$, and $c=4$. In this case, if expected market size in the low-demand state is 68% or lower of the high-demand state, it matters who owns the units in the channel. If the low-demand market size is even smaller (34% or lower of the high-demand market-size), the manufacturer and the retailer will have opposing interests regarding ownership of the units. The profit implications are also substantial: for example, if $\alpha_h=200$ and $\alpha_l=60$, the manufacturer’s profits are 64% higher under manufacturer ownership than under retailer ownership, but the retailer’s profits are 148% higher under retailer ownership than under manufacturer ownership.

To understand what drives this result, one has to realize that it matters who owns the units in the channel only if the firm that owns the units finds it optimal to restrict sales in the low-demand case to less than the available inventory. obviously, it is always optimal to sell all units in high-demand conditions. If it is also optimal to sell all units in low-demand conditions, then there is no waste from not selling all the units and there is no benefit from the flexibility to react to demand conditions while bearing the cost of unsold units. This is exactly what happens when $k < \frac{\alpha_l}{\alpha_h}$. In that case the difference in market size is small and the optimal policy is always to sell all the units (see Table 1). Therefore, it does not matter who owns the units.

Next, consider what happens when the difference in market sizes increases as $\alpha_l$ decreases (holding $\alpha_h$ constant). Clearly there comes a point at which it is no longer

---

10 Notice that the production quantity is the same whether the manufacturer or the retailer owns the units. Therefore, it does not affect the question of ownership.
optimal to sell all the units if demand turns out to be low. The wholesale price decreases faster than the retail price when $\alpha_l$ decreases. The manufacturer’s marginal contribution from selling more units in the low-demand state becomes negative for values of $\alpha_l < k\alpha_h$. Therefore, the manufacturer wants to restrict sales when $\alpha_l < k\alpha_h$. To do that, the manufacturer needs to have control over the units in the channel and therefore wants to retain ownership. As a consequence, sales in the high-demand state increase over the optimal quantity and sales in the low-demand state decrease when the manufacturer does not hold inventory. It turns out that, for values of $\frac{k}{2} < \frac{\alpha_l}{\alpha_h} < k$, the added contribution for the retailer in the high-demand state is larger than the loss in contribution from the low-demand state. Therefore, the retailer is better off (as, obviously, is the channel) under these conditions when the manufacturer owns the units.

When the difference between the demand states is very large, $\frac{\alpha_l}{\alpha_h} < \frac{k}{2}$, the manufacturer is still better off owning the units; however, the retailer and the channel are better off if the retailer owns the units. When the manufacturer owns the units, the retailer gives up some potential contribution in the high-demand state (compared to when the retailer owns the units) because the manufacturer increases the wholesale price when demand is high. This is compensated by the additional contribution the retailer gains in the low-demand state when the manufacturer reduces the wholesale price.

However, when $\frac{\alpha_l}{\alpha_h} < \frac{k}{2}$, this compensation is not sufficient (think what happens, for example, when $\alpha_l=0$; there are no sales in the low-demand state and the retailer gains nothing from letting the manufacturer own the units) and therefore the retailer is better
off owning the units. The channel is better off when the retailer owns the units because
the retailer sells more units in the low-demand state.

**Insert Figures 3 and 4**

Figure 3 depicts how, under market-size uncertainty, ownership is impacted by the
production cost  \( c \). The regions in which retailer ownership or channel conflict occurs
and where all prefer the manufacturer to own the units are largest when the production
cost is zero. As \( c \) increases, those regions diminish in size and eventually disappear, at
which point it does not matter who owns the units. This reflects the fact that the optimal
production quantity decreases with \( c \). At low production levels, all units are sold
regardless of the demand state and it does not matter who owns the units. As the optimal
production level increases, the possibility of being stuck with unsold units in the low-
demand state increases and ownership becomes important.

**4.1.2 Price-Sensitivity Uncertainty**

As can be seen from Table 2, under price-sensitivity uncertainty, all units are
sold even in the low-demand state. Thus, like the case of small differences in market
size, ownership does not matter. Indeed, comparing the resulting profits between the
cases of manufacturer ownership and of retailer ownership, we find that

**Proposition 2:** When price sensitivity is uncertain, the manufacturer, the retailer,
and the channel are indifferent to whether the manufacturer or the retailer owns the
units in the channel.\(^{11}\)

The reason that it is optimal to sell all the units even under low-demand
conditions when firms are initially uncertain about price sensitivity is that the market’s
size is known and fixed. Since the firm already has the units when the pricing decision
is made, the relevant marginal cost is zero as all the costs are already sunk. Therefore,

---

\(^{11}\) While expected profits are the same, their distribution over the demand states differs depending on
ownership. Thus, the result holds only for risk-neutral parties.
there is always a positive price at which it is optimal to sell all the units regardless of the demand condition and it does not matter who owns the units.

4.1.3 Combined Market-Size and Price-Sensitivity Uncertainty

In most cases, firms will be uncertain about both market size and price sensitivity. The findings from the case of market-size uncertainty hold in this case as well. Briefly, this occurs because the effects of market-size uncertainty and price-sensitivity uncertainty on the ownership decision are orthogonal to each other. In particular, price-sensitivity uncertainty does not change the ownership decision and, therefore, the driving force behind the ownership decision is market-size uncertainty even if there is some price-sensitivity uncertainty.

4.2. The Effect of Lead Time on Profits

As expected, under uncertain demand conditions, the presence of lead time reduces the total channel profits and the manufacturer profits compared to a channel without lead time. In addition, under uncertain demand conditions and in the presence of lead time, the retailer earns less profits and Consumer surplus are lower than the profits and consumer surplus without lead time, except:

**Proposition 3:** when market size is uncertain, the retailer owns the units in the channel, and \( \frac{\beta k [2 \theta - \beta c (1 + \theta)]}{\theta (3 - \beta c) (1 + \beta c)} < \frac{\alpha_l}{\alpha_b} < \frac{k}{2} \), in which case retailer profits and consumer surplus are greater with lead time than without lead time.

Surprisingly, under specific conditions the retailer and consumers can be better off. The retailer is better off because the wholesale price is lower with lead time than without it when the retailer owns the units (see Table 1). This lower wholesale price is obviously beneficial to the retailer. If the preceding condition holds, this effect is stronger than the cost of assuming ownership (because of excess inventory if demand is
low) and facing lead time for the retailer. The reason consumer surplus is higher is that
retailer ownership generates a higher level of sales in the low-demand condition; and
although sales are lower in the high-demand condition, the total effect is to increase
consumer surplus under the right conditions. This counterintuitive result underscores the
importance of the decision about ownership over the units in the channel. It
demonstrates that, even with the overall inefficiencies and waste resulting from lead
time, consumers and the retailer may be better off when lead time is present if the
retailer owns the units. This occurs because the manufacturer cannot respond to the
actual revealed demand when the retailer owns the units. Therefore, some channel
coordination problems are mitigated by the uncertainty about demand and the fact that
the retailer controls the units in the channel.

4.3 Pricing Decisions

One feature of our model is the possibility of state-dependent prices. Retail (and
sometimes wholesale) prices may depend on the actual demand state. In a monopoly
setting, intuition suggests that prices should be lower in the low-demand state than in
the high-demand state.\textsuperscript{12} The following result shows that this is not always the case and
that price discounting depends on the nature of the demand uncertainty and the presence
of lead time in the channel:

\textit{Proposition 4: Prices (retail and wholesale) are lower in low-demand states than
in high-demand states if:}
\begin{itemize}
  \item[a.] price sensitivity is stochastic, or
  \item[b.] market size is stochastic and there is production lead time.
\end{itemize}

As price sensitivity increases, the optimal price decreases. Thus, when there is
price-sensitivity uncertainty, we expect to observe reduced prices if demand drops. On

\textsuperscript{12} In a competitive setting, this is not as clear since the temptation to cut prices may be stronger when
demand is high (Rotemberg and Saloner 1986).
the other hand, it is not always optimal to reduce prices in the case of market-size uncertainty. The reason is that, under market-size uncertainty, the number of consumers varies but the consumers’ willingness-to-pay stays the same across demand conditions. Therefore, without production lead time, a firm would always charge the same price and adjust the quantities produced and sold according to the size of the market. However, with production lead time, the firm cannot adjust the production quantity after demand is revealed. This leads to more inventory on hand when demand drops (compared to the case without lead time). As a result, there are only some conditions under which it is optimal to offer price discounts in the low-demand state—given *a priori* market-size uncertainty and lead time in the channel.

Another way to think of Proposition 4 is to reinterpret our model in the spirit of Gerstner and Hess (1991)—as the static analog of a dynamic model of promotions.13 Thus, the change in retail and wholesale prices between demand states can be interpreted as the offering of consumer and trade promotions, respectively, and Proposition 4 states when promotions will be offered as a result of demand uncertainty.

*Proposition 5:* Retail and wholesale price discounts are deeper with production lead time than without production lead time.

Production lead time has two effects on pricing decisions: (1) because the quantity produced is smaller than the desired sale quantity in the high-demand state, the regular price is higher under lead time than under no lead time; and (2) the production cost is sunk when the firm makes the pricing decision. Therefore, the sales quantity in the low-demand case is higher and the corresponding price is lower with lead time than without lead time. Obviously, the difference between the regular price and the promotional price is larger with lead time than without lead time.
4.4 Pass-through Rate

We now turn our attention to understanding how demand uncertainty and the presence of production lead time affect pass-through by the retailer of reduced wholesale prices by the manufacturer.

**Proposition 6:** Pass-through is less than 100% when market size is uncertain. Pass-through is greater than 100% when price sensitivity is uncertain.

This result comes from the opposite effects that market-size and price-sensitivity uncertainties have on the demand functions. Market-size uncertainty leads to the demand function in the low-demand state being steeper (rotated counter clockwise) than in the high-demand state (see Figure 5, top panel). As a result, for the same number of units to be sold, the wholesale price must change more than the retail price and pass-through is less than 100%. In contrast, price-sensitivity uncertainty leads to the demand function in the low-demand state being less steep (rotated clockwise) than in the high-demand state (see Figure 5, bottom panel). As a result, for the same number of units to be sold, the wholesale price must change less than the retail price and pass-through is greater than 100%.

Insert Figure 5

5. Discussion

5.1 Ownership and Decision Authority in a Channel

Lee, Padmanabhan, and Whang (1997) demonstrated in an influential paper that uncertainty is magnified as we move further away from the consumer in a supply chain. Based on this, conventional wisdom is that, to the extent that information asymmetries cannot be addressed by better information systems, decision authority should be

---

13 One such model is of perishable products with iid demand over periods.
relegated to the member of the channel closest to the consumer (i.e., the retailer)\textsuperscript{14} with the notion being that everyone benefits when the member with the best information makes the decision. Since the owner of the units in a channel has the residual decision rights regarding the units, this implies that it is the retailer that should assume ownership.

There is, however, some anecdotal evidence in the popular business press that suggests that following this prescription and pushing the decision authority down in the channel has been less beneficial to manufacturers than expected. Our results suggest that letting the retailer have the decision authority indeed may not be in the best interest of the manufacturer. In addressing the issue of decision authority in the channel, channel members should consider the strategic benefits of making the decision as well as the information asymmetries. In our model (which does not have any information asymmetry), ownership, while potentially costly, also confers added flexibility in decision-making. This flexibility is valuable, and indeed we find that the manufacturer prefers to retain ownership and that, under some conditions, manufacturer ownership is also in the interest of the retailer. However, under other conditions the retailer prefers to assume ownership.

These results suggest that strategic considerations are important in addition to any information asymmetry in deciding who should have the decision authority in a channel. If the information asymmetries in the channel are not too great, strategic considerations may dominate and manufacturers (at least) may be better off if they have the decision authority.

\textsuperscript{14} Note that Lee, Padmanabhan, and Whang (1997) did not make this claim. They focused instead on information sharing as their recommendation.
The ownership issue may also impact the retailer’s inclination to share information with the manufacturer. Following Lee et al. (1997), many studies investigated when information sharing in a channel is beneficial (see, for example, Gavirneni, Kapuscinski, and Tayur 1999; Gaur, Giloi, and Seshadri 2005; and Yang et al. 2003). Obviously, when the retailer prefers that the manufacturer own the units in the channel there are incentives for the retailer to share information with the manufacturer in order to improve its decision-making. But what happens when the retailer does not want the manufacturer to own the units? Might withholding the information actually lead to decisions that are more profitable to the retailer? And can withholding of information be used to more easily convince the manufacturer to agree to retailer ownership?

5.2 Pass-through

Empirical research on pass-through rates reports values ranging from 0% to more than 200% (Chevalier and Curhan 1976; Walters 1989; Armstrong 1991). Retailer opportunism in the form of low pass-through rates is a vexing problem for manufacturers, and understanding its causes and how to increase pass-through rates is an important research question (Kumar, Rajiv, and Jeuland 2001). Previous studies explained the large range of observable pass-through rates and, in particular, the less intuitive values of rates greater than 100% as resulting from different demand-function shapes for different products (Bulow and Pfleiderer 1983; Blattberg and Neslin 1990; Tyagi 1999).15 The approach taken by these studies was to compute the optimal reaction by the retailer to changes in the wholesale price. The assumption was that the motivation for the change in the wholesale price is exogenous to the retailer—consumer

---

15 Neslin, Powell, and Stone (1995) also explained rates greater than 100% using a “loss leader” argument.
demand in particular remains the same and, therefore, the only effect the retailer notices is the change in wholesale price. Thus Tyagi (1999), for example, considered changes in the manufacturer’s input costs and an increase in competitive intensity at the manufacturer level.

Our results provide a different rationale for pass-through rates that are less than or greater than 100%. We have shown that, when the wholesale price changes in response to changes in demand conditions, the nature of the demand uncertainty determines whether the pass-through is more or less than 100%. Specifically, we have shown that, for a linear demand function, the pass-through rate is greater than 100% when there is price-sensitivity uncertainty and less than 100% when there is market-size uncertainty. We have demonstrated different pass-through rates by relying not on different demand-function shapes but on the type of demand uncertainty facing the channel. Therefore, it is feasible to observe different pass-through rates for the same product over time if the nature of the uncertainty regarding demand changes over time. In our model, changes in demand conditions drive pricing decisions and, as a result, the retailer reacts not only to a change in wholesale price but also to the actual change in demand conditions. A second important difference from the previous literature is that in our case price discounts involve changing price between two demand curves (high and low demand). In the previous literature, price changes were along the same demand curve.

6. Conclusions

In this paper we have looked at the question of whether the manufacturer or the retailer should have ownership of the units in a channel when demand is uncertain. In our setting, production (and possibly ordering) must take place before channel members learn of the actual demand conditions while prices can be adjusted to actual demand
conditions. The presence of production lead time raises new issues regarding the relationship between manufacturers and retailers and has a profound effect on our understanding of channel behavior. Ownership over the units in the channel matters under such conditions, and channel members’ pricing decisions differ from those taken when there is no lead time.

When there is uncertainty regarding market size and the possible difference in size is large, the manufacturer and the retailer each prefer to own the units in the channel. When the difference in the possible market size is not as large, all members of the channel prefer to have the manufacturer own the units. And when the difference is small or the uncertainty is only regarding price sensitivity, it does not matter who owns the units. We also find that retail and wholesale price discounts are deeper, regular prices are higher, and promotional prices are lower when there is production lead time than when there is no lead time. Finally, the nature of the uncertainty affects the pass-through rate. The pass-through rate is less than 100% if there is market-size uncertainty and greater than 100% if there is price-sensitivity uncertainty.

These findings have important managerial and theoretical implications. They point to the importance of the decision regarding who will have ownership of the units in the channel. They provide an explanation for why we observe different arrangements regarding ownership of units in channels and under what conditions those arrangements should be used.

In order to make informed decisions regarding ownership, firms need to understand the nature and amount of uncertainty they face in different situations. Music CDs, for example, have a fairly well known price elasticity based on large quantities of historical data available to the industry, but the popularity and therefore available
market size for an individual CD are highly uncertain. Many consumer electronics goods have well-defined price points and the main uncertainty for new models is market potential. On the other hand, in many mature product categories, firms may face greater price-sensitivity uncertainty and little market-size uncertainty. A firm introducing a slightly improved dishwasher model will expect demand for dishwashers to depend on the need for replacement purchases and the number of new households created with the level of demand unaffected by introduction of a new model. The main uncertainty for the firm will be the price premium it can charge for the improved model. Completely new products would generally face substantial uncertainty regarding both market size and price sensitivity.

It is also important to understand what leads to uncertainty about demand. For example, lead time itself is a cause of uncertainty with longer lead times generating greater uncertainty. Thus, one might expect to see a higher incidence of channel conflict in channels with long lead times. Consequently, an additional benefit of shortening lead times could be a reduction in channel conflict.

Managers and researchers must be aware and take into account that pricing decisions in the presence of production lead time differ from the normal prescriptions of models that do not consider production lead time. For example, empirical research in the NEIO tradition may use theoretical solutions to derive knowledge regarding unobserved information such as wholesale prices (see, for example, Sudhir 2001), but those theoretical solutions would vary depending on the existence of production lead time in the channel.

Our model results also provide an explanation for the empirical phenomenon of pass-through rates that range from less than 100% to much greater than 100%. We have
shown that the nature of the demand uncertainty determines the pass-through rate and thus can explain why a brand can have different pass-through rates at different times.

Finally, the results demonstrate how the type of uncertainty that firms face can have a major impact on their decisions.

The basic tension in our model is between the benefits ownership confers through greater flexibility in decision-making and the potential costs of ownership in the form of overstocks and inventory risks. Thus, our model is suited for situations in which direct production costs are substantial and therefore the potential cost of ownership is large. This is true for products like cars, durable consumer goods, clothes, and toys. On the other hand, the model does not capture well situations in which direct production costs are relatively low or even nonexistent, as for completely digitized products. First, in those situations the cost of overstock is very low. Therefore, the issues associated with making the production decision before demand is known are not as important. Second, when production costs are relatively low, other costs, which we assumed to be zero in our model, become more significant in the decision process. For example, retailers incur a selling cost with the sale of each unit. If these selling costs are substantial relative to production costs, Proposition 2 about the indifference to ownership when there is price-sensitivity uncertainty no longer holds. As long as production costs are sufficiently high, however, selling costs do not affect the results and Proposition 2 holds.\footnote{Details of this analysis are available from the authors upon request.}

We assume in the model that there is only one production run that takes place before firms learn about demand. This corresponds well to situations in which replenishment orders cannot be fulfilled during the selling season (see, for example, Fisher et al. 1994; and Moon 2002) but it is clearly a simplification of situations where
firms can place replenishment orders. The ability to have an additional production run in response to actual demand conditions may affect ownership choices as well as other decisions, such as the initial quantity ordered by the retailer. Multiple production runs may lead to situations in which both the manufacturer and the retailer own units at the same time. In this paper, we conceptualized ownership over the units in the channel as a simple either/or construct.

A natural follow-up question is whether the manufacturer or the retailer will actually retain ownership of the units in the channel, especially in cases where their interests differ. Since total channel profits are higher under retailer ownership when both the retailer and the manufacturer want to retain ownership, the efficiency criterion suggests that the retailer will assume ownership. Indeed, if one allows side payments between the retailer and the manufacturer, it is easy to construct an arrangement that makes everyone better off under retailer ownership and thus guarantees retailer ownership. Although the efficiency criterion is theoretically appealing, it may not be so easy to reach such arrangements in practice. For example, it is well known in the literature on the double marginalization channel coordination problem that two-part tariffs can coordinate the channel (Moorthy 1987). Yet such arrangements are not commonly observed in practice (except in franchising; see Desai and Srinivasan 1996). Thus, it is not clear which channel member will actually retain ownership when the retailer and manufacturer incentives differ. It appears that the ownership question presents another coordination issue for channel members.

These issues, as well as other questions relating to the effect of competition and risk-sharing arrangements like return policies on ownership decisions, require additional

17 Our model obviously does not directly address this question since we do not model the decision within the channel regarding ownership, only the incentives of the channel members to retain ownership.
follow-up research. This paper provides the beginnings of an understanding of the implications of ownership for the channel and of the effects of production lead time and demand uncertainty on decision-making by channel members.
7. References


Table 1: Equilibrium Outcomes – Market-Size Uncertainty

<table>
<thead>
<tr>
<th></th>
<th>Retailer Ownership</th>
<th>Manufacturer Ownership</th>
<th>Indifference $^\dagger$</th>
<th>No Lead Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price (high demand)</strong></td>
<td>$\frac{\theta c + 3\theta}{2\beta\theta}$</td>
<td>$\frac{\theta c + 3\theta}{2\beta\theta}$</td>
<td>$-\frac{\beta c + \theta}{\theta}$</td>
<td>$\frac{3 + \beta \theta}{2\beta}$</td>
</tr>
<tr>
<td></td>
<td>$\frac{\theta c + 3\theta}{2\beta\theta}$</td>
<td>$\frac{\theta c + 3\theta}{2\beta\theta}$</td>
<td>$-\frac{\beta c + \theta}{\theta}$</td>
<td>$\frac{3 + \beta \theta}{2\beta}$</td>
</tr>
<tr>
<td><strong>Price (low demand)</strong></td>
<td>$\frac{1}{2\beta}$</td>
<td>$\frac{3}{4\beta}$</td>
<td>$\frac{4\theta a_h + (3 + \beta - 4\theta) a_h}{2\beta[\theta a_h + (1 - \theta) a_h]}$</td>
<td>$\frac{3 + \beta \theta}{2\beta}$</td>
</tr>
<tr>
<td><strong>Wholesale price</strong></td>
<td>$\frac{c\beta + \theta}{2\beta}$</td>
<td>$\frac{\beta c + \theta}{2\beta\theta}$</td>
<td>$-\frac{(1-c\beta) a_h + 2(1-\theta) a_h}{2\beta[\theta a_h + (1 - \theta) a_h]}$</td>
<td>$\frac{1 + \beta \theta}{2\beta}$</td>
</tr>
<tr>
<td><strong>Wholesale price</strong></td>
<td>$\frac{c\beta + \theta}{2\beta}$</td>
<td>$\frac{\beta c + \theta}{2\beta\theta}$</td>
<td>$-\frac{(1-c\beta) a_h + 2(1-\theta) a_h}{2\beta[\theta a_h + (1 - \theta) a_h]}$</td>
<td>$\frac{1 + \beta \theta}{2\beta}$</td>
</tr>
<tr>
<td><strong>Sales (high demand)</strong></td>
<td>$\frac{-\beta c + \theta a_h}{4\theta}$</td>
<td>$\frac{-\beta c + \theta a_h}{4\theta}$</td>
<td>$\frac{(1-c\beta) a_h}{4[\theta a_h + (1 - \theta) a_h]}$</td>
<td>$\frac{1}{4}(1-c\beta) a_h$</td>
</tr>
<tr>
<td><strong>Sales (low demand)</strong></td>
<td>$\frac{a_h}{4}$</td>
<td>$\frac{a_h}{4}$</td>
<td>$\frac{(1-c\beta) a_h}{4[\theta a_h + (1 - \theta) a_h]}$</td>
<td>$\frac{1}{4}(1-c\beta) a_h$</td>
</tr>
<tr>
<td><strong>Production (ordering) quantity</strong></td>
<td>$\frac{-\beta c + \theta a_h}{4\theta}$</td>
<td>$\frac{-\beta c + \theta a_h}{4\theta}$</td>
<td>$\frac{(1-c\beta) a_h}{4[\theta a_h + (1 - \theta) a_h]}$</td>
<td>$\frac{1}{4}(1-c\beta) a_h$</td>
</tr>
<tr>
<td><strong>Retailer profit</strong></td>
<td>$-\frac{4(1-c\beta)^2 a_h}{16\beta}$</td>
<td>$\frac{(1-c\beta)^2 a_h}{16\beta}$</td>
<td>$\frac{(1-c\beta)^2 a_h}{16\beta}$</td>
<td>$\frac{(1-c\beta)^2 a_h}{16\beta}$</td>
</tr>
<tr>
<td><strong>Manufacturer profit</strong></td>
<td>$\frac{(1-c\beta)^2 a_h}{16\beta}$</td>
<td>$\frac{(1-c\beta)^2 a_h}{16\beta}$</td>
<td>$\frac{(1-c\beta)^2 a_h}{16\beta}$</td>
<td>$\frac{(1-c\beta)^2 a_h}{16\beta}$</td>
</tr>
<tr>
<td><strong>Consumer surplus</strong></td>
<td>$\frac{4\theta a_h + (1-c\beta)^2 a_h}{32\beta\theta}$</td>
<td>$\frac{4\theta a_h + (1-c\beta)^2 a_h}{32\beta\theta}$</td>
<td>$\frac{8\beta}{\theta a_h + (1 - \theta) a_h}$</td>
<td>$\frac{(1-c\beta)^2 (1-\theta) a_h}{32\beta}$</td>
</tr>
</tbody>
</table>

$^\dagger$ This is the equilibrium solution for the case when the manufacturer carries the inventory and when the retailer carries the inventory. Thus, when $\frac{-\beta c + \theta a_h}{\theta}$, it does not matter who carries the inventory.
Table 2: Equilibrium Outcomes – Price-Sensitivity Uncertainty

<table>
<thead>
<tr>
<th></th>
<th>Retailer Ownership</th>
<th>Manufacturer Ownership</th>
<th>No Lead Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price (high demand)</strong></td>
<td>[ \frac{1}{4} (3 \cdot \frac{\beta_h}{\beta_h} + \frac{c \beta_h}{\theta \beta_h - (1 + \theta) \beta_h}) ]</td>
<td>[ \frac{1}{4} (3 \cdot \frac{\beta_h}{\beta_h} + \frac{c \beta_h}{\theta \beta_h - (1 + \theta) \beta_h}) ]</td>
<td>[ \frac{3 + c \beta_h}{4 \beta_h} ]</td>
</tr>
<tr>
<td><strong>Price (low demand)</strong></td>
<td>[ \frac{1}{4} \left( \frac{3}{\beta_i} + \frac{c \beta_h}{\theta \beta_i - (1 + \theta) \beta_h} \right) ]</td>
<td>[ \frac{1}{4} \left( \frac{3}{\beta_i} + \frac{c \beta_h}{\theta \beta_i - (1 + \theta) \beta_h} \right) ]</td>
<td>[ \frac{3 + c \beta_i}{4 \beta_i} ]</td>
</tr>
<tr>
<td><strong>Wholesale price</strong></td>
<td><strong>(high demand)</strong></td>
<td>[ \frac{1}{2} \left( \frac{1}{\beta_h} + \frac{c \beta_h}{\theta \beta_h - (1 + \theta) \beta_h} \right) ]</td>
<td>[ \frac{1 + c \beta_h}{2 \beta_h} ]</td>
</tr>
<tr>
<td><strong>Wholesale price</strong></td>
<td><strong>(low demand)</strong></td>
<td>[ \frac{1}{2} \left( \frac{1}{\beta_i} + \frac{c \beta_i}{\theta \beta_i - (1 + \theta) \beta_h} \right) ]</td>
<td>[ \frac{1 + c \beta_i}{2 \beta_i} ]</td>
</tr>
<tr>
<td><strong>Sales (high demand)</strong></td>
<td>[ \frac{1}{4} \alpha \left( 1 - \frac{c \beta_h \beta_h}{\theta \beta_h + \beta_h - \theta \beta_h} \right) ]</td>
<td>[ \frac{1}{4} \alpha \left( 1 - \frac{c \beta_i \beta_h}{\theta \beta_i + \beta_i - \theta \beta_h} \right) ]</td>
<td>[ -\frac{1}{4} \alpha (1 + c \beta_h) ]</td>
</tr>
<tr>
<td><strong>Sales (low demand)</strong></td>
<td>[ \frac{1}{4} \alpha \left( 1 - \frac{c \beta_i \beta_h}{\theta \beta_i + \beta_i - \theta \beta_h} \right) ]</td>
<td>[ \frac{1}{4} \alpha \left( 1 - \frac{c \beta_h \beta_h}{\theta \beta_h + \beta_h - \theta \beta_h} \right) ]</td>
<td>[ -\frac{1}{4} \alpha (1 + c \beta_i) ]</td>
</tr>
<tr>
<td><strong>Production</strong></td>
<td><strong>(ordering) quantity</strong></td>
<td>[ \frac{1}{4} \alpha \left( 1 - \frac{c \beta_i \beta_h}{\theta \beta_i + \beta_i - \theta \beta_h} \right) ]</td>
<td>[ -\frac{1}{4} \alpha (1 + c \beta_h) ]</td>
</tr>
<tr>
<td></td>
<td><strong>(high demand)</strong></td>
<td>[ \frac{1}{4} \alpha \left( 1 - \frac{c \beta_h \beta_h}{\theta \beta_h + \beta_h - \theta \beta_h} \right) ]</td>
<td>[ -\frac{1}{4} \alpha (1 + c \beta_i) ]</td>
</tr>
<tr>
<td><strong>Retailer profit</strong></td>
<td>[ \alpha (1 + \theta + (1 + \theta) c \beta_i) \beta_i^2 ]</td>
<td>[ \alpha (1 + \theta + (1 + \theta) c \beta_h) \beta_h^2 ]</td>
<td>[ 1 \cdot \frac{\alpha}{16} \left( \frac{-(1 + \theta)(-1 + c \beta_h)^2}{\beta_h} + \frac{\theta(-1 + c \beta_h)^2}{\beta_h} \right) ]</td>
</tr>
<tr>
<td><strong>Manufacturer</strong></td>
<td><strong>profit</strong></td>
<td>[ \alpha (1 + \theta + (1 + \theta) c \beta_i) \beta_i^2 ]</td>
<td>[ 1 \cdot \frac{\alpha}{8} \left( \frac{-(1 + \theta)(-1 + c \beta_i)^2}{\beta_i} + \frac{\theta(-1 + c \beta_i)^2}{\beta_i} \right) ]</td>
</tr>
<tr>
<td><strong>Consumer surplus</strong></td>
<td>[ \alpha (1 + \theta + (1 + \theta) c \beta_i) \beta_i^2 ]</td>
<td>[ \alpha (1 + \theta + (1 + \theta) c \beta_h) \beta_h^2 ]</td>
<td>[ 1 \cdot \frac{\alpha}{32} \left( \frac{-(1 + \theta)(-1 + c \beta_i)^2}{\beta_i} + \frac{\theta(-1 + c \beta_i)^2}{\beta_i} \right) ]</td>
</tr>
</tbody>
</table>
Figure 1A: Retailer Ownership

Retailer orders product
Retailer produces units
Retailer takes delivery
Retailer sets retail price
Retailer scraps unsold units

Manufacturer sets wholesale price

Figure 1B: Manufacturer Ownership

Retailer orders products and sets retail price
Retailer takes delivery
Retailer sets wholesale price
Retailer scraps unsold units

Manufacturer produces units

Uncertainty resolved
Figure 2

LEGEND

- Indifferent
- Manufacturer ownership
- Retailer ownership

Channel

Manufacturer

Retailer

\[ \frac{k}{2} \quad k \quad \frac{\alpha_1}{\alpha_h} \]
Figure 3: Ownership as a Function of Manufacturing Cost

The diagram illustrates the relationship between ownership and manufacturing cost. It delineates three areas:

- **Indifferent**: The region between the two lines where the ownership decision is not clear.
- **Manufacturer Ownership**: The area to the left of the diagonal line.
- **Retailer Ownership/Channel Conflict**: The area to the right of the diagonal line.

The axes are labeled as follows:

- Vertical axis: \( \alpha_i / \alpha_h \)
- Horizontal axis: \( \theta / \beta \)
- Bottom of the diagram: \( 0 \)
- Right side of the diagram: \( C \)
Figure 4: Ownership as a Function of $\theta$ ($\beta c = 0.1$)
Figure 5: Pass-through and Demand Uncertainty

\[ \frac{1}{\beta} \]

\[ \Delta P \]

\[ \Delta w \]

\[ q^* \quad \frac{\alpha_i}{2} \quad \frac{\alpha_h}{2} \quad \alpha_i \quad \alpha_h \]

\[ q \]

\[ \frac{1}{\beta_h} \]

\[ \Delta P \]

\[ \Delta w \]

\[ q^* \quad \frac{\alpha}{2} \quad \alpha \]

\[ q \]