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Forward Buying by Retailers

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Abstract

Conventional wisdom in marketing holds that retailer forward buying (1) is a consequence of manufacturer trade promotions and (2) stockpiling units helps the retailer but hurts the manufacturer. This paper provides a deeper understanding of forward buying by analyzing it within the context of manufacturer trade promotions, competition and demand uncertainty. The authors find that regardless of whether the manufacturer offers a trade promotion or not, allowing the retailer to forward buy and hold inventory for the future can, under certain conditions, be beneficial for both parties. Disallowing forward buying by the retailer may lead the manufacturer to lower merchandising requirements and change the depth of the promotion. In competitive environments, there are situations in which retailers engage in forward buying due to competitive pressures in a prisoners' dilemma situation. Finally, when the authors consider the case of uncertain demand, they find further evidence of strategic forward buying. In particular, the authors find cases in which the retailer orders a quantity that is higher than what it expects to sell in even the most optimistic demand scenario.

Keywords: marketing channels, game theory, trade promotions, pricing, inventory

Forward buying occurs when retailers purchase units during a particular period, hold some of them in inventory and then sell them in subsequent periods. Because retailer forward buying tends to be correlated with trade promotions (temporary wholesale price reductions) offered by manufacturers, conventional wisdom in marketing suggests that were it not for these trade promotions, manufacturers would not have to deal with the problem of retailer forward buying (e.g., Kotler and Keller 2006, Coughlan et al 2006). As a result, researchers have focused their efforts on explaining why we observe trade promotions and not on why we observe forward buying. An exception is a paper by Anand, Anupindi and Basook (2003) that looks at the role of forward buying in a monopoly setting where the manufacturer does not offer a trade promotion. In contrast, we address the effects of forward buying on the retailers and manufacturers in a variety of settings, including competitive environments and under conditions of demand uncertainty. We also examine the consequences of preventing retailers from forward buying during trade promotions.

Forward buying is an important phenomenon in both the marketing and the operations literatures. In marketing, the general view is that because trade promotions are temporary price discounts, retailers simply stock up on good deals when they are offered (e.g. Blattberg and Neslin 1990). The interesting question here is why the price reduction has to be temporary and not permanent? Several explanations have been put forth for this, all of them relying on the competition among firms. From a theoretical standpoint, the consensus views are that trade promotions persist because of the intense competition for the switching segment of the consumer market (e.g., Narasimhan 1988, Raju, Srinivasan and Lal 1990, Rao 1990) or because of implicit collusion among manufacturers (e.g., Lal 1990). Note that the aforementioned models do not include a strategic retailer in the analysis, so they can not speak directly to the issue of forward buying. However, they show that the competition leads to trade promotions, which we know tends to be correlated with forward buying. In contrast, Lal, Little and Villas Boas (1996) explicitly model two competing manufacturers who sell through a common retailer that has an option to forward buy. From a manufacturer's perspective, being in the retailer's inventory is important because it makes the manufacturer's product more competitive for switchers in the subsequent period. Indeed, it is the presence of the switching segment that leads to trade promotions and forward buying. In the absence of switchers, there would be a single price and no forward buying. More recently, Cui, Raju and Zhang (2007b) show that manufacturer trade promotions can also be a mechanism to price discriminate among retailers who differ in their holding costs.

Forward buying is also a rich area of study in operations management where researchers have studied firms' inventory decisions in a variety of models. In these papers, inventory emerges as a mechanism to deal with demand or supply uncertainty or as a tradeoff between ordering and holding costs. However, the role of inventory as a strategic choice has not been a prominent issue in this literature. A notable exception is a working paper by Anand, Anupindi and Bassok (2003) that shows how inventory plays an important strategic role such that a retailer would hold inventory even when there is no uncertainty about demand. The focus of their paper is on coordinating the supply chain by using contracts that allow the manufacturer to commit to wholesale prices over time. In contrast, we consider the situation where manufacturers cannot make credible commitments not to lower prices in the future. This is the case in most packaged goods markets – manufacturers can possibly commit not to raise prices but it is much harder to commit not to lower prices. Furthermore, we look at more complex competitive channel structures and focus on the marketing variables of merchandising support and trade promotions and also on the role of demand uncertainty.

We first develop a simple model that specifically excludes the standard operations reasons advanced by researchers for why retailers would forward buy and hold inventory. Thus, we assume a market in which there is no uncertainty about demand or supply, no production lead time, and no ordering or set-up costs. Within this framework, we consider both the case when the manufacturer offers a trade promotion and also when it does not offer a trade promotion.[1] Based on the terms offered by the manufacturer, the retailer chooses the quantity to order, the retail price and the inventory level. We analyze forward buying with three channel structures: (1) A single manufacturer sells to a single retailer; (2) Two competing manufacturers sell through a single, common retailer; and (3) a single manufacturer sells to two competing retailers.

In the single manufacturer – single retailer case, we find conditions under which both the retailer and the manufacturer are better off with forward buying and conditions under which forward buying is profitable for the retailer but not for the manufacturer. In the competitive case, we allow two manufacturers to sell through a common retailer and find that compared to the previous bilateral monopoly case, forward buying becomes even more likely. Importantly, each manufacturer reduces wholesale price in response to the retailer's forward buying not only of its own product but also of the competing manufacturer's product. As a result, forward buying becomes even more attractive for the retailer. When we introduce competition at the retailer level and allow a single manufacturer to sell through two competing retailers, we still find the presence of forward buying. We also find that the competition between retailers can also lead to a prisoner's dilemma situation where both retailers are worse off with forward buying. This occurs partly because competition forces each retailer to pass through a greater part of any reduction in wholesale price. Furthermore, as the retailer competition becomes more intense, we find that the incidence of forward buying goes down.

While the bulk of our paper rules out other reasons for forward buying, we note that two of the most common reasons cited for forward buying are the presence of retailer trade promotions and uncertainty about demand. Therefore, we extend our basic framework to specifically allow for trade promotions and the presence of demand uncertainty. Importantly, we verify that the effects of forward buying identified earlier continue to hold even when the manufacturer offers a trade promotion. Furthermore, we also show that if the terms of the trade promotion prohibit the retailer from forward buying, the manufacturer will be forced to require a lower merchandising effort and may also have to adjust its trade promotion discount. When it comes to demand uncertainty, we note that forward buying continues to play an important strategic role. When demand can either be high or low with specific probabilities, then under certain cases, the retailer orders enough units such that it carries inventory regardless of the demand state that may arise. This is interesting because conventional wisdom argues that retailers will end up carrying inventory only when demand turns out to be low. These two extensions further enhance our understanding of forward buying.

Finally, we note that most of the channels research in marketing looks at a manufacturer-retailer framework in a static setting and one in which the retailer's ordering quantity is also its selling quantity. However, this static setting becomes inappropriate when we realize that retailers can stockpile for the future – a retailer's purchases in one period have an effect on its purchases in subsequent periods. Given the prevalence of this phenomenon, it is important to develop models that account for this behavior.

The remainder of this paper is organized as follows. In the next section, we lay out the basic model and detail our assumptions. In subsequent sections, we analyze forward buying within the three different channel structures. Later, we allow for trade promotions and explore the impact of forward buying on trade promotion.

MODEL

We begin with the simplest possible model that can capture the interactions between manufacturers and retailers and allow the retailer to forward buy. Recall that the typical reasons put forward to explain the presence of forward buying or carrying inventory are: temporary price reductions offered by the manufacturer, demand or supply uncertainty, demand or supply lead times, and retailer ordering costs. Our initial model specifically rules out the aforementioned reasons – thus, there is no temporary price cut, no uncertainty, no lead times and no ordering costs. By ruling out the aforementioned reasons, we can see whether there is an alternate explanation for forward buying and isolate the effect of forward buying on manufacturers and retailers. Subsequently, we incorporate trade promotion and retailer merchandising effort into our analysis.

We assume a two-period model in which the retailer has the option to purchase additional units in period 1 and carry them as inventory into period 2. Because there is no uncertainty about demand, a decision to forward buy is based solely on the wholesale prices offered by the manufacturer. We analyze these wholesale prices both with and without trade promotions. We first analyze cases where the retailer has the option to forward buy when the manufacturer does not offer any trade promotions. Later we consider the case where the retailer has the option to forward buy during a trade promotion. Therefore, the retailer in our model may forward buy even when trade promotions are not offered and may forego forward buying even in the presence of trade promotions.

We begin our analysis with a base model in which one manufacturer sells its products through a single retailer. Subsequently, we examine two duopoly cases, one with two competing manufacturers selling through a single retailer, and the other with a single manufacturer selling through two competing retailers. Finally, we consider a case in which the manufacturer offers a trade promotion to its retailer. The remainder of this section describes the base model with a single manufacturer selling through a single retailer. In the subsequent sections, we describe the embellishment to the basic structure that we consider.

Consumer demand for the product in period t (t=1,2), d_t, is given by

$$d_t = \tau - p_t \tag{1}$$

where τ is the base level of demand for the product and p_t is the retailer's price in period *t*.

In each period, the manufacturer offers the retailer the opportunity to purchase goods at an announced wholesale price, w_t. We relax a major assumption of prior models and distinguish between the retailer's order quantity and selling quantity. Thus, given the wholesale price, the retailer has to make two simultaneous decisions in each period: the quantity of units to order from the manufacturer and the retail price to charge consumers.[2] The forward buying quantity or the inventory in period *t (t=1,2)*, I_t, is the difference between the quantity q_t that the retailer orders from the manufacturer and the quantity d_t that consumers demand at the price chosen by the retailer: $I_t=q_t-d_t \geq 0$. If the retailer carries inventory, it incurs a holding cost of $h>0$ per unit. Units carried in inventory do not deteriorate or perish and can be sold in the subsequent period as new goods. The manufacturer faces a constant marginal cost of production that we set to zero. Both players face the same discount factor, $\rho \in (0,1]$.

In each period there are two stages. In the first stage, the manufacturer makes its wholesale price decision and in the second stage the retailer makes its order quantity, retail price and merchandising decisions. Thus, the four stages of the game are as follows:

- Stage 1: The manufacturer sets the first period wholesale price, w_t.
- Stage 2: The retailer chooses the first period order quantity, q_1, and the first period retail price, p_1.
- Stage 3: The manufacturer sets the second period wholesale price, w_2.
- Stage 4: The retailer chooses the second period order quantity, q_2, and the second period retail price, p_2.

We adopt the notion of subgame perfect Nash equilibrium and solve the game backward, starting from Stage 4. In the subsequent sections, we solve this game in several channel settings that differ on the number of players that are in competition. In the simplest case, we study forward buying in a situation where a single manufacturer sells to a single retailer. Subsequently, we introduce competition, first at the manufacturer level and then at the retailer level.

ONE MANUFACTURER – ONE RETAILER CHANNEL

The simplest possible case to analyze is one where a single manufacturer sells through a single retailer. This case is also analyzed in Anand, Anupindi and Bassok (2003) under the assumption that there is no discounting. In this section, we consider the more general case where the retailer and the manufacturer face a discount factor, $\rho \in (0,1]$.[3] This serves as a useful benchmark for the subsequent sections when we consider competition and the impact of trade promotions and demand uncertainty.

We begin with the analysis of the retailer's second period (stage 4) decisions. In period 2, the retailer has $I_1 \geq 0$ units in its inventory and hence the maximum number of units it can sell is q_2+I_1. At this stage, there is no reason to have any unsold units at the end of the period. Therefore, the actual sales at price $p_2$is going to be the smaller of two quantities: τ-p_2 and q_2+I_1. Thus, the retailer's optimization problem is given by

$$\underset{q_2, p_2}{Max}\ \pi_2^R = p_2(\min\{\tau - p_2,\ q_2 + I_1\}) - w_2 q_2,$$

where π_2^R is retailer R's profits in period 2. At a given price p_2, the retailer's optimal ordering quantity is $q_2^* = \tau - p_2 - I_1$. Substituting q_2^* in π_2^R and solving the optimization problem, we get $p_2^* = \dfrac{\tau + w_2}{2}$, $q_2^* = \dfrac{\tau - w_2}{2} - I_1$. This shows that as the retailer forward buys more units in period one, it orders fewer units in period two.

The manufacturer's profit function at this stage is given by: $\pi_2^M = w_2 q_2^* = w_2(\dfrac{\tau - w_2 - 2I_1}{2})$. Anticipating the retailer's decision, the manufacturer maximizes its second period profit by choosing its optimal second period wholesale price: $w_2^* = \dfrac{\tau}{2} - I_1$. This shows that as the retailer forward buys more units in period 1, it decreases its optimal ordering quantity in the second period, forcing the manufacturer to decrease its second period wholesale price.

We next analyze the first period decisions, starting with the retailer's decisions in Stage 2. The retailer's profit in the first period is $\pi_1^R = p_1(\tau - p_1) - w_1 q_1 - hI_1$. The retailer chooses q_1 and p_1 to maximize the discounted sum of its profits over the two-period horizon,

$$\Pi^R = \pi_1^R + \rho \pi_2^R = p_1(\tau - p_1) - w_1 q_1 - hI_1 + \rho \pi_2^R.$$

The optimal values of q_1 and p_1 are given by

$$p_1^* = \frac{\tau + w_1}{2}, \quad q_1^* = Max \quad \{\frac{\rho(6\tau - 3w_1) - 4(h + w_1)}{6\rho}, \frac{\tau - w_1}{2}\}.$$

Given the retailer's optimal choices, the manufacturer chooses the first period wholesale price to maximize the discounted sum of its profit, $\Pi^M = w_1 q_1^* + \rho\pi_2^{M*}$. This yields:

$$w_1^* = \frac{9\rho\tau - 2h}{8 + 9\rho} \text{ when } 0 \le h < h_{r1} = \frac{\tau\rho(9\rho - 4)}{8 + 12\rho} \text{ and } w_1^* = \frac{\tau}{2} \text{ otherwise.}$$

This leads to the following proposition.[4]

Proposition 1: *The retailer forward buys if and only if $0 \le h < h_{r1}$. However, the manufacturer is better-off with the retailer's forward buying only when*

$$0 < h < h_{m1} = \frac{\tau[2\rho - (1-\rho)\sqrt{\rho(8 + 9\rho)}]}{4(1 + \rho)} < h_{r1}.$$

Proposition 1 highlights an important result: when the holding cost is not too high, the retailer orders more units than it plans to sell in the first period, holds the additional units in inventory and sells them in the second period. This happens in our model in the absence of all the typical reasons for a retailer to carry inventory, namely, demand or supply uncertainty, supply lead times or high ordering costs. Forward buying occurs because a positive inventory in period 2 gives the retailer a strategic advantage that leads the manufacturer to charge a lower wholesale price in period 2. Even though forward buying in period 1 clearly has a benefit in period 2, it also has additional holding costs in period 1 and the possibility that the manufacturer can raise wholesale price in period 1. These additional costs in the first period can offset the second period benefits of forward buying to the retailer. Therefore, forward buying is not always optimal for the retailer but is optimal when the holding costs are sufficiently low, $0 \le h < h_{r1}$.

Conventional wisdom in marketing argues that manufacturers are hurt by forward buying by retailers. We acknowledge that retailer's forward buying can have other negative effects that are not captured in our model, e.g., variable production cycles that increase manufacturing costs. But Proposition 1 shows that forward buying by a retailer can have a positive impact on the manufacturer's profits. Therefore, even when the manufacturer is able to prevent forward buying by the retailer, it may choose not to do so. However, when $0<h_{m1}<h<h_{r1}$, the manufacturer's profit decreases with forward buying whereas the retailer's profit increases with forward buying. These findings are summarized in Figure 1. Note that when there is no discounting, then $h_{r1}=h_{m1}$ and both retailer and manufacturer are always better off with forward buying.

It is interesting to consider how the retailer's optimal ordering quantity (q_1) as a function of wholesale price (w_1) changes with forward buying. In particular, the retailer's optimal q_1 with and without forward buying is given by: $q_1^* = \frac{(6\tau\rho - 4h) - (3\rho + 4)w_1}{6\rho}$ $\quad if \;\; I_1^* > 0$ and

$q_1^* = \frac{\tau - w_1}{2}$ if $I_1^* = 0$. Thus, when the retailer forward buys, any change in the first-period wholesale price has a bigger impact on the retailer's purchase quantity. Because of this, the retailer not only shifts part of its second period purchase to the first period but it also increases the total quantity it purchases across the two periods. In some cases, this increase in total quantities also increases the manufacturer's profits.

Although forward buying in this framework is driven by wholesale prices charged by the manufacturer, the relationship between the two wholesale prices is not completely straightforward. In particular, from Table 1, $w_1^* - w_2^* = \frac{3\tau\rho(3\rho - 2) - 4h(1 + 2\rho)}{\rho(8 + 9\rho)}$. Therefore,

$w_1^* \geq w_2^* \Leftrightarrow h \leq h_w = \frac{3t\rho(3\rho-2)}{4+8\rho}$. Because $h_w \leq 0$ for any value of $\rho \leq 2/3$, $w_1^* < w_2^*$ for any positive value of holding costs so long as $\rho \leq 2/3$. When $\rho > 2/3$, w_1^* can exceed w_2^* only when the holding costs are sufficiently low. If we assume there is no discounting (as in Anand, Anupindi and Bassok, 2003), then $w_1^* \geq w_2^*$. Our results show that although the presence of a positive discount rate is not necessary for the retailer to forward buy, the discount rate determines the wholesale price path, which depending on the rate can either be decreasing or increasing over time.

COMPETITION AND FORWARD BUYING

In this section, we study two cases that explore the effect of competition on forward buying. In the first, we consider a single manufacturer selling to two competing retailers, and in the second, we consider two competing manufacturers selling through a single retailer.

Two Retailers – One Manufacturer

We modify our base model to allow for two retailers, A and B, which sell a product from a single manufacturer. Retailers A and B are symmetric, differentiated from each other and their demand functions are given by:

$$\left.\begin{aligned} d_{At} &= \frac{1}{2}(\tau - p_{At} + \theta(p_{Bt} - p_{At})) \\ d_{Bt} &= \frac{1}{2}(\tau - p_{Bt} + \theta(p_{At} - p_{Bt})) \end{aligned}\right\} \tag{2}$$

where the parameter θ represents the intensity of competition between the two retailers. These demand functions are based on the quadratic utility function developed by Shubik and Levitan (1980) and are analogous to the demand function used in the previous section (see Equation (1)). It is important to note that the parameter θ applies only when both demands are positive. An appealing property of this formulation is that the intercept for the total demand does not change as a consequence of bringing an additional manufacturer into the market. This ensures that if we observe forward buying in this framework, it is not because of an expansion of demand that may arise from a second retailer entering the market. Because both retailers are symmetrical, the manufacturer cannot discriminate between them and charges them the same wholesale price.

The sequence of events is the same as before except that the two retailers make their price and ordering quantity decisions simultaneously. Therefore, we report only the important parts of the analysis and delegate the details to the appendix. The second period optimal price and ordering quantity for Retailer A are as follows (Retailer B's decisions are symmetrically defined).

$$p_{A2}^{*} = \frac{\tau + w_2(1+\theta)}{2+\theta}, \; q_{A2}^{*} = \frac{(\tau - w_2)(1+\theta) - 2(2+\theta)I_{A1}}{2(2+\theta)} \tag{3}$$

As in the previous case, if a retailer carries inventory from the previous period, it buys less in the second period. An important effect of competition is that as the competitive intensity increases, each retailer's price responds more to the wholesale price charged by the manufacturer. More formally, $\frac{\partial p_{A2}^{*}}{\partial w_2} = \frac{1+\theta}{2+\theta} > 0$ and $\frac{\partial^2 p_{A2}^{*}}{\partial w_2 \partial \theta} = \frac{1}{(2+\theta)^2} > 0$. We know from the previous discussion that the main benefit of forward buying for the retailer is that it enjoys a reduction in the second period wholesale price. But $\frac{\partial^2 p_{A2}^{*}}{\partial w_2 \partial \theta} > 0$ indicates that with competition, a greater part of any reduction in the second period wholesale price will get passed on to the customers and therefore, the retailer may have less to gain from such reductions in wholesale price.[5]

In order to better understand why retailers may have less to gain from wholesale price reductions, consider how the retailer's second period profit is affected by changes in the second period wholesale price. In particular, $\frac{\partial \pi^*_{A2}}{\partial w_2} = -\frac{(\tau - w_2)(1+\theta) + 2I_{A2}(2+\theta)^2)}{(2+\theta)^2} < 0$ and $\frac{\partial^2 \pi^*_{A2}}{\partial w_2 \partial \theta} = \frac{(\tau - w_2)\theta}{(2+\theta)^3} > 0$. In other words, the retailer's second period profits increase with a decline in the second period wholesale price, but this change becomes smaller as the competition between the retailers increases.

The manufacturer's optimal wholesale price in the second period is given by

$$w_2^* = \frac{\tau(1+\theta) - (I_{A2} + I_{B2})(2+\theta)}{2(1+\theta)} . \tag{4}$$

Equation (4) shows two new strategic effects that are due to the retail competition. First, when either retailer carries inventory from the previous period, the second period wholesale price decreases. Therefore, even if a single retailer carried inventory from the first period, the manufacturer reduces the second period wholesale price for both retailers. This results in a free-riding problem between the two retailers: each retailer wants the benefits of a lower w_2, but may have an incentive to let the other retailer carry the inventory and incur the holding costs. Second, compared to the monopoly case, for a given level of inventory carried by a retailer, the manufacturer's wholesale price is less sensitive to changes in retailer inventory. This arises because the competition between the retailers dilutes each one's market power.

Given the optimal prices and quantities in period 2, each retailer maximizes its overall profits by making its first-period price and ordering quantity decisions. Below, we provide the optimal choices for retailer A and note that Retailer B's choices are symmetric:

$$p_{A1}^{*}=\frac{\tau(10+6\theta+\rho\theta^{2})+2(1+\theta)[w_{1}(5+2\theta)-\theta h]}{20+22\theta+6\theta^{2}}, \qquad (5)$$

$$q_{A1}^{*}=\frac{2(1+\theta)\rho[5\tau(2+\theta)+\theta h-w_{1}(5+2\theta)]-\tau\theta^{2}\rho^{2}-8(h+w_{1})(1+\theta)(2+\theta)}{4\rho(2+\theta)(5+3\theta)}. \qquad (6)$$

Similar to period 2, as the competition between the retailers becomes more intense, the retail price is more sensitive to changes in the wholesale price.

Table 2 shows the equilibrium choices of all the players and demonstrates that even in the case of retail competition, the retailers may engage in forward buying. The next proposition describes how the extent of forward buying is influenced by the intensity of competition.

Proposition 2: *As the competition between the retailers increases, each retailer decreases its equilibrium forward buying quantity.*

This result arises because of the effects described earlier: compared to the monopoly case, an increase in inventory leads to a smaller reduction in wholesale prices. Furthermore, a wholesale price reduction is less valuable for the retailer because a larger fraction of it needs to be passed on to final consumers. Finally, each retailer has incentives to free ride on the forward buying done by the other retailer.

An implication of the above result is that there are conditions under which a retailer would forward buy in a less competitive situation but would not do so in a more competitive situation. This suggests that price competition among retailers can be exacerbated by forward buying: If retailers carry inventory in a highly competitive market, they also have an incentive to lower retail prices in both periods and, as a consequence, earn lower profits. This raises the possibility that retailers may engage in forward buying because they might find themselves in a prisoners' dilemma situation. This leads to the following:

Proposition 3: *When* $0 < h < h_{r3}$*, both retailers find it optimal to forward buy. However, when* $h_{r4} < h < h_{r3}$*, both retailers are worse–off with forward buying compared to the outcome when neither one forward buys.*

Proposition 3 confirms our conjecture of a prisoner's dilemma and we find that even though the two retailers may be worse-off with forward buying, they still forward buy for competitive reasons. Finally, we conclude this section by noting that as in the previous case, for some values of the parameters, the manufacturer can also be better-off with the retailers' forward buying.

Two Manufacturers-one Retailer Channel

Now we consider our second case of competition, specifically the effect of manufacturer competition on the incidence and profitability of forward buying by a retailer. We consider two manufacturers selling to a single retailer and modify our demand function as follows.

$$\left.\begin{aligned} d_{it} &= \frac{1}{2}(\tau - p_{it} + \phi(p_{jt} - p_{it})) \\ d_{jt} &= \frac{1}{2}(\tau - p_{jt} + \phi(p_{it} - p_{jt})) \end{aligned}\right\} \tag{7}$$

where *i* and *j* denote the two manufacturers, ϕ is a parameter representing the intensity of competition between the two manufacturers (or the substitutability between the products), and *t* ($t=1,2$) denotes time period. These demand functions are analogous to the demand function used in the previous section, i.e., the intercept for the total demand for the goods is fixed. That is, compared to the previous section where the retailer sells a single product, by adding another manufacturer's product to its line, the retailer does not expand the size of the market.

Furthermore, it is important to note that if retailer sells zero units of a product, then the demand system reverts to the single product case (Equation 1) and the idea of substitutability (ϕ) between the two products is moot.[6] Finally, we note that it is always optimal for the retailer to sell both manufacturers products.

The manufacturers are symmetrical in all respects and move simultaneously to choose their wholesale prices. The other aspects of the model are the same as before. Because we solve the model in a manner that is similar to the procedure used in the previous section, we do not present all the details. In the second period, the retailer maximizes profits by choosing the optimal quantity to order and retail price to charge. This yields:

$$p_{i2}^* = \frac{\tau + w_{i2}}{2}, q_{i2}^* = \frac{\tau - (1+\phi)w_{2i} + \phi w_{2j} - 4I_{2i}}{4}.$$

$$p_{i2}^* = \frac{\tau + w_{i2}}{2}, q_{i2}^* = \frac{\tau - (1+\phi)w_{2i} + \phi w_{2j} - 4I_{2i}}{4}. \quad (8)$$

The retailer's decisions for Manufacturer j are symmetrically defined. The two manufacturers maximize their period 2 profits by simultaneously choosing their optimal wholesale prices. This yields:

$$w_{i2}^* = \frac{\tau(2+3\phi) - 8I_{i1}(1+\phi) - 4I_{j1}\phi}{4+8\phi+3\phi^2}, w_{j2}^* = \frac{\tau(2+3\phi) - 8I_{j1}(1+\phi) - 4I_{i1}\phi}{4+8\phi+3\phi^2} \quad (9)$$

The above equations show the following two effects of the retailer's forward buying on the manufacturers.

(1) Direct effect: When the retailer has inventory of a manufacturer *i*'s product, the retailer buys less from manufacturer *i* , which reduces the manufacturer to lower its optimal wholesale price.

(2) Strategic effect: When the retailer has manufacturer *j*'s product in its inventory, it leads manufacturer *i* to lower its wholesale price.

Note that the direct effect is similar to the effect in the bilateral monopoly case. The strategic effect arises because of the competition between the two manufacturers and results in each manufacturer's wholesale price declining with the competing manufacturer's price.

The retailer's optimal first period decision for Manufacturer i's products are given below (its decisions for Manufacturer j's products are symmetrically given).

$$p_{i1}^* = \frac{\tau + w_{i1}}{2},\ q_{i1}^* = \frac{\tau}{2} + \frac{\chi_j w_{j1} - \chi_i w_{i1} - h(2+\phi)^2(3+4\phi)}{4(3+2\phi)(3+4\phi)\rho} \tag{10}$$

where $\chi_i = (1+\phi)[12 + 9\rho + \phi(24 + 11\phi + 18\rho + 8\phi\rho)]$ and

$\chi_j = \phi[8 + 9\rho + \phi(16 + 7\phi + 18\rho + 8\phi\rho)]$.

As in the monopoly manufacturer case, a manufacturer's choice of first-period wholesale price affects not only the retailer's first-period decisions but also its second-period decisions. Furthermore, with forward buying, the retailer orders a higher total quantity than it would order if there were no forward buying. In addition, because of the substitutability between the two products, any increase in one manufacturer’s wholesale price leads the retailer to shift demand toward the competing manufacturer. As a result, even when the retailer engages in forward buying, the competition between the two manufacturers limits each manufacturer's ability to increase its first period wholesale price.

The full solution to this game is provided in Table 3. Note that the manufacturers’ optimal wholesale prices in the first period are given by

$$w_{i1}^* = w_{j1}^* = \frac{2\tau(3+2\phi)^2(3+4\phi)\rho - h(2+\phi)(6+9\phi-2\phi^3)}{48 + 156\phi + 186\phi^2 + 99\phi^3 + 20\phi^4 + (2+\phi)(3+2\phi)^2(3+4\phi)\rho}. \tag{11}$$

This leads to the following Proposition:

Proposition 4: *The retailer will find it optimal to forward buy from two competing manufacturers when* $0 \le h < \dfrac{\tau\rho[(2+\phi)(3+2\phi)^2(3+4\phi)\rho - 24 - 60\phi - 40\phi^2 - \phi^3 + 4\phi^4]}{(2+\phi)^2[(2+\phi)(3+2\phi)(3+4\phi)\rho + 12 + 36\phi + 35\phi^2 + 11\phi^3]}$.

As in the manufacturer-monopoly case, the retailer finds it optimal to buy more than what it needs in period 1, so that it can get lower wholesale prices in period 2. The main difference here is that forward buying of either manufacturer's product lowers the wholesale price of both manufacturers' products in the second period. Therefore, when there is competition between the manufacturers, forward buying in the first period provides greater second-period benefits to the retailer. Essentially, forward buying of either product allows the retailer to play the manufacturers off each other.

The above discussion also indicates that the manufacturers may have less to gain from the retailer's forward buying when there is competition between the manufacturers. We can also derive the conditions for the manufacturers to be better-off with the retailer's forward buying. However, intractable algebra prevents us from fully characterizing the interaction between the degree of manufacturer competition and forward buying. In general, it is still possible for the competing manufacturers to be better-off with the retailer's forward buying. However, as the competition between manufacturers becomes more intense, i.e., ϕ increases, the parameter space for which this is true shrinks.

MODEL EXTENSIONS

In the previous two sections, we showed how forward buying by the retailer affects manufacturer and retailer prices and profitability. Importantly, forward buying occurred in the absence of any trade promotions offered by the manufacturer and in the absence of any uncertainty about demand. The question that this raises is the following: How do trade promotions and demand uncertainty affect retailer forward buying? In this section, we focus on each of these issues.

Incorporating Merchandising Effort and Trade Promotion

The essential idea behind trade promotions is that the manufacturer can lower price temporarily and induce the retailer to purchase additional units, some of which can be carried in inventory and sold in future periods. In our basic bilateral monopoly model, because we consider prices across two periods, the cases in which the first period wholesale price is lower than the second period wholesale price can be thought of as a trade promotion. Strictly speaking, a lower wholesale price in period 1 does not qualify as a typical trade promotion because there is no viable alternative of a "regular" wholesale price. In other words, the retailer does not have the option of rejecting the manufacturer's offer in favor of a regular offer. Therefore, in this section, we formally model a trade promotion by giving the retailer a choice between a trade promotion that consists of a special wholesale price tied specifically to a level of merchandising effort and a regular wholesale price with no merchandising requirement. This embellishment allows us to examine forward buying when the manufacturer offers a trade promotion. Importantly, it also allows us to examine the implications of a manufacturer's policy of disallowing forward buying, e.g., through the use of scan backs.

We modify the bilateral monopoly model developed earlier to include merchandising effort put in by the retailer and trade promotion offered by the manufacturer. In particular, the demand function is given by:

$$d_t = \tau - p_t + \kappa e_t \qquad (12)$$

Where e_t is the retailer's merchandising effort and κ is the effectiveness of the merchandising effort in increasing sales. Note that the level of merchandising support offered by the retailer increases the demand for the product. For example, demand increases if a retailer offers more service or provides valuable end-of-aisle displays. Finally, merchandising has an in-store effect only in that period, i.e., merchandising effort in one period does not affect demand in the subsequent period.

With a trade promotion, the manufacturer specifies the retailer's effort level but the retailer bears the cost of merchandising effort which is given by $c=e^2/2$. Thus, the trade promotion offered by the manufacturer is a reduced first-period wholesale price that is tied to a specific level of merchandising effort. The retailer has the option of not accepting the trade promotion offer, in which case it chooses its own optimal level of merchandising effort and pays the regular wholesale price. More formally, when the manufacturer offers the retailer a trade promotion, it offers the following choice of first period wholesale prices:

$$w_1 = \begin{cases} w_1^p \text{ if } e_m \geq e_m^p \\ w_1^r \geq w_1^p \text{ otherwise,} \end{cases} \tag{13}$$

where w_1^p is the first period trade promotion price, w_1^r is the regular (without trade promotion) wholesale price in the first period, and e_m^p is the promotional merchandising effort. It is straightforward to see that the retailer would choose the promotional price, w_1^p, only if it is lower than the regular price, w_1^r which also comes without any requirement on merchandising effort. This formulation is consistent with industry practice in which manufacturers offer promotional prices that are contingent upon specific performance levels. That is, if retailers want to benefit from the trade promotion, they also have to invest in additional marketing activities. Such a performance-contingent contract has also been used by Lal, Little and Villas-Boas (1996) who make an important point that a realistic model should allow the retailer the option of rejecting a trade deal and purchasing at the regular price.[7] Finally, in keeping with the spirit of trade promotions as temporary price discounts, we assume that the retailer does not offer a trade promotion in period 2. Therefore, in period 2, the manufacturer's wholesale price should be higher than the promotional price in period 1. In our model, this condition is always satisfied when $h \le \frac{3\tau\rho(3\rho-2)}{4(1+2\rho)}$.

Clearly, the manufacturer may not always find it optimal to offer a trade promotion, in which case, the effect of forward buying is very similar to our earlier discussion in the bilateral monopoly case.[8] Therefore, in this section, we focus only on those cases when it is profitable for the manufacturer to offer a trade promotion and when it is profitable for the retailer to accept the equilibrium trade promotion offer. As in the previous section, we let the retailer have the option of forward buying in period 1.

In period 2, the retailer's maximization problem is:

$$\underset{q_2, p_2, e_2}{Max}\ \pi_2^R = p_2(\min\{\tau - p_2 + \kappa e_2,\ q_2 + I_1\}) - w_2 q_2 - \frac{e_2^2}{2}.$$

The retailer's second period choices are given by

$$e_2^* = \frac{\kappa(\tau - w_2)}{2-\kappa^2},\ q_2^* = \frac{\tau - w_2}{2-\kappa^2} - (q_1 - d_1) \text{ and } p_2^* = \frac{\tau + (1-\kappa^2)w_2}{2-\kappa^2}.$$

As one would expect, the optimal effort level is influenced by the wholesale price chosen by the manufacturer: a higher wholesale price leads to a lower effort level. In addition, any increase in inventory carried from period 1 decreases the quantity ordered in period 2.

The manufacturer's second period problem is to choose w_2 to maximize $\pi_2^M = w_2 q_2$, which gives

$$w_2^* = \frac{\tau - (2-\kappa^2)(q_1 - d_1)}{2}.$$

In period 1, if the manufacturer offers a trade promotion, the retailer has the option of choosing either the promotional wholesale price with the manufacturer-specified merchandising effort or the higher (regular) wholesale price with no requirement on merchandising effort. Therefore, the trade promotion offer has to ensure that it provides the retailer at least as much profit as the regular wholesale price:

$$\Pi^{Rp}(w_1^p, e_1^p) \geq \Pi^{Rr}(w_1^r). \quad (14)$$

Equation (14) is the retailer's voluntary participation constraint for the promotion.9

If the retailer chooses the trade promotion offer, its profit in the first period is given by

$$\pi_1^{Rp} = p_1(\tau - p_1 + \kappa e_1^p) - w_1 q_1 - hI_1 - \frac{(e_1^p)^2}{2}.$$

The retailer's problem is to choose an optimal q_1 and p_1 and to maximize the discounted sum of its two-period profits. Similarly, the manufacturer's problem is to choose w_1^p and e_1^p to maximize the discounted sum of its two period profits. This leads to the following:

Proposition 5: *Both with and without a trade promotion, the retailer's optimal level of forward buying is given by*

$$Max\left[0, q_1^* - d_1^* = \frac{3\rho\tau - 4(w_1 + h)}{3\rho(2-\kappa^2)}\right]. \quad (15)$$

Thus, forward buying can take place both with and without the presence of trade promotions from the manufacturer. Furthermore, equation (15) shows that the level of forward buying decreases with an increase in the wholesale price offered by the manufacturer and that it is independent of the specific effort level chosen by either the manufacturer or the retailer. Also, note that as the effectiveness of merchandising increases, the retailer carries fewer units in inventory. Because a trade promotion always has a lower wholesale price, it is straightforward to see that the retailer will do more forward buying if it participates in the trade promotion. Thus, the retailer forward buys for two reasons: (1) to benefit from a temporary wholesale price reduction in period 1, and (2) to create an inventory that can induce the manufacturer to charge a lower wholesale price in period 2.[10] Thus, even when we allow for trade promotions, we continue to find that retailer forward buying can be used to get a lower wholesale price in the future.

Proposition 5 also suggests that a trade promotion has a tendency to increase retailer forward buying. This means that there are parameters for which the retailer will forward buy only when a trade promotion is offered. This suggests that there can be instances where it is not optimal for the retailer to forward buy for strategic reasons. However, if the terms of the trade promotion are attractive enough, then the retailer would forward buy. This result is consistent with the conventional wisdom that forward buying occurs because of trade promotions being offered by the manufacturer. Because we have analyzed forward buying without trade promotion in previous cases, in this section we restrict our attention to those parameters for which the retailer forward buys only with a trade promotion.

Recall that manufacturers have often complained about the negative consequences of retailer forward buying associated with trade promotions and some have suggested that they would like to eliminate the practice entirely. Clearly, eliminating forward buying smoothes out the production process and reduces costs for the manufacturer – both these effects are beyond the scope of this paper. However, there are other consequences of eliminating forward buying and these are captured by the following proposition:

Proposition 6: *If the manufacturer disallows forward buying by the retailer, it will have to specify a lower merchandising effort for the trade promotion. In addition, the retailer will choose a lower level of merchandising effort in the post-promotion period 2.*

Proposition 6 is applicable to those situations where the retailer would find it optimal to forward buy with a trade promotion. In these cases, if the manufacturer does not allow the retailer to forward buy during a trade promotion, the trade promotion clearly is less profitable for the retailer. In order to make the trade promotion more attractive to the retailer, the manufacturer will have to rethink the terms of the trade promotion such that the retailer's voluntary participation constraint is satisfied. The manufacturer can do this by either requiring a lower level of costly merchandising effort from the retailer or by changing the wholesale price. What makes this result particularly intriguing is that while the required merchandising effect will be lower, the depth of the promotional discount can either decrease or increase. To understand this result, note that by disallowing forward buying, the retailers' first-period order quantity, q_1, becomes less sensitive to the first-period wholesale price, w_1^p, and more sensitive to the effort parameter, κ. When κ is low, the manufacturer meets the voluntary participation constraint by reducing e_1^p and decreasing the promotion depth (i.e., increasing w_1^p). On the other hand, when κ is high, the merchandising effort has a relatively high impact on sales and therefore a reduction in the merchandising effort is more costly to the manufacturer. Therefore, the manufacturer does not try to meet the voluntary participation constraint solely by reducing e_1^p but rather through a combination of lower e_1^p and an increase in promotional depth (i.e., lower w_1^p).

It is important to note that disallowing forward buying in one period can carry through and have an impact in period 2. In particular, the retailer chooses a lower post-promotion merchandising effort in period 2. The reason is that the second-period wholesale price is higher without forward buying, and this decreases the marginal benefits of merchandising effort for the retailer.

Incorporating Demand Uncertainty

Uncertainty about future demand is often cited as one of the main reasons why a retailer would hold inventory. In particular, if demand turns out to be high, a retailer does not penalize itself by not having enough stock on hand. In the previous sections, we showed that even when a firm is certain about the level of demand, for strategic reasons, it may still choose to forward buy. The issue then is to see what happens to forward buying when the players are uncertain about demand. In particular, regardless of the demand state, are there conditions under which a firm would hold inventory?

We follow Desai, Koenigsberg and Purohit (2007) and model uncertainty by assuming that the base level of demand, τ, can be either high, $\tau = \tau_H$, with probability γ, or low, $\tau = \tau_L$, with probability $(1- \gamma)$. The demand state is assumed to be the same in periods 1 and 2. Once firms learn the demand in period 1, there is no remaining uncertainty about the level of demand in period 2. There are five stages of the game:

Period 1

Stage 1: The manufacturer sets the first period wholesale price, w_1.

Stage 2: The retailer chooses the first period order quantity, q_1. After placing its order, the players learn the true state of demand, either τ_H or τ_L.

Stage 3: The retailer sets the first period retail price, p_1 and carries unsold units in inventory.

Period 2

Stage 4: The manufacturer sets the second period wholesale price, w_2.

Stage 5: The retailer chooses the second period order quantity, q_2, and the second period retail price, p_2.

We note that as period 1 begins, the firms observe the true level of demand state after the retailer has ordered and the manufacturer has produced the quantity for period 1. At this stage there are three possible cases:

A. $q_1 < d_{1L} < d_{1H}$: The retailer does not have enough units for either the high or the low demand states and it does not carry any units from period 1 into period 2.

B. $d_{1L} \leq q_1 < d_{1H}$: The retailer does not have enough units for the high demand state but has enough units for the low state. Only when demand is low can the retailer carry inventory into period 2.

C. $d_{1L} < d_{1H} \leq q_1$: In this case, the retailer will either have just enough units to satisfy the high demand or will carry inventory into period 2 (under both demand states).

This leads to the following proposition:

Proposition 7: *When $0<h<h_{u2}$, the retailer orders a high enough quantity such that it is optimal to carry inventory regardless of whether demand turns out to be high or low, where* $h_{u2} = \rho \frac{\tau_H[4\gamma(4+9\rho)-(4-3\rho)(8+9\rho)]-4\tau_L(1-\gamma)(4+9\rho)}{4[8+9\rho(2+\rho)]}$. *When $h_{u2}<h<h_{u1}$, the retailer orders a quantity such that it is optimal to carry inventory only if demand turns out to be low, where* $h_{u1} = \frac{2\gamma\tau_H(4+3\rho)-\tau_L[4\gamma(4-\rho)+\rho(4-9\rho)]}{4(2+2\gamma+3\rho)}$. *When $h_{u1}<h$, the retailer orders a quantity such that it never carries inventory. In contrast to the above results, an integrated firm would carry inventory only in the low demand and never in the high demand state.*

The issue here is whether the retailer carries inventory or not. Clearly, carrying inventory in the high demand state is evidence of strategic behavior. Most models ignore this strategic effect because they assume that the retailer would never carry inventory in the high demand state. On the other hand, we find that under certain conditions, the retailer will carry inventory not only in the low but also in the high demand state.

Finally, one way of looking at our results is to compare the decisions made by an integrated firm facing uncertain demand with the decisions of the retailer. In this case, facing uncertain demand, the integrated firm looks at inventory solely as a safety stock. In contrast, because of the manufacturer's problem with time consistency, a retailer views inventory as a safety stock as well as a strategic variable. Looked at in this manner, we find that unlike the retailer, an integrated firm would never carry inventory in the high demand state.

DISCUSSION AND CONCLUSION

We began this paper by noting that the conventional wisdom in marketing is that trade promotions are the leading culprits behind retailer forward buying (e.g., Kotler and Keller 2006). Moreover, if there is no overall increase in consumer demand associated with the trade promotion, then all the manufacturers have achieved is to sell a larger quantity at a lower price – a practice that helps the retailer at the expense of the manufacturer. Furthermore, manufacturers have to deal with the costs of large swings in production volume that leads to a further decrease in profits (Ailawadi, Farris and Shames 1999). In contrast, Anand, Anupindi and Bassok (2003) show that manufacturers are always better-off by allowing retailers to do forward buying when the manufacturers cannot commit to future prices. In this paper, we examine additional complexities that arise from forward buying in a variety of settings including product market competition, demand uncertainty and trade promotions.

We find that regardless of whether trade promotions are offered by a manufacturer, forward buying can still be an optimal strategy for a retailer. Thus, a trade promotion increases the level of forward buying, but eliminating trade promotions does not mean that forward buying will go away. Importantly, however, forward buying need not always be profitable for retailers. In particular, when two competing retailers purchase from a single manufacturer, competition forces each retailer to pass through more of the wholesale price reductions. In some cases, retailers forward buy because they may be in a prisoners' dilemma situation. This result provides an interesting contrast to the belief that although manufacturers are hurt by retailer's forward buying, they allow this practice because of competitive pressures from other manufacturers. Our analysis suggests that the level of retailer competition can also drive forward buying.

The main effect of forward buying is that it results in an overall increase in the purchase order from the retailer. In contrast to the commonly-held belief that the manufacturer is hurt by forward buying, we show that the manufacturer is better off when the increase in its total sales offsets the reduction in wholesale prices. Furthermore, when two competing manufacturers are selling to a common retailer, forward buying becomes even more likely compared to the manufacturer monopoly case. However, competition between manufacturers limits each one's ability to capitalize on the forward buying.

While conventional wisdom argues that eliminating forward buying would be good for manufacturers, we show that this logic holds only when the holding costs are high enough. For lower levels of holding cost, forward buying by the retailer can benefit the manufacturer and the overall channel. In other words, forward buying potentially can move the channel closer to a coordinated level. The essential problem in channel coordination is that retailers and manufacturers have conflicting incentives that increase channel inefficiencies and lower the overall profits of the channel.[11] Our analysis suggests that by lessening the problem associated with double marginalization, forward buying can play a heretofore undiscovered role in moving the channel closer to a coordinated level.[12] The essential problem with double marginalization is that, compared to an integrated channel, the total quantity sold is too low. On the other hand, forward buying leads to a decrease in the average wholesale price charged by the manufacturer and an increase in the total quantity sold, thus bringing the solution closer to that of an integrated channel. Furthermore, our analysis suggests that, under certain conditions, total channel profits can increase with holding costs. This surprising result occurs only when the holding cost inefficiency is offset by a decrease in the double marginalization inefficiency.

Disallowing forward buying during a trade promotion can also have other consequences. In particular, we find that if a retailer is disallowed from forward buying, the manufacturer will have to reduce the merchandising requirement associated with the trade promotion. Furthermore, in the subsequent period when there is no promotion, the retailer will also reduce its own merchandising effort. These decreases in overall effort result in an overall decrease in demand for the product. The effect of disallowing forward buying on the trade promotion wholesale price depends on the effectiveness of the merchandising effort. In particular, when merchandising has a large effect on demand, then the manufacturer has to increase the depth of the trade promotion; on the other hand, when merchandising has a small effect on demand, then the manufacturer will decrease the depth of the promotion. All of these changes can have important effects of the manufacturer's profitability.

It is interesting to consider how forward buying plays a role within the context of demand uncertainty. The typical way to model uncertainty is that if a retailer is uncertain about whether demand will be "high" or "low," they it keeps inventory on hand. It is important to note that inventory plays the role of safety stock – that is, it provides protection for the case when demand turns out to be high and does not particularly help if demand turns out to be low. Thus, we typically assume that the firm will not order more than what it expects to sell in the high demand state. In this paper, we relax that assumption and find that in some cases, the retailer ends up holding inventory regardless of whether demand turns out to be high or low. This is interesting and further highlights the role of strategic forward buying by the retailer.

Our research adds to the extensive literature on distribution channels by discovering a new insight from a familiar framework. In particular, Spengler's bilateral monopoly model has been used extensively in marketing, beginning with McGuire and Staelin (1983). With a few exceptions, most applications of this manufacturer-retailer framework have been in static settings and assumed that the retailer's ordering quantity is also its selling quantity. The fundamental problem we are posing occurs over time – forward buying by the retailer in one period has an effect in the subsequent period and we need to separate the ordering and selling decision. When we take a simple channel model and introduce a linkage over time, it gives us a new perspective on the basic model. Allowing forward buying in one-level marketing channel significantly changes the nature of the solution because it alters the strategic interaction between the manufacturer(s) and the retailer(s). In particular, in the standard static framework, the manufacturer plays the role of Stackelberg leader and is able to take advantage of its position by moving first. In our dynamic setting, the manufacturer still plays the role of leader in period 1, but the presence of retailer inventory in period 2 takes away part of the manufacturer's advantage. Another way of thinking about this is that by having inventory in period 2, the retailer needs the manufacturer only for the residual demand that its inventoried units can not satisfy; in this way, the retailer can be thought of as playing the role of leader in period 2 and earning higher profits than before. As we show, depending upon the parameters, the manufacturer's profitability is both helped and hurt by this behavior.

In order to maintain tractability, we had to make some simplifying assumptions. In particular, the choice of linear demand function was made for this reason. However, Lee and Staelin (1997) have shown that in many channel models, the nature of strategic interaction (strategic substitutability versus strategic complementarity), rather than the specific demand function determines the equilibrium outcomes. In spite of using a relatively simple demand function, we were not able to analyze a model in which both retailers and manufacturers faced competition. However, our analysis does provide insights about the individual effect of competition at each level. In other words, although we are unable to say much about the interaction between two types of competition, we are able to describe their main effects. Finally, we acknowledge that having only two periods may seem as a limiting assumption. Dynamic models often have to make this assumption for tractability reasons (see, for example, Hauser, Simester and Wernerefelt 1994). We have also analyzed a more general n-period version of the one manufacturer-one retailer model and have found that depending on the level of holding costs, the retailers will carry inventory in some periods.

There are several interesting avenues for extending our research. One possibility is to allow the manufacturers to charge quantity discounts or quantity premia. This can allow the manufacturers to reward or penalize forward buying as necessary and achieve full coordination by using more general contracts. Another factor that could affect our results and therefore merit further investigation is the high-end or low-end positioning of the retailers and manufacturers. Another is to consider situation in which retailers as well as consumers can do forward buying (Hong et al, 2002, Anton and Das Varma 2005, Guo and Villas-Boas 2008). This strikes us as fruitful directions in which to take this research.

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FOOTNOTES

1. As we show in more detail in Section 4, a trade promotion in our model is defined as a temporary price reduction that is contingent on a specific level of merchandising support provided by the retailer.
2. We can generate qualitatively identical results when the retailers' decisions are made sequentially. However, the algebra is more tedious and the intuition is less clear in that case.
3. One can easily replicate the results in Anand, Anupindi and Bassok (2003) by setting $\rho=1$ in this section. It is important to note that the full "cost" of forward buying is captured not only through the holding cost but also through the discount factor. As we show subsequently, both these parameters play a crucial role in determining the effects on the manufacturer and retailer.
4. All proofs are available on the *JMR* website.
5. Desai (2000) observes a similar effect in a single period model.
6. If ϕ continued to play a role with zero units of one of the products, we would have a perverse case of a money pump, where the manufacturer sets an exorbitantly high price for one product to drive up demand for the other.
7. Lal, Little and Villas-Boas (1996) develop a model in which a manufacturer offers a trade promotion to two competing retailers. In their model, trade promotions are driven entirely by the competition for a switching segment of consumers. In our case, the trade promotion has its own demand enhancing effect that is independent of any switchers in the market.

8. If we include merchandising effort, e_m, in the model in Section 3, all the essential results go through with only minor modifications.
9. The model with a regular wholesale price in which the retailer also chooses an effort level is derived in a manner that is similar to the procedure laid out in Section 3. These details are provided in the Appendix.
10. A lower wholesale price in period 2 compared to what it would get without forward buying.
11. A large portion of channels research is focused on understanding the nature of these inefficiencies and on designing contractual and non-contractual mechanisms that align manufacturers' and retailers' incentives, such that retailers choose the appropriate price, service, promotional spending, or any other marketing decision. See, for example, McGuire and Staelin 1983, Coughlan and Wernerfelt 1985, Moorthy 1987, Lal 1990, Lee and Staelin 1997, Desai, Koenigsberg and Purohit 2004, Bruce, Desai and Staelin 2005, Cui, Raju and Zhang 2007a, among others). The economics literature on double marginalization (Spengler 1950), downstream moral hazard (Holmstrom 1979) and bilateral moral hazard (e.g., Holmstrom 1982, Bhattacharya and Lafontaine 1995, Desai 1997) also deals with vertical relations where incentives are misaligned.
12. It is well-established that a linear price contract, such as a wholesale price charged by the manufacturer, leads to inefficiencies because of double marginalization. On the other hand, in many situations, including in some of the cases that we consider in this paper, more general contracts can lead to full channel coordination.

Figure 1: Cutoff Values of Holding Cost

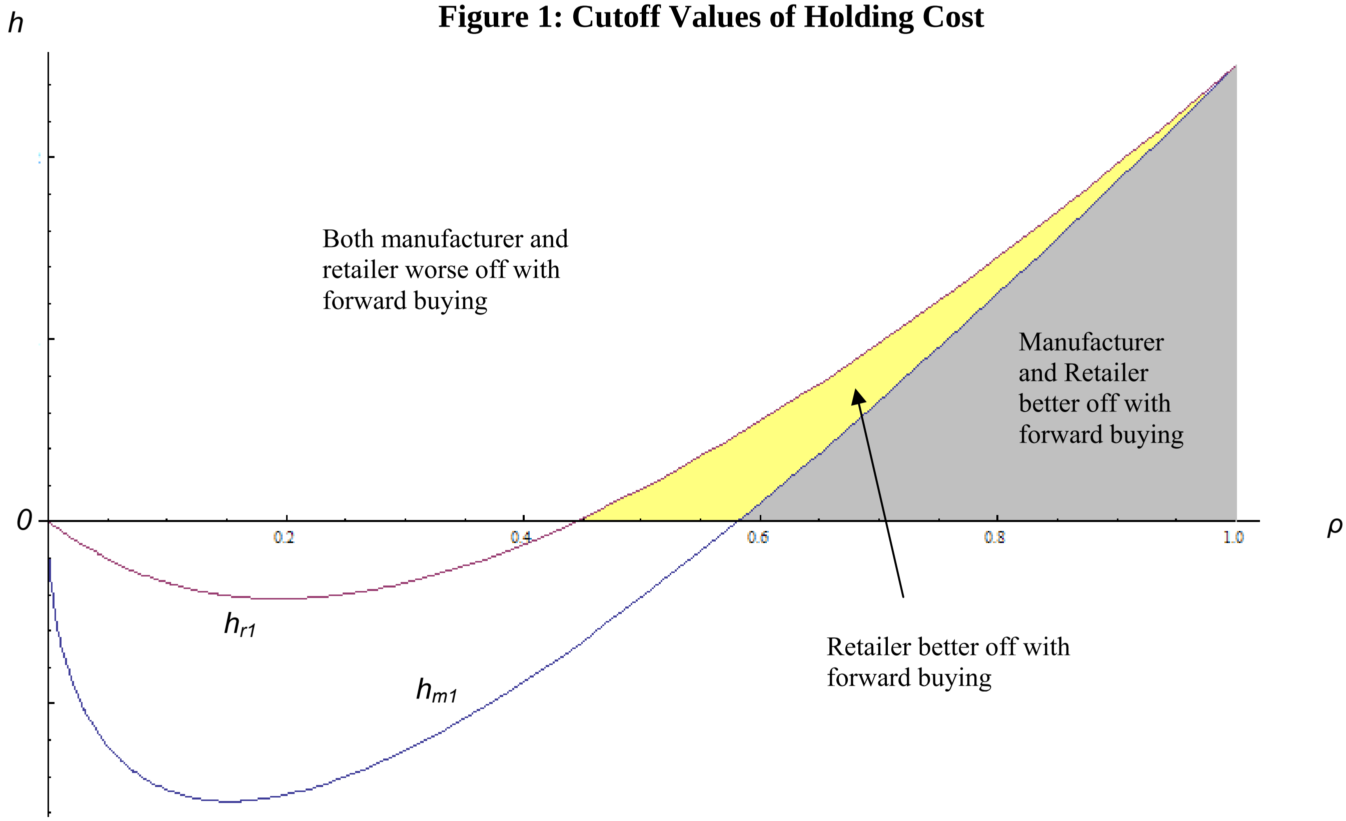

Table 1: Analysis of a single manufacturer and a single retailer channel

Condition	$0 \le h < h_{r1} = \dfrac{\tau\rho(-4+9\rho)}{8+12\rho}$	$h \ge h_{r1} \ge 0$
w_1	$\dfrac{9\tau\rho - 2h}{8+9\rho}$	$\dfrac{\tau}{2}$
w_2	$2\dfrac{3\rho(h+\tau)+h}{\rho(8+9\rho)}$	$\dfrac{\tau}{2}$
q_1	$\dfrac{\tau\rho(4+9\rho)-2h(4+5\rho)}{2\rho(8+9\rho)}$	$\dfrac{\tau}{4}$
q_2	$\dfrac{3\rho(h+\tau)+2h}{\rho(8+9\rho)}$	$\dfrac{\tau}{4}$
d_1	$\dfrac{4\tau+h}{8+9\rho}$	$\dfrac{\tau}{4}$
d_2	$\dfrac{\tau\rho(2+9\rho)-2h(2+3\rho)}{2\rho(8+9\rho)}$	$\dfrac{\tau}{4}$
p_1	$\dfrac{\tau(4+9\rho)-h}{8+9\rho}$	$\dfrac{3\tau}{4}$
p_2	$\dfrac{\tau\rho(14+9\rho)+h(4+6\rho)}{2\rho(8+9\rho)}$	$\dfrac{3\tau}{4}$
I_1	$\dfrac{\tau\rho(-4+9\rho)-4h(2+3\rho)}{2\rho(8+9\rho)}$	0

Table 2: Analysis of a single manufacturer and two-retailer channel.*

	$0 \le h < h_{r3} = \rho\tau \dfrac{[25+\theta[45+\theta(26+5\theta)]]-2(1+\theta)(2+\theta)(4+3\theta)}{2(1+\theta)(2+\theta)^2(4+5\rho)}$	$h \ge h_{r3} \ge 0$
w_{A1}	$\dfrac{2(1+\theta)[h\theta(5+3\theta)+\tau(2+\theta)(25+17\theta)]\rho-\tau(\theta\rho)^2(5+3\theta)-8h(1+\theta)^2(2+\theta)}{4(1+\theta)[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]}$	$\dfrac{\tau}{2+\theta}$
w_{A2}	$\dfrac{2h(1+\theta)(2+\theta)^2(4+5\rho)+\tau\rho[2(1+\theta)(2+\theta)(10+7\theta)+\theta[5+\theta(5+\theta)]\rho]}{2\rho(1+\theta)[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]}$	$\dfrac{\tau}{2+\theta}$
q_{A1}	$\dfrac{\tau\rho[8(1+\theta)(2+\theta)^2+2(1+\theta)(2+\theta)(25+8\theta)\rho-(\theta\rho)^2(5+2\theta)]+2h(1+\theta)[\theta\rho^2(5+2\theta)-12\rho(2+\theta)(3+\theta)-16(2+\theta)^2]}{8\rho(2+\theta)[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]}$	$\dfrac{\tau(1+\theta)}{4(2+\theta)}$
q_{A2}	$\dfrac{2h(1+\theta)(2+\theta)^2(4+5\rho)+\tau\rho[2(1+\theta)(2+\theta)(10+7\theta)+\theta[5+\theta(5+\theta)]\rho]}{4\rho(2+\theta)[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]}$	$\dfrac{\tau(1+\theta)}{4(2+\theta)}$
d_{A1}	$\dfrac{\tau[96+\theta[2(104+\rho)+\theta[(24-5\rho)(6+\rho)+2\theta[16-\rho(2+\rho)]]]]+2h(1+\theta)[8+\theta(5+2\theta)(4+\rho)]}{8(2+\theta)[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]}$	$\dfrac{\tau(1+\theta)}{4(2+\theta)}$
d_{A2}	$\dfrac{\tau\rho[4+25\rho+\theta[6+35\rho+\theta(2+11\rho)]]-2h(1+\theta)(2+\theta)(4+5\rho)}{4\rho[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]}$	$\dfrac{\tau(1+\theta)}{4(2+\theta)}$
p_{A1}	$\dfrac{\tau[96+200\rho+\theta[112+298\rho+\theta[32+\rho[154+5\rho+2\theta(14+\rho)]]]]-2h(1+\theta)(2+\theta)[8+\theta(5+2\theta)(4+\rho)]}{4(2+\theta)[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]}$	$\dfrac{\tau(3+\theta)}{2(2+\theta)}$
p_{A2}	$\dfrac{2h(1+\theta)(2+\theta)(4+5\rho)+\tau\rho[44+25\rho+\theta[50+15\rho+\theta(14+\rho)]]}{4\rho(2+\theta)[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]}$	$\dfrac{\tau(3+\theta)}{2(2+\theta)}$
I_{A1}	$\dfrac{\tau\rho[25\rho+\theta^3(5\rho-6)+9\theta(5\rho-4)-16-26\theta^2(1-\rho)]-2h(1+\theta)(2+\theta)^2(4+5\rho)}{2\rho(2+\theta)[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]}$	0

* Retailer B's decisions are defined symmetrically.

Table 3: Analysis of two manufacturers and a single retailer channel.*

	$0 \le h < h_{r2} = \rho\tau \frac{[\rho(2+\phi)(3+2\phi)^2(3+4\phi)+4\phi^4-\phi^3-40\phi^2-60\phi-24]}{(2+\phi)^2[12+36\phi+35\phi^2+11\phi^3+\rho(2+\phi)(3+2\phi)(3+4\phi)]}$	$h \ge h_{r2} \ge 0$
w_{i1}	$\frac{2\tau\rho(3+2\phi)^2(3+4\phi)-h(2+\phi)(6+9\phi-2\phi^3)}{48+156\phi+186\phi^2+99\phi^3+20\phi^4+\rho(2+\phi)(3+2\phi)^2(3+4\phi)}$	$\frac{\tau}{2(2+\theta)}$
w_{i2}	$\frac{(2+\phi)\{\rho(3+2\phi)(3+4\phi)[2\tau+h(2+\phi)]+h(1+\phi)[12+\phi(24+11\phi)]\}}{\rho[48+156\phi+186\phi^2+99\phi^3+20\phi^4+\rho(2+\phi)(3+2\phi)^2(3+4\phi)]}$	$\frac{\tau}{2(2+\theta)}$
q_{i1}	$\frac{(1+\phi)\{2\tau\rho[12+36\phi+37\phi^2+12\phi^3+\rho(3+2\phi)^2(3+4\phi)]-h(2+\phi)[6(4+5\rho)+\phi[60+69\rho+\phi[46+44\rho+\phi(11+8\rho)]]]\}}{4\rho[48+156\phi+186\phi^2+99\phi^3+20\phi^4+\rho(2+\phi)(3+2\phi)^2(3+4\phi)]}$	$\frac{\tau(1+\phi)}{4(2+\phi)}$
q_{i2}	$\frac{(1+\phi)(2+\phi)\{\rho(3+2\phi)(3+4\phi)[2\tau+h(2+\phi)]+h(1+\phi)[12+\phi(24+11\phi)]\}}{4\rho[48+156\theta+186\theta^2+99\theta^3+20\theta^4+\rho(2+\theta)(3+2\theta)^2(3+4\theta)]}$	$\frac{\tau(1+\phi)}{4(2+\phi)}$
d_{i1}	$\frac{\tau[48+\phi[156+186\phi+99\phi^2+20\phi^3+\rho(3+2\phi)^2(3+4\phi)]]+h(2+\phi)(6+9\phi-2\phi^3)}{4[48+156\phi+186\phi^2+99\phi^3+20\phi^4+\rho(2+\phi)(3+2\phi)^2(3+4\phi)]}$	$\frac{\tau(1+\phi)}{4(2+\phi)}$
d_{i2}	$\frac{\tau\rho[12+66\phi+118\phi^2+83\phi^3+20\phi^4+\rho(2+\phi)(3+2\phi)^2(3+4\phi)]-h(2+\phi)[11+36\phi+35\phi^2+11\phi^3\rho(2+\phi)(3+2\phi)(3+4\phi)]}{4\rho[48+156\phi+186\phi^2+99\phi^3+20\phi^4+\rho(2+\phi)(3+2\phi)^2(3+4\phi)]}$	$\frac{\tau(1+\phi)}{4(2+\phi)}$
p_{i1}	$\frac{\tau}{2}+\frac{2\tau\rho(3+2\phi)^2(3+4\phi)-h(2+\phi)(6+9\phi-2\phi^3)}{2[48+156\phi+186\phi^2+99\phi^3+20\phi^4+\rho(2+\phi)(3+2\phi)^2(3+4\phi)]}$	$\frac{\tau(3+\phi)}{2(2+\phi)}$
p_{i2}	$\frac{h(2+\phi)^2(3+2\phi)(3+4\phi)+\tau[84+\phi[246+\phi[254+5\phi(23+4\phi)]]]+\tau\rho^2(2+\phi)(3+2\phi)^2(3+4\phi)+h(1+\phi)(2+\phi)[12+\phi(24+11\phi)]}{2\rho[48+156\phi+186\phi^2+99\phi^3+20\phi^4+\rho(2+\phi)(3+2\phi)^2(3+4\phi)]}$	$\frac{\tau(3+\phi)}{2(2+\phi)}$
I_{i1}	$\frac{\tau\rho[\rho(2+\phi)(3+2\phi)^2(3+4\phi)+4\phi^4-24-60\phi-40\phi^2-\phi^3]-h(2+\phi)^2[12+36\phi+35\phi^2+11\phi^3+\rho(2+\phi)(3+2\phi)(3+4\phi)]}{4\rho[48+156\phi+186\phi^2+99\phi^3+20\phi^4+\rho(2+\phi)(3+2\phi)^2(3+4\phi)]}$	0

* Decisions related to Manufacturer *j* are defined symmetrically.

Web Appendix

Forward Buying by Retailers

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Proof of Proposition 1

From Table 1, $q_1^* = \dfrac{\tau\rho(4+9\rho) - 2h(4+5\rho)}{2\rho(8+9\rho)}$ and $d_1^* = \dfrac{4\tau + h}{8+9\rho}$. Therefore,

$I_1^* = q_1^* - d_1^* = \dfrac{\tau\rho(9\rho-4) - 4h(2+3\rho)}{2\rho(8+9\rho)}$, which is positive if and only if $h < h_{r1} = \dfrac{\tau\rho(-4+9\rho)}{8+12\rho}$. □

The manufacturer's profit with the retailer's forward buying is given by

$\prod^M = \dfrac{\tau\rho(-4h+9\tau\rho) + 4h^2(1+\rho)}{2\rho(8+9\rho)}$ and the manufacturer's profit without the retailer's forward

buying is given by $\pi^M = \dfrac{\tau^2(1+\rho)}{8}$. $\prod^M - \pi^M = \dfrac{\tau^2\rho[\rho(19-9\rho)-8] + 16h^2(1+\rho) - 16\tau\rho h}{8\rho(8+9\rho)} > 0$

iff $h < h_{m1} = \dfrac{\tau(2\rho-(1-\rho)\sqrt{\rho(8+9\rho)}}{4(1+\rho)}$. □

Proof of Proposition 2

From Table 2, Retailer A's optimal inventory is given by:

$$I_{A1}^* = \frac{\tau\rho[25\rho + \theta^3(5\rho-6) + 9\theta(5\rho-4) - 16 - 26\theta^2(1-\rho)] - 2h(1+\theta)(2+\theta)^2(4+5\rho)}{2\rho(2+\theta)[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]}.$$

$$\frac{\partial I_{A1}^*}{\partial\theta} = \frac{1}{2\rho[(2+\theta)[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]]^2}$$
$$\{\tau\rho\{-8(2+\theta)^2[14+\theta(20+7\theta)] - 2(2+\theta)\rho[110+\theta[225+\theta(140+27\theta)]]$$
$$+\rho^2[375+\theta[750+\theta[585+\theta(210+29\theta)]]]\} - 2h(2+\theta)^2(4+5\rho)[4(2+\theta)^2 + \rho[25+\theta(26+7\theta)]]\}.$$

$\dfrac{\partial I_{A1}^*}{\partial\theta\partial h} = -\dfrac{(4+5\rho)[4(2+\theta)^2 + \rho[25+\theta(26+7\theta)]]}{\rho[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]}$ is negative for any $0 < \rho \le 1$ and $0 \le \theta$.

Next we show that the value of $\frac{\partial I^*_{A1}}{\partial \theta}(\mathrm{h}=0)$ is negative and therefore for any positive value of h, $\frac{\partial I^*_{A1}}{\partial \theta}$ is negative.

$$\frac{\partial I^*_{A1}}{\partial \theta}_{|h=0} = \frac{\tau\rho\{-8(2+\theta)^2[14+\theta(20+7\theta)]-2(2+\theta)\rho[110+\theta[225+\theta(140+27\theta)]]+\rho^2[375+\theta[750+\theta[585+\theta(210+29\theta)]]]\}}{2\rho[(2+\theta)[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]]^2}.$$

It is easy to see that the denominator is positive. It is also can be verified that the numerator is negative for values of $0 \le \theta$ and $\rho_1 < 0 < \rho < 1 \le \rho_2$ where

$$\rho_1 = \frac{1}{375+\theta[750+\theta[585+\theta(210+29\theta)]]}\{220+\theta[560+\theta[505+\theta(194+27\theta)]]- \sqrt{(2+\theta)^3[27050+\theta[83225+\theta[102360+\theta[62850+\theta(19254+2353\theta)]]]]}\},$$

and $$\rho_2 = \frac{1}{375+\theta[750+\theta[585+\theta(210+29\theta)]]}\{220+\theta[560+\theta[505+\theta(194+27\theta)]]- \sqrt{(2+\theta)^3[27050+\theta[83225+\theta[102360+\theta[62850+\theta(19254+2353\theta)]]]]}\}.$$

Thus, $\frac{\partial I^*_{A1}}{\partial \theta}(h)$<0 for any h>0 and the forward buying quantity decreases with the level of competition. □

Proof of Proposition 3

The optimal forward buying quantity is,

$$I^*_{A1} = \frac{\tau\rho[25\rho+\theta^3(5\rho-6)+9\theta(5\rho-4)-16-26\theta^2(1-\rho)]-2h(1+\theta)(2+\theta)^2(4+5\rho)}{2\rho(2+\theta)[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]}$$, which is positive for $0 \le h < h_{r3} = \tau\frac{\rho[25+\theta[45+\theta(26+5\theta)]]-2(1+\theta)(2+\theta)(4+3\theta)}{2(1+\theta)(2+\theta)^2(4+5\rho)}$. Thus both retailers forward buy for values of $0 < h < h_{r3}$. Next, we compare the profits of a retailer with and without forward buying. We find that the retailers are better-off with forward buying for values of $0 < h < h_{r4} < h_{r5}$ or $0 < h_{r4} < h_{r5} < h$, but the retailers are worse off with forward buying for values of $0 < h_{r4} < h < h_{r5}$ where h_{r4} *and* h_{r5} are given by;

$$h_{r4} = \frac{\rho\tau}{2(1+\theta)[64(2+\theta)^5+\gamma_1]}$$
$$\{-2\sqrt{\sigma 1}[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]] - \{32(1+\theta)(2+\theta)^2[16+\theta[31+\theta(15+\theta)]] -$$
$$8\rho(2+\theta)(150+\theta\gamma_2) - 2\rho^2(2500+\theta\gamma_3) + \theta^3\rho^3(5+2\theta)[15+\theta(18+5\theta)]\}\},$$

$$h_{r5} = \frac{\rho\tau}{-2(1+\theta)[64(2+\theta)^5+\gamma_1]}$$
$$\{2\sqrt{\sigma_1}[24+25\rho+\theta[28+25\rho+\theta(8+6\rho)]]^2 - \{32(1+\theta)(2+\theta)^2[16+\theta[31+\theta(15+\theta)]] -$$
$$8\rho(2+\theta)(150+\theta\gamma_2) - 2\rho^2(2500+\theta\gamma_3) + \theta^3\rho^3(5+2\theta)[15+\theta(18+5\theta)]\}\}$$

and $\gamma_1 = 16(2+\theta)^2[81+\theta[122+\theta(59+8\theta)]] + 4\rho^2(2+\theta)[400+\theta[790+\theta[554+\theta(154+13\theta)]]] - \theta^2\rho^3(5+2\theta)[15+\theta(18+5\theta)]$

$$\gamma_2 = 364+\theta[361+\theta[197+\theta(59+7\theta)]],\ \gamma_3 = 8100+\theta[10760+\theta[7451+\theta[2790+\theta(521+36\theta)]]]$$

$$\sigma_{1=} -192(1+\theta)^2(2+\theta)^5 + 16\rho(1+\theta)(2+\theta)^2(45+\theta\gamma_4) + 4\rho^2(1+\theta)(2+\theta)(4+\theta)(114+\theta\gamma_5) + \rho^3(400+\theta\gamma_6)$$
$$+\theta^2\rho^4(3+2\theta)(5+2\theta)[15+\theta(18+5\theta)],$$
$$\gamma_4 = 127+\theta[154+\theta[86+\theta(19+\theta)]],\ \gamma_5 = 356+\theta[430+\theta(227+43\theta)],$$

$$\gamma_6 = 1840+\theta[3909+\theta[4402+\theta[2593+2\theta[351+5\theta(4-\theta)]]]].$$

It can be shown that $h_{r5} > h_{r3}$. Since forward buying occurs only when $h < h_{r3}$, $h_{r5} > h_{r3}$ rules out all cases with $h > h_{r5}$. The two remaining possibilities are $0 < h < h_{r4} < h_{r5}$ and $0 < h_{r4} < h < h_{r5}$. When $0 < h < h_{r3} < h_{r4} < h_{r5}$, the retailers are better-off with forward buying and they do forward buy in equilibrium. However, when $h_{r4} < h < h_{r3} < h_{r5}$ and $0 < h_{r3}$, the retailers forward buy in equilibrium but are worse-off doing so.

Proof of Proposition 4

From Table 3, the equilibrium level of inventory, I_{i1} is given by

$\frac{\tau\rho[\rho(2+\phi)(3+2\phi)^2(3+4\phi)+4\phi^4-24-60\phi-40\phi^2-\phi^3]-h(2+\phi)^2[12+36\phi+35\phi^2+11\phi^3+\rho(2+\phi)(3+2\phi)(3+4\phi)]}{4\rho[48+156\phi+186\phi^2+99\phi^3+20\phi^4+\rho(2+\phi)(3+2\phi)^2(3+4\phi)]}$ which is

positive iff $h < h_{r2} = \dfrac{\tau\rho[(2+\phi)(3+2\phi)^2(3+4\phi)\rho-24-60\phi-40\phi^2-\phi^3+4\phi^4]}{(2+\phi)^2[(2+\phi)(3+2\phi)(3+4\phi)\rho+12+36\phi+35\phi^2+11\phi^3]}$.□

Proof of Proposition 5:

The retailer's first period purchase and selling quantity in the case when there is no trade promotion are given by $q_1^{*NTP} = \frac{3\rho(2\tau - w_1) - 4(h+w_1)}{3\rho(2-\kappa^2)}$ and $d_1^{*NTP} = \frac{\tau - w_1}{2-\kappa^2}$ respectively.

Therefore when there is no trade promotion, the forward buying quantity, if positive, is given by $I_1^{*NTP} = q_1^{*NTP} - d_1^{*NTP} = \frac{3\rho\tau - 4(h+w_1)}{3\rho(2-\kappa^2)}$. The retailer's first period purchase and sales quantities in the case when there is trade promotion are given by

$q_1^{*TP} = \frac{3\rho[4\tau + \kappa[e_1^p(2-\kappa^2) - k(\tau - w_1)] - 2w_1] - 8(h+w_1)}{6\rho(2-\kappa^2)}$ and $d_1^{*TP} = \frac{\tau + \kappa e_1^p - w_1}{2}$ respectively.

Therefore, when there is trade promotion the forward buying quantity, if positive, is given by

$I_1^{*TP} = q_1^{*TP} - d_1^{*TP} = \frac{3\rho\tau - 4(h+w_1)}{3\rho(2-\kappa^2)} = I_1^{*NTP}$.

Proof of Proposition 6

The proof is by contradiction. Suppose $e_1^{pNFB} > e_1^{pFB}$ where the superscript NFB and FB denote no forward buying and forward buying cases. Because the manufacturer prohibits forward buying, the retailer's participation constraint (14) is tighter. With a tighter voluntary participation constraint and higher e_1^p, $w_1^{pNFB} < w_1^{pFB}$.

But in both cases (with and without forward buying), $\frac{\partial \Pi^M}{\partial e_1^p} = \frac{\kappa\, w_1^p}{2}$, which is increasing in w_1^p, i.e., the marginal benefit of e_1^p is higher with higher w_1^p. Therefore, both $w_1^{pNFB} < w_1^{pFB}$ and $e_1^{pNFB} > e_1^{pFB}$ cannot be true. Thus, we get a contradiction. □

Proof of Proposition 7 and Analysis of the Uncertain Demand Case

We adopt the notion of subgame perfect Nash equilibrium and solve the game backward, starting from Stage 5 in period 2. For ease of exposition, we describe the analysis for the following three cases separately: **A**) $q_1 < d_{1L} < d_{1H}$, **B**) $d_{1L} \le q_1 < d_{1H}$, **C**) $d_{1L} < d_{1H} \le q_1$.

Analysis of case A: At the beginning of stage 5, the firm does not face any uncertainty and knows whether $\tau = \tau_H$ or $\tau = \tau_L$. As there is no inventory at this stage (case A), the inverse demand is $p_{2i} = \tau_i - q_{2i}\ i \in \{L, H\}$. Thus, the retailer maximizes profit in stage 5, $\pi_{2i}^R = (p_{2i} - w_{2i})q_{2i}$, by choosing an optimal quantity, q_{2i}, to order and sell in period 2. This optimization problem yields; $q_{2i} = \frac{\tau_i - w_{2i}}{2}$. At stage 4 the manufacturer maximizes profit, $\pi_{2i}^M = w_{2i}q_{2i}$, by choosing an optimal wholesale price, w_{2i}. This optimization problem yields; $w_{2i} = \frac{\tau_i}{2}$. At the beginning of stage 3, the retailer knows the exact demand state and (whether $\tau = \tau_H$ or $\tau = \tau_L$). Case A captures the case where there is no inventory in neither low nor high demand states and therefore the retailer sells and order quantities are equivalent, q_1=d_{1i}. The demand function is $q_1 = \tau_i - p_{1i}\ i \in \{L, H\}$ and the retailer retail price is $p_{1i} = \tau_i - q_1\ i \in \{L, H\}$. The retailer profits in stage 3, are $\pi_{1i}^R = \frac{\rho(\tau_i)^2}{16} - (q_1)^2 + \rho\pi_{2i}^R, i \in \{L, H\}$. At the beginning of stage 2, the retailer does not know the exact demand state and he maximizes the expected profit, $\prod_A^R = \gamma\pi_{1H}^R + (1-\gamma)\pi_{1L}^R$, by choosing the optimal order quantity q_1. This optimization problem yields; $q_1 = \frac{\gamma\tau_H + (1-\gamma)\tau_L - w_1}{2}$. At stage 1 the manufacturer (who does not know demand state) maximizes profit, $\prod_A^M = (w_1 * q_1) + \gamma\pi_{2H}^M + (1-\gamma)\pi_{1H}^M = w_1 * q_1 + \frac{\gamma\rho(\tau_H)^2}{8} + \frac{(1-\gamma)\rho(\tau_L)^2}{8}$, by choosing an optimal wholesale price, w_1. This optimization problem yields; $w_2 = \frac{\gamma\tau_H + (1-\gamma)\tau_L}{2}$. The manufacturer and the retailer optimal expected profits are

$$\prod_A^M = \frac{(\tau_H)^2\gamma(\gamma+\rho) - (1-\gamma+\rho)(1-\gamma)(\tau_L)^2 + 2\gamma(1-\gamma)(\tau_H)^2(\tau_L)^2}{8}$$ and

$$\prod_A^R = \frac{(\tau_H)^2\gamma(\gamma+\rho) - (1-\gamma+\rho)(1-\gamma)(\tau_L)^2 + 2\gamma(1-\gamma)(\tau_H)^2(\tau_L)^2}{16}$$ respectively.

Analysis of case B: We solve the game backward, starting from Stage 5 in period 2.
At the beginning of stage 5, the firm does not face any uncertainty and knows whether $\tau = \tau_H$ or $\tau = \tau_L$. In case B, we consider the scenario where the retailer carries inventory into the second period if demand turns low ($\tau = \tau_L$) but does not carry inventory if demand is high ($\tau = \tau_H$). The

inverse demand is $p_{2i} = \tau_i - q_{2i} - I_{1i}, i \in \{L, H\}$ where I_{1L} is the inventory in the end of period 1 if demand state is low and where $I_{1H}=0$. Thus, the retailer maximizes profit in stage 5, $\pi_{2i}^R = (p_{2i} - w_{2i})q_{2i}$, by choosing an optimal quantity, q_{2i}, to order and sell in period 2. This optimization problem yields; $q_{2i} = \dfrac{\tau_i - w_{2i} - 2I_{1i}}{2}$. At stage 4 the manufacturer maximizes profit, $\pi_{2i}^M = w_{2i}q_{2i}$, by choosing an optimal wholesale price, w_{2i}. This optimization problem yields; $w_2 = \dfrac{\tau_i - 2I_{1i}}{2}$. At the beginning of stage 3, the retailer knows the exact demand state and (knows whether $\tau = \tau_H$ or $\tau = \tau_L$). If demand turns high, the retailer (just like in case A) sells and order quantities are equivalent, $q_1=d_{1H}$. In such case the retailer profits in stage 3, are $\pi_{1H}^R = \dfrac{\rho(\tau_H)^2}{16} - (q_1)^2 + \rho\pi_{2H}^R$. If demand turns low, the retailer sells some of the units, d_{1L}, and forward buys the unsold inventory, $I_{1L}=q_1- d_{1L}$, into period 2. The demand function in stage 3 is $d_{1L} = \tau_L - p_{1L}$. Thus, the retailer maximizes profit in stage 3 when demand is low, $\pi_{1L}^R = p_{1L}d_{1L} - w_1q_1 - hI_{1L} + \rho\pi_{2L}^R$, by choosing an optimal retail price, p_{1L}, to charge in period 1. This optimization problem yields; $p_{1L} = \dfrac{\tau_L(4+9\rho) - 4h - 6\rho q_1}{8+6\rho}$. At the beginning of stage 2, the retailer does not know the exact demand state and thus he maximizes the expected profit, $\prod^R = \gamma\pi_{1H}^R + (1-\gamma)\pi_{1L}^R$, by choosing the optimal order quantity q_1. This optimization problem yields; $q_1 = \dfrac{(\gamma\tau_H - w_1)(4+3\rho) + 6\rho(1-\gamma)\tau_L - 4(1-\gamma)h}{2(3\rho+4\gamma)}$. At stage 1 the manufacturer maximizes profit, $\prod^M = w_1q_1 + \gamma\pi_{2H}^M + (1-\gamma)\pi_{1H}^M = w_1q_1 + \dfrac{\gamma\rho(\tau_H)^2}{8} + \dfrac{2(1-\gamma)\rho(2\tau_L - 2q_1 + h)^2}{(4+3\rho)^2}$, by choosing an optimal wholesale price, w_1. This optimization problem yields;

$$w_2 = \frac{\gamma\tau_H[4\gamma(4+5\rho) + \rho(4+9\rho)] + 2\rho(1-\gamma)\tau_L(20\gamma+9\rho) - 4(1-\gamma)(4\gamma+\rho)h}{2[16\gamma(1+\rho) + \rho(8+9\rho)]}.$$

The manufacturer and the retailer optimal expected profits are $\prod_B^M$ *and* $\prod_B^R$ respectively.

Analysis of case C: At the beginning of stage 5, the firm does not face any uncertainty and knows whether $\tau = \tau_H$ or $\tau = \tau_L$. In case C, we consider the scenario where the retailer carries inventory into the second period whether demand turns low ($\tau = \tau_L$) or high ($\tau = \tau_H$). The inverse demand is $p_{2i} = \tau_i - q_{2i} - I_{1i}, i \in \{L, H\}$ where I_{1i} is the inventory in the end of period 1 if demand state is $i \in \{L, H\}$. Thus, the retailer maximizes profit in stage 5, $\pi_{2i}^R = (p_{2i} - w_{2i})q_{2i}$ by choosing an optimal quantity, q_{2i}, to order and sell in period 2. This optimization problem yields; $q_{2i} = \frac{\tau_i - w_{2i} - 2I_{1i}}{2}$. At stage 4 the manufacturer maximizes profit, $\pi_{2i}^M = w_{2i}q_{2i}$, by choosing an optimal wholesale price, w_{2i}. This optimization problem yields; $w_2 = \frac{\tau_i - 2I_{1i}}{2}$. At the beginning of stage 3, the retailer knows the exact demand state (whether $\tau = \tau_H$ or $\tau = \tau_L$). At this stage the retailer sells some of the units, d_{1i}, and forward buys the unsold inventory, $I_{1i}=q_1- d_{1i}$, into period 2. The demand function in stage 3 is $d_{1i} = \tau_i - p_{1i}$. Thus, the retailer maximizes profit in stage 3, $\pi_{2i}^R = p_{1i}d_{1i} - w_1q_1 - hI_{1i} + \rho\pi_{2i}^R \;\; i \in \{L, H\}$, by choosing an optimal retail price, p_{1i}, to charge in period 1. This optimization problem yields; $p_{1i} = \frac{\tau_i(4+9\rho) - 4h - 6\rho q_1}{8+6\rho}$. At the beginning of stage 2, the retailer does not know the exact demand state and he maximizes the expected profit, $\prod^R = \gamma\pi_{1H}^R + (1-\gamma)\pi_{1L}^R$, by choosing the optimal order quantity q_1. This optimization problem yields; $q_1 = \frac{6\rho[\gamma\tau_H + (1-\gamma)\tau_L] - w_1(4+3\rho) - 4h}{6\rho}$. At stage 1 the manufacturer maximizes profit,

$\prod^M = w_1q_1 + \gamma\pi_{2H}^M + (1-\gamma)\pi_{1H}^M = w_1q_1 + \frac{2\gamma\rho(2\tau_H - 2q_1 + h)^2}{(4+3\rho)^2} + \frac{2(1-\gamma)\rho(2\tau_L - 2q_1 + h)^2}{(4+3\rho)^2}$, by choosing an optimal wholesale price, w_1. This optimization problem yields;

$w_2 = \frac{9\rho[\gamma\tau_H + (1-\gamma)\tau_L] - 2h}{8+9\rho}$. The manufacturer and the retailer optimal expected profits are $\prod_C^M$ *and* $\prod_C^R$ respectively[1].

To prove Proposition 7, the analysis of case C implies that the retailer carries

$I_{H1}^C = \frac{\tau_H\rho[4\gamma(4+9\rho) - (4-3\rho)(8+9\rho)] + 4\tau_L(1-\gamma)(4+9\rho) - 4h[8+9\rho(2+\rho)]}{2\rho[32+3\rho(20+9\rho)]}$ units in inventory when demand turns high, which is positive for values of

$h < h_{u2} = \rho\frac{\tau_H[4\gamma(4+9\rho) - (4-3\rho)(8+9\rho)] + 4\tau_L(1-\gamma)(4+9\rho)}{4[8+9\rho(2+\rho)]}$. The analysis of case B implies

[1] $\prod_B^M, \prod_B^R, \prod_C^M$ *and* $\prod_C^R$ are algebraically messy and not reproduced in this appendix.

that the retailer carries $I_{L1}^{B} = \frac{2\gamma\tau_H(4+3\rho) - \tau_L[4\gamma(4-\rho) + \rho(4-9\rho)] - 4h[2+2\gamma+3\rho)]}{2[16\gamma(1+\rho) + \rho(8+9\rho)]}$ units in inventory when demand turns high, which is positive for values of $h_{u2} < h < h_{u1} = \frac{2\gamma\tau_H(4+3\rho) - \tau_L[4\gamma(4-\rho) + \rho(4-9\rho)]}{4(2+2\gamma+3\rho)}$. For values of $h > h_{u1}$, the firm would not carry inventory.