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Optimal Returns Policy under Demand Uncertainty

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Abstract

Multiple categories of retail products suffer limited shelf life, demand uncertainty, and, in some cases, long lead times. To provide retailers with an incentive to increase the stocking quantity of such products, manufacturers may offer an option to return unsold items at wholesale or less than wholesale prices. This article extends the additive price-dependent demand model in three ways. First, partial returns are optimal for the manufacturer but do not induce higher stocking quantities compared with when the manufacturer offers no returns. Second, in terms of the effect of investment in demand-enhancing activities, when retailers invest, they set higher resale prices, but an optimal partial returns policy still does not induce higher stocking quantity, whereas when manufacturers invest, the optimal returns policy induces higher stocking quantity. Third, when the manufacturer and retailer have different expectations of demand uncertainty, the retailer's estimate influences the expected profits for both, whereas the manufacturer's estimate has a major impact on its profits only.

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The unpredictability of consumer preferences, changing trends, and long lead times force retail buyers to make ordering decisions about products with limited shelf lives, long before they can predict actual demand. In these cases, retail buyers balance the probability of product success, and resultant stock-outs, against the probability of product failure and the resultant costs of carrying and disposing of surplus inventory. Such decisions are prevalent in the context of fashion items or those with seasonal demand cycles (e.g., toys, seasonal decorations, books), because these product categories encourage consumers' variety-seeking behaviors (cf. Kahn 1993; Levy and Weitz 2009; Menon and Kahn 1995). Grewal and Levy (2007, p. 448) thus have called for more research to understand "the process by which merchandise buyers make their decisions and the degree to which those decisions are optimal."

To reduce the potential risk of overstock, a retailer may order less than the desired amount required by the channel (Padmanabhan and Png 1997; hereafter, PP97). Such an ordering pattern likely leads to more retail out-of-stock situations. In an

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effort to enhance sales and distribute the risk of overstocking, manufacturers may accept returns from retailers, even though such a policy enhances their vulnerability to fluctuations in demand. For certain products, such as new books, CDs, software, fashion wear, and winter clothing, demand is highly uncertain and therefore, manufacturers must carefully select their returns policy carefully to maximize their profits (Padmanabhan and Png 1995). There are several examples of returns policies used in different industries—in books, magazine publishing, electronic distributors, mass merchandisers, catalog retailers, etc (PP 97, Rogers and Tibben-Lembke, 1999; Stock and Mulki, 2009).

In a comparison of manufacturers who offer no versus full return policies, PP97 show, with both model and empirical data, that the manufacturer earns higher profits with a no return policy when demand variability is high. In addition, the "returns policy shifts the cost of excess inventory from the retailer to the manufacturer, and hence encourages the retailer to increase stock" (PP97, p. 89). The focus of our research is to extend Padmanabhan and Png's (1997) model to the situation of partial returns, because we believe a partial returns policy may actually be the optimal policy. A partial returns policy is defined as one in which the returns price is strictly less than the wholesale price, with the difference interpreted as the restocking fee. Intuitively, a partial returns policy allows for the manufacturer and the retailer to share demand risk. We show that the real benefit

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Table 1

Literature review.

Article	Focus and results	Model	Empirical
Pasternack (1985)	Role of returns in achieving channel coordination. Strategy depends on whether the target is a single retailer or multiple retailer	Newsvendor model	None
Kandel (1996)	Examination of extreme contracts (e.g., consignment with a no returns contract) to identify the factors affecting choice of contract. Factors include inventory policy, relative advantage in disposing of the unsold inventory, risk allocation, incentives to invest in promotions, information asymmetry, and costs of contracts.	Newsvendor model	Data from the publishing industry
Padmanabhan and Png (1997)	Comparison of no returns policy with full returns, which demonstrates that returns are less attractive when demand variability is high.	Linear pricing model with additive demand	Profitability data from the retail industry
Tsay (2001)	Role of using markdowns versus returns in achieving channel coordination and determining conditions in which markdowns would be the preferred option. If the cost of handling returns is high or the retailer is better equipped to dispose of excess inventory, markdowns would be preferred to a returns policy.	Newsvendor model	None
Su and Shi (2002)	Examination of quantity discounts and returns policies to achieve channel coordination. Demonstrate that returns policy is similar to quantity discounts policy.	Newsvendor model	None
Iyer and Miguel Villas-Boas (2003)	Examination of the impact of bargaining power on the choice of returns versus no returns contracts. Returns contracts are more attractive when retailer's bargaining power is low.	Utility theory and linear pricing model with additive demand	Yes, experiments
Arya and Mittendorf (2004)	Use of returns policy to elicit private demand information from the retailer. Manufacturers can use a menu contract with self-selection that reduces the incentive for retailer to misstate the market conditions.	Utility theory	None
Krishnan, Kapuscinski, and Butz (2004)	Returns reduce the incentive for retailers to use channel optimal promotional effort. Use a promotional cost-sharing subsidy along with returns policy to achieve channel coordination.	Newsvendor model with multiplicative impact of effort on demand	None
Wang (2004)	Examine role of return policies when there is retail competition. For deterministic demand case, returns policies do not have impact on nature of competition.	Deterministic demand with additive model	No
Padmanabhan and Png (2004)	Examine role of return policies when demand is uncertain. Returns policies serve to both manage competition and mitigate demand uncertainty.	Linear pricing model with additive demand	

of offering partial returns is that it allows the manufacturer to maintain its high margins rather than encouraging the retailer to increase its order quantity.

We also extend the PP97 model to consider the effects of offering returns in three new contexts. First, we examine situations in which the retailer exerts selling effort to increase demand potential, such as by setting the appropriate selling effort, including breaking bulk, promotional displays, and advertising (Desiraju and Moorthy 1997). Second, we study contexts in which the manufacturer invests in quality-improving/brandbuilding activities to increase demand potential for the product. By examining these two elements, we establish that partial returns help manufacturers maximize profits, even though they induce higher stocking quantities from the retailer only when the manufacturer invests in its product quality. Third, we examine a situation in which the manufacturer and retailer have different estimates of demand uncertainty by deriving an optimal partial returns policy and determining the effect of the retailer's and manufacturer's demand estimate on optimal profits.

Our model

We extend PP97's model as follows: (1) we study the use of partial returns and compare the results with the no and full return cases; (2) we analyze the effect of the returns policy when the retailer invests in selling effort or the manufacturer invests in demand-enhancing product quality/brand name efforts; and (3) we consider partial returns with asymmetric demand estimates. The goal of our research therefore is to address the following research questions:

- 1. What is the benefit of a partial returns policy for the manufacturer? When does an increase in the returns price induce higher stocking quantity from the retailer?
- 2. Does the benefit to the manufacturer from offering partial returns increase as demand variability increases?
- 3. How do manufacturer's and retailer's estimates of demand uncertainty affect their profits?

In the next section, we contrast our model with extant literature and highlight our research focus. We then pose the model assumptions and formulate the problem for the manufacturer and the retailer. After determining the optimal returns and ordering policy, we extend our analysis to the case of investments in demand-enhancing activities by the retailer or manufacturer. We examine the problem of unequal demand estimates. Finally, we discuss the implications of our research and provide some directions for further investigations.

Literature review

In Table 1, we provide a summary of relevant articles pertaining to the use of returns policies. Although return policies have been widely studied, we choose PP97 as a starting point for the type of products we consider. In addition, we discuss different types of models, decision timing, and the relationship among price, nonprice factors, and demand.

Types of demand models

For a manufacturer, the use of a returns policy depends on the nature of demand faced by the retailer. Specifically, it depends on the whether the coefficient of variation of demand is constant or not. The literature has considered use of returns policies with both multiplicative and additive demand. In multiplicative demand models, $X = D(p)\varepsilon$, in which ε represents the random part, so they are appropriate for products whose coefficient of variation remains *constant* across all prices (e.g., Granot and Yin 2005; Song, Ray, and Li 2006). In contrast, in additive demand models, $X = D(p) + \varepsilon$, and the variance of demand is unaffected by the expected demand, though the coefficient of variation depends on the price and decreases as expected demand increases (i.e., resale price is smaller). As PP97 reveal, additive models are relevant for our context (i.e., shifting consumer preferences, changing trends, and long lead times).

Partial returns always appear optimal in the additive model, whereas research suggests that they may not optimal in multiplicative models. For example, both Granot and Yin (2005) and Song, Ray, and Li (2006) show that no returns are optimal for isoelastic demand and that the form of the expected demand function influences the returns policy, such that returns may be optimal with other (nonisoelastic) demand distributions. Furthermore, Song, Ray, and Li (2006) prove that the optimal return price is independent of the uncertainty in demand in multiplicative models.

Timing of pricing decision

The timing of the pricing decision also provides an important differentiating factor. Granot and Yin (2005) and Song, Ray, and Li (2006) assume the pricing decision occurs prior to the realization of demand. In our model (as in PP97), the retailer has the flexibility to determine the resale price after the realization of the demand outcome. Then, even though the retailer must make the quantity (procurement) decision in advance of the selling season, due to production lead times, using flexible pricing, it can better handle demand uncertainty. In turn, the manufacturer may benefit by offering partial returns. The use of flexible pricing as assumed by PP97 has gained popularity with the growing use of Internet-based mechanisms which allow firms to learn about their customers more quickly and accordingly offer products using flexible pricing (Dewan, Jing, and Seidmann, 2003). Our choice of PP97 as the starting point for this research recognizes that pricing flexibility drives supply chain efficiency (cf. Gurnani and Xu 2006; Van Mieghem and Dada 1999) and is common practice in retailing (Dutta, Bergen, and Levy, 2002). In addition, we contrast this with fixed pricing policies adopted by retailers of "catalogue style goods" (Emmons and Gilbert 1998).

Emmons and Gilbert (1998), who incorporate a multiplicative demand model and a pricing decision before demand uncertainty is resolved, demonstrate that partial returns are optimal with this model, though they cannot obtain an optimal solution to the manufacturer's problem analytically. With PP97's model, we can determine the expression for the manufacturer's optimal returns policy and introduce pricing flexibility and investments in our proposed model, thus extending Emmons and Gilbert's (1998) work.

Price-dependent demand

Whereas PP97 consider a price-dependent demand model, Pasternack (1985) addresses price-independent demand and uses buyback mechanisms to achieve channel coordination. Marvel and Peck (1995) also develop a price-independent demand model but do not consider additive or multiplicative demand functions. Sales uncertainty in their model derives from two sources: (1) the stochastic number of customers who arrive at the store and their decisions to purchase (which does not depend on the price offered) and (2) customer uncertainty about their valuation of the product. If only one type of uncertainty exists, the optimal returns policy is either no or full returns; with both types of uncertainty, partial returns become optimal (Marvel and Peck 1995). Unlike Marvel and Peck (1995), we consider an additive model with demand uncertainty, in which the retailer's selection of the resale price partially controls that demand. Because in PP97's model, the resale price is a decision variable, their discussion does not include uncertainty in product valuation. Each player (manufacturer and retailer) maximizes its own profit function and not the joint function, so the channel profits may be suboptimal. However, the focus of our research is not coordination across the channel, which has been studied previously (e.g., Arya and Mittendorf 2004; Pasternack 1985; Su and Shi 2002; Tsay 2001).

Finally, we refer to papers by Mantrala and Raman (1999), Sarvary and Padmanabhan (2001), and Mantrala, Basuroy, and Gajanan (2005) that have also studied the role of return policies in analyzing interactions between a manufacturer and a retailer when demand is uncertain.

Base model with partial returns

In a system consisting of a manufacturer that uses the services of a downstream retailer to sell a product, demand for the product is uncertain. Because the product has a limited useful shelf life, whether due to obsolescence or physical decay, the retailer faces the risk of overstocking if demand is low. Moreover, because demand for the product is uncertain, the manufacturer offers a returns option to the retailer to hedge against the risk of carrying excess inventory. We consider the use of a partial returns policy by a manufacturer to share inventory risk with a retailer in decentralized channel and define a partial returns policy as one in which the return price is strictly less than the wholesale price, with the difference interpreted as a restocking fee.

For many products, such as those in the apparel industry, long lead times challenge the ability to predict which designs will sell. That is, the nature of the final demand is not known with certainty. Retail demand depends on two elements: the primary market potential of the product (which depends on product characteristics) and store-level factors that influence customers' sensitivity to retail price.

We use the linear pricing model provided by PP97 and other researchers (Desai 1997; Gurnani and Erkoc 2008), in which we incorporate the effects of both demand uncertainty and pricing decisions on demand. We subsequently include the effects of nonprice factors, such as retailer and manufacturer investments in selling effort and quality-improving activities, in our demand model.

The structure of the three-stage game (as in PP97) is as follows: in stage 1, the manufacturer sets the returns policy, which includes the wholesale and return prices (w and r). In stage 2, the retailer determines the stocking quantity and places order sfrom the manufacturer before the selling season (due to long production lead times). In stage 3, demand uncertainty is resolved, retail prices p_i are set, and returns are made as needed.

At price p_i charged by the retailer, demand for the product $d_i = \alpha_i - \beta p_i$, where i = h and i = l denote high and low demand outcomes, respectively. In addition, α_h and α_l ($\alpha_h > \alpha_l$) repre-

sent the primary demand potentials for the case of high and low demand outcomes, respectively, and β indicates the price sensitivity of demand, whereas λ represents the probability of low demand.

We capture demand uncertainty with two features: the range of market potential outcomes $(\alpha_h - \alpha_l)$ and the probability of each event, λ and $(1 - \lambda)$. For a given probability λ , as $(\alpha_h - \alpha_l)$ increases, demand uncertainty increases. Because retailers place their orders before the selling season, higher demand variability increases the risk of retailer overstock if demand is low, which prompts the retailer to order less. The manufacturer therefore may provide the retailer an incentive to induce it to place a larger-sized order, such as the option to return any unsold items to the manufacturer at a predetermined price.

In the first stage, the manufacturer (Stackelberg leader), for a given production $\cos c$, sets a uniform wholesale price w and the return price r. As a function of the manufacturer's returns policy, the retailer selects its order quantity of s units during the second stage. In the third stage, demand uncertainty gets resolved (i.e., demand is high or low), and the retailer sets the price p_i , such that i = h or l.

Retailer's problem

The manufacturer, the leader in the first stage, sets the wholesale and return prices. For a given returns policy, the retailer's decisions include the order quantity s and the retail price p_i , after demand uncertainty is resolved.

When the demand outcome is high (probability $1 - \lambda$), the retailer sets the price p_h , subject to demand $d_h \leq s$. Because the return price $r \leq w$, the retailer never orders units with the intention of returning them. Therefore, when the demand outcome is high (best case), the number of units ordered in the second stage is just sufficient to meet the demand, that is, *s*. (We can prove by contradiction that $s > d_h$ is not optimal if r < w.) In turn, $d_h = \alpha_h - \beta p_h = s$, so $p_h = (\alpha_h - s)/\beta$. The optimal profit for the retailer then is:

$$d_h p_h - sw = \left(\frac{\alpha_h - s}{\beta}\right)s. \tag{1}$$

If demand is low (probability λ), because the retailer has ordered *s* units in the second stage, its objective is to set the price p_l . For a chosen value of p_l , demand is $d_l = \alpha_l - \beta p_l$; for this demand to be feasible, $s > d_l$. We first consider the case in which this constraint does not hold, such that sales are not constrained when the demand outcome is low; we determine the conditions in which this assumption is true subsequently.

The optimization problem for the retailer (third stage) when demand is low is $Max_{pl}d_lp_l + (s - d_l)r$, where $d_l = \alpha_l - \beta p_l$. The first term refers to the revenue collected by selling the product, whereas the second term is the revenue from returning merchandise. Because the order is placed in the second stage, the purchasing cost (*sw*) is a sunk cost and does not figure into the optimization problem during the third stage. Taking the derivative w.r.t. p_l , we get $p_l = (\alpha_l + \beta r)/2\beta$ and $d_l = (\alpha_l - \beta r)/2$. Note that we need $d_l = ((\alpha_l - \beta r)/2) \le s$ to ensure that the solution is feasible. The optimal profit for the retailer when demand

	Partial returns (PR)	No returns (NR)	Full returns (FR)	Ranking
w	$\frac{\bar{\alpha}+\beta c}{2\beta}$	$\frac{(1-\lambda)\alpha_h+\beta c}{2\beta}$	$\frac{\bar{\alpha}+\beta c}{2\beta}$	PR = FR > NR
r	$\frac{\alpha_l}{2\beta}$	0	$w^{2\rho}$	FR > PR > NR
S	$\frac{\tilde{(1-\lambda)}\alpha_h - \beta c}{4(1-\lambda)}$	$rac{(1-\lambda)lpha_h-eta c}{4(1-\lambda)}$	$\frac{2\alpha_h - \bar{\alpha} - \beta c}{4}$	FR > PR = NR
p_h	$\frac{3(1-\lambda)\alpha_h + \beta c}{4\beta(1-\lambda)}$	$\frac{3(1-\lambda)\alpha_h + \beta c}{4\beta(1-\lambda)}$	$rac{2lpha_h+arlpha+eta c}{4eta}$	PR = NR > FR
p_l	$\frac{3\alpha_l}{4\beta}$	$\frac{\alpha_l}{2\beta}$	$rac{2lpha_l+arlpha+eta c}{4eta}$	FR > PR > NR
\bar{p}	$\frac{3\bar{lpha}+eta c}{4eta}$	$rac{(1-\lambda)lpha_h+2arlpha+etaar lpha}{4eta}$	$\frac{3\bar{lpha}+eta c}{4eta}$	PR = FR > NR
$\bar{p} - w$	$rac{arlpha-eta c}{4eta}$	$rac{2arlpha - (1-\lambda)lpha_h + eta c}{4eta}$	$\frac{ar{lpha} - eta c}{4eta}$	NR > PR = FR
$p_h - p_l$	$\frac{3(1-\lambda)(\alpha_h-\alpha_l)+\beta c}{4\beta(1-\lambda)}$	$\frac{(1-\lambda)\alpha_h + 2(1-\lambda)(\alpha_h - \alpha_l) + \beta c}{4\beta(1-\lambda)}$	$\frac{\alpha_h - \alpha_l}{2\beta}$	NR > PR > FR
Π_{M}	$\frac{((1-\lambda)\alpha_h - \beta c)^2 + \lambda(1-\lambda)\alpha_l^2}{8\beta(1-\lambda)}$	$\frac{((1-\lambda)\alpha_h - \beta c)^2}{8\beta(1-\lambda)}$	$\frac{(\bar{\alpha}+\beta c)^2 - 4\beta c\alpha_h}{4\beta}$	PR – highest

is low therefore is

$$d_l p_l + (s - d_l)r = \left(\frac{\alpha_l^2 - \beta^2 r^2}{4\beta}\right) + \left(s - \frac{\alpha_l - \beta r}{2}\right)r.$$
 (2)

According to Eqs. (1) and (2), the expected profit for the retailer (including purchasing cost) is:

$$\Pi^{r} = \lambda \left[\frac{\alpha_{l}^{2} - \beta^{2} r^{2}}{4\beta} + \left(s - \frac{\alpha_{l} - \beta r}{2} \right) r \right] + (1 - \lambda) \left[\left(\frac{\alpha_{h} - s}{\beta} \right) s \right] - sw.$$
(3)

The expected profit function \prod^r clearly is concave in *s*, so the first conditions are sufficient as well. From the first-order conditions, we get $s = ((1 - \lambda)\alpha_h + \lambda\beta r - \beta w)/2(1 - \lambda)$. Accordingly, the excess stock returned to the manufacturer $(s - d_l)$ when demand is low is $((\alpha_h - \alpha_l)(1 - \lambda) - \beta(w - r))/2(1 - \lambda)$.

Manufacturer's problem

We now solve the manufacturer's problem (first stage) to determine the optimal returns policy (w^* and r^*). The profit for the manufacturer includes the profit from selling *s* units to the retailer, less any loss from returned merchandise. Because the retailer returns items only when demand is low,

$$\Pi^{m} = s(w-c) - \lambda(s-d_{l})r$$

$$= \left[\frac{(1-\lambda)\alpha_{h} + \gamma\beta r - \beta w}{2(1-\lambda)}\right](w-c)$$

$$-\lambda \left[\frac{(\alpha_{h} - \alpha_{l})(1-\lambda) - \beta(w-r)}{2(1-\lambda)}\right]r.$$
(4)

Again, we can easily show that the expected profit function for the manufacturer is jointly concave in w and r. Then, using the first-order conditions, we get $r^* = \alpha_l/2\beta$ and $w^* = ((\alpha_h - \lambda(\alpha_h - \alpha_l) + \beta c)/2\beta) = ((\bar{\alpha} + \beta c)/2\beta)$, where $\bar{\alpha} = \lambda \alpha_l + (1 - \lambda)\alpha_h$ is the expected market potential of the product. Although the optimal wholesale price depends on the nature of the demand (i.e., market potential and the probability of low and high demand outcomes), the return price depends only on the market potential when demand is low, because returns occur only when demand outcomes are low. Also, $r^* < w^*$, which means it is optimal for the manufacturer to offer partial returns.

By substituting the values of w^* and r^* into the expression for s, we obtain $s^* = ((1 - \lambda)\alpha_h - \beta c)/4(1 - \lambda)$. Thus, the optimal order quantity does not depend on α_l , because when demand outcomes are low, the retailer sets the price (and hence the demand) with an assumption of an unconstrained supply of goods. In addition, $d_l = ((\alpha_l - \beta r)/2) = (\alpha_l/4)$. Because we assume that $s \ge d_l$, we verify that $s^* \ge d_l$ if $(\alpha_h - \alpha_l) \ge (\beta c/(1 - \lambda))$. We refer to this condition as high variability in demand. Finally, substituting the optimal values of w^* , r^* , and s^* into Eq. (4), we realize the optimal profit for the manufacturer:

$$\prod_{partial}^{m*} = \frac{\left[(1-\lambda)\alpha_h - \beta_c\right]^2 + \lambda(1-\lambda)\alpha_l^2}{8(1-\lambda)\beta}.$$
(5)

We summarize the expressions for the partial returns case in Table 2, compared with the expressions derived for the no and full returns cases (cf. PP97, Table 3).

Summary and discussion

We thus can derive the difference in the manufacturer's profits in the partial, full, and no return cases:

$$\prod_{partial}^{m^*} - \prod_{full}^{m^*} = \frac{\lambda [(1-\lambda)(\alpha_h - \alpha_l) + \beta c]^2}{8(1-\gamma)\beta} > 0,$$

and
$$\prod_{partial}^{m^*} - \prod_{no \ returns}^{m^*} = \frac{\lambda \alpha_l^2}{8\beta} > 0.$$

As expected, the manufacturer's profits are highest with partial returns, which is not surprising because the optimal value lies between no returns and full returns.

We measure demand variability according to the difference $(\alpha_h - \alpha_l)$ for a fixed λ . Therefore, if α_l is fixed, increasing α_h signifies higher demand variability. In this context, PP97 suggest that a no returns policy becomes more attractive as demand

Table 3
Retailer effort model results.

	Partial returns (PR)	No returns (NR)	Full returns (FR)	Ranking
\overline{w}	$\frac{\ddot{\alpha}+\beta c}{2\beta}$	$\frac{(1-\lambda)\alpha_h+\beta c}{2\beta}$	$\frac{\bar{\alpha}+\beta c}{2\beta}$	PR = FR > NR
r	$\frac{\alpha_l}{2\beta}$	0	w	FR > PR > NR
S	$\frac{\frac{1}{\eta\beta}((1-\lambda)\alpha_h - \beta_c)}{2(1-\lambda)(2\eta\beta - 1)}$	$\frac{\eta\beta((1-\lambda)\alpha_h - \beta c)}{2(1-\lambda)(2\eta\beta - 1)}$	$\frac{\eta\beta(2\alpha_h - \bar{\alpha} - \beta c)}{2(2\eta\beta - 1)}$	FR > PR = NR
p_h	$\frac{(3\eta\beta-1)(1-\lambda)\alpha_h+\beta c(\eta\beta-1)}{2\beta(1-\lambda)(2\eta\beta-1)}$	$\frac{(3\eta\beta-1)(1-\lambda)\alpha_h+\beta c(\eta\beta-1)}{2\beta(1-\lambda)(2\eta\beta-1)}$	$\frac{(\eta\beta-1)(\bar{\alpha}+\beta c)+2\eta\beta\alpha_h}{2\beta(2\eta\beta-1)}$	PR = NR > FR
p_l	$\frac{(3\eta\beta-1)\alpha_l}{2\beta(2\eta\beta-1)}$	$\frac{\eta \alpha_l}{2\eta \beta - 1}$	$\frac{(\eta\beta-1)(\bar{\alpha}+\beta c)+2\eta\beta\alpha_l}{2\beta(2\eta\beta-1)}$	FR > PR > NR
\bar{p}	$\frac{(3\eta\beta-1)\bar{\alpha}+\beta c(\eta\beta-1)}{2\beta(2\eta\beta-1)}$	$\frac{(3\eta\beta-1)\bar{\alpha}+\beta c(\eta\beta-1)-\lambda(\eta\beta-1)\alpha_l}{2\beta(2\eta\beta-1)}$	$\frac{(3\eta\beta-1)\bar{\alpha}+\beta c(\eta\beta-1)}{2\beta(2\eta\beta-1)}$	PR = FR > NR
$\bar{p} - w$	$rac{\eta(ar{lpha}-eta c)}{2(2\etaeta-1)}$	$rac{\eta(ar{lpha}-eta c)+\lambda\etalpha_l}{2(2\etaeta-1)}$	$rac{\eta(ar{lpha}-eta c)}{2(2\etaeta-1)}$	NR > PR = FR
$p_h - p_l$	$\frac{(1-\lambda)(3\eta\beta-1)(\alpha_h-\alpha_l)+\beta c(\eta\beta-1)}{2\beta(1-\lambda)(2\eta\beta-1)}$	$\frac{(1-\lambda)\eta\beta\alpha_h + (1-\lambda)(2\eta\beta-1)(\alpha_h - \alpha_l) + \beta c(\eta\beta-1)}{2\beta(1-\lambda)(2\eta\beta-1)}$	$\frac{\eta(\alpha_h - \alpha_l)}{(2\eta\beta - 1)}$	NR > PR > FR
e_h	$\frac{(1\!-\!\lambda)\alpha_h\!-\!\beta c}{2(1\!-\!\lambda)(2\eta\beta\!-\!1)}$	$rac{(1-\lambda)lpha_h-eta c}{2(1-\lambda)(2\etaeta-1)}$	$\frac{\lambda(\alpha_h - \alpha_l) + (\alpha_h - \beta c)}{2(2\eta\beta - 1)}$	FR > PR = NR
el	$\frac{\alpha_l}{2(2\eta\beta-1)}$	$rac{lpha_l}{2\etaeta-1}$	$\frac{\lambda(\alpha_h - \alpha_l) + (\alpha_l - \beta_c) - (\alpha_h - \alpha_l)}{2(2\eta\beta - 1)}$	NR > PR > FR
$e_h - e_l$	$rac{ar{lpha} - (lpha_l + eta c)}{2(1 - \lambda)(2\etaeta - 1)}$	$\frac{(1-\lambda)(\alpha_h-\alpha_l)-\beta c-(1-\lambda)\alpha_l}{2(1-\lambda)(2\eta\beta-1)}$	$rac{lpha_h-lpha_l}{2\etaeta-1}$	FR > PR > NR
ē	$\frac{\bar{\alpha}-eta c}{2(2\etaeta-1)}$	$rac{(ar{lpha}-eta c)+\lambda lpha_I}{2(2\etaeta-1)}$	$rac{ar{lpha} - eta c}{2(2\etaeta - 1)}$	NR > PR = FR
Пм	$\frac{\eta[((1-\lambda)\alpha_h - \beta c)^2 + \lambda(1-\lambda)\alpha_l^2]}{4(1-\lambda)(2\eta\beta - 1)}$	$\frac{\eta((1-\lambda)\alpha_h - \beta_c)^2}{4(1-\lambda)(2\eta\beta - 1)}$	$\frac{\eta[(\bar{\alpha}-\beta c)^2-4\lambda\beta c(\alpha_h-\alpha_l)]}{4(2\eta\beta-1)}$	PR – highest

variability increases (that is, as α_h increases for a fixed α_l and λ) or as production costs *c* increase. Intuitively, if the manufacturer can only offer full returns, as α_h increases, the retailer increases its stocking level, because it can return any unsold item at the full wholesale price. For a fixed α_l and λ , the manufacturer's cost associated with the risk of returns increases, reducing the appeal of the full return policy. For sufficiently large α_h (fixed α_l and λ), the no return policy dominates the full return policy.

As α_h increases (or α_l decreases for a fixed λ), demand variability increases, and partial returns become even more attractive than full returns. The same effect occurs for higher production costs *c*. A sufficient condition for $\partial [\prod_{partial}^{m^*} - \prod_{full}^{m^*}]/\partial \lambda$ to be greater than 0 takes place when $\lambda \leq 1/2$, such that partial returns become more attractive as λ (probability of low demand) increases ($\lambda = 1/2$ is the maximum variability for a fixed α_h and α_l). The difference in the profits increases in λ even when $\lambda > 1/2$, but other conditions also are needed.

This result differs from PP97's observation because they do not consider partial returns. The difference in manufacturer profits between partial and no returns depends on α_l and is independent of α_h , which means we can measure the impact of demand variability by changing α_l . The difference in profits between the partial return and no return policies decreases as α_l decreases, but it increases with λ (probability of low demand). Thus, this result is similar to PP97's, because the attraction of partial returns (over no returns) declines as demand variability increases. Finally, we note that $\prod_{partial}^{m^*} = \prod_{noreturns}^{m^*}$ if $\alpha_l = 0$, because the optimal returns price $r^* = 0$ as well. Essentially, partial returns are preferable to full returns for high demand variability, but their value compared with no returns decreases with demand variability.

Whereas PP97 establish that return policy encourage retailers to stock merchandise and the inventory costs are borne by the manufacturer, we find that this result does not hold for the linear additive demand model when the manufacturer offers partial returns. The optimal stocking level *s* with partial returns (see Table 2) remains the same as that with no returns, even though partial returns yield the highest expected profit for the manufacturer. Partial returns thus do not provide any incentive for the retailer to order excess quantity (compared with a no return situation). The optimality of partial returns case may result from the unit profit margin for the manufacturer.

When the firm offers partial returns, it charges the wholesale price it would earn if it were offering full returns. However, the retailer does not stock more and orders the same amount it would have ordered with a no return policy, though the average retail price equals that of the full return case. Thus, the partial returns case cannot be the average of the full and no returns cases. According to PP97, full returns induce more stocking (which contributes to the attractiveness of the returns policy), whereas our analysis shows that with partial returns, the optimal wholesale price is higher than that with no returns, and the manufacturer's unit profit margin is higher. It also decreases the quantity of returned items at a lower return price (compared with the full return case).

For the retailer, the unit margin $(\bar{p} - w)$ is highest with no returns; the margins are equal (but lower) for the other two cases. The price dispersion $(p_h - p_l)$ is greatest for the no returns case and lowest for full returns, with an intermediate value for partial returns. Intuitively, as the manufacturer increases the return price, the retailer likely prices higher for the low demand outcome and thus prefers to use the return option.

Partial returns do not encourage the retailer to hold more stock than it would in the no returns case, even though that decision would maximize profits for the manufacturer. We next consider the case in which the retailer and manufacturer invest in demand-enhancing activities and determine the conditions in

	Partial returns (PR)	No returns (NR)	Full returns (FR)	Ranking
w	$\frac{2\bar{\alpha}+(2\beta-1)c}{4\beta-1}$	$\frac{2(1-\lambda)\alpha_h + ((2\beta-1)+\lambda)c}{(4\beta-1)+\lambda}$	$\frac{2\bar{lpha}+(2\beta-1)c}{4\beta-1}$	PR = FR > NR
r	$\frac{\alpha_l}{2\beta} + \frac{\bar{\alpha} - \beta c}{2\beta(4\beta - 1)}$	0	w	FR > PR > NR
θ	$\frac{\bar{\alpha}-eta c}{4eta-1}$	$rac{(1-\lambda)lpha_h-eta c}{(4eta-1)+\lambda}$	$\frac{\bar{lpha} - eta c}{4eta - 1}$	PR = FR > NR
S	$\frac{(1-\lambda)(\bar{\alpha}-\beta c)+(4\beta-1)[(1-\lambda)\alpha_h-\beta c]}{4(1-\lambda)(4\beta-1)}$	$\frac{\beta[(1-\lambda)\alpha_h - \beta_c]}{(1-\lambda)[(4\beta-1)+\lambda]}$	$\frac{\lambda(\alpha_h-\alpha_l)(2\beta-1)-2\beta(\alpha_h-\beta c)}{2(4\beta-1)}$	FR>PR>NR
p_h	$\frac{3(1-\lambda)(4\beta\alpha_h-\lambda(\alpha_h-\alpha_l))+\beta c(4\beta-4+3\lambda)}{4\beta(1-\lambda)(4\beta-1)}$	$\frac{3(1-\lambda)\alpha_h + c(\beta-1+\lambda)}{(1-\lambda)[(4\beta-1)+\lambda]}$	$\frac{6\beta\alpha_h+2\beta c(\beta-1)-\lambda(1+2\beta)(\alpha_h-\alpha_l)}{2\beta(4\beta-1)}$	PR > FR > NR
p_l	$\frac{3((1-\lambda)\alpha_h - \beta c) + (4\beta - 1 + \lambda)\alpha_l}{4\beta(4\beta - 1)}$	$\frac{4\beta\alpha_l + (1-\lambda)(\alpha_h - \alpha_l) - \beta c}{2\beta[(4\beta - 1) + \lambda]}$	$\frac{(2\beta+1)(1-\lambda)\alpha_h+2\beta c(\beta-1)-(2\beta(2+\lambda)-(1-\lambda))\alpha_l}{2\beta(4\beta-1)}$	FR>PR>NR
\bar{p}	$\frac{3\bar{\alpha} + (\beta - 1)c}{4\beta - 1}$	$\frac{(1-\lambda)(6\beta+\lambda)\alpha_h+\lambda(4\beta-1+\lambda)\alpha_l+\beta c(2\beta-2+\lambda)}{2\beta(4\beta-1+\lambda)}$	$\frac{3\tilde{\alpha}+(\beta-1)c}{4\beta-1}$	PR = FR > NR
$\bar{p} - w$	$\frac{\bar{\alpha}-\beta c}{4\beta-1}$	$\frac{(1-\lambda)(2\beta+\lambda)\alpha_h+\lambda(4\beta-1+\lambda)\alpha_l-\beta c(2\beta+\lambda)}{2\beta(4\beta-1+\lambda)}$	$\frac{\bar{lpha} - eta c}{4eta - 1}$	NR > PR = FR
$p_h - p_l$	$\frac{3(1-\lambda)(\alpha_h-\alpha_l)+\beta c}{4\beta(1-\lambda)}$	$\frac{2(1-\lambda)(4\beta-1+\lambda)(\alpha_h-\alpha_l)+\beta c(4\beta-1+\lambda)+\beta(1-\lambda)(4\alpha_h-c)}{2\beta(4\beta-1+\lambda)}$	$\frac{\alpha_h - \alpha_I}{2\beta}$	NR > PR > FR
Π_{M}	See below	$\frac{((1-\lambda)\alpha_h - \beta c)^2}{2(1-\lambda)(4\beta - 1 + \lambda)}$	$\frac{(\alpha_h-\beta c)^2+\lambda^2(\alpha_h-\alpha_l)^2-\lambda(\alpha_h-\alpha_l)(2\alpha_h+(2\beta-1)c)}{2(4\beta-1)}$	PR – highest
Notes: П _M	(partial) = $\frac{[(1-\lambda)^2(4\beta-\lambda)\alpha_h^2 - 2\lambda(1-\lambda)\beta c\alpha_h]}{8}$	$+(4\beta-\lambda)\beta^2c^2+\lambda(1-\lambda)(4\beta-1)\alpha_l^2+\lambda^2(1-\lambda)\alpha_l^2]$ $\frac{(4\beta-\lambda)(4\beta-1)}{(4\beta-1)}$		

Table 4 Manufacturer branding model results.

more stock.

 $8\beta(1-\lambda)(4\beta-1)$ which partial returns provide an incentive for the retailer to order

Returns model with retailer investment in effort

We now consider the case in which, in addition to setting the retail price, the retailer makes an investment decision about selling effort, and $d_i = \alpha_i - \beta p_i + e_i$, where i = l and i = h with probability λ and $(1 - \lambda)$, respectively. The cost of the retailer's selling effort is $\eta e_i^2/2$, which enables us to model the diminishing impact of effort on demand. Similar demand models appear in Desai and Srinivasan (1995).

Using the same methodology as that for the base model, we determine the optimal parameters for the case of partial returns and compare it with the no and full returns cases. Although PP97 do not consider retailer effort, the solution method for the no and full returns cases is identical to that in a model without effort. We summarize the expressions for the partial returns case in Table 3, with comparisons for the no returns and full returns cases.

As shown for the base model, the expected profits for the manufacturer are highest in the partial returns case. The optimal returns policy (w, r) remains the same regardless of whether the retailer chooses to exert effort, and the retailer's stocking level s stays the same for the no returns and partial returns cases (see Table 3). That is, the provision of partial returns again does not provide sufficient incentive for the retailer to choose a higher stocking level (compared with no returns).

Does the retailer order more in the effort model (Table 3) compared with the base model with no effort (Table 2)? In the comparison of the order quantity s between the two models (for each scenario of no returns, partial returns, and full returns), we note that the retailer orders more in the effort model. Essentially, because retailer investment in effort increases overall demand potential, the order quantity is higher than in the base model. However, within the effort model, the provision of partial return polices does not lead to higher order quantities; that is, partial returns do not provide incentive to the retailer to increase order quantity compared with the case of no returns. Instead,

the retailer exerts costly selling effort and benefits from the investment by setting higher resale price.

The trade-off the manufacturer confronts in selecting (w, r)remains exactly the same as that without retailer effort, and the optimal (w, r) in the retailer effort model are identical to those in the base model. The manufacturer therefore sets the optimal wholesale and return policy to improve its margins (compared with no returns) and reduce the quantity of returned items (compared with full returns).

We now discuss the contrasting use of price and effort dispersion by the retailer. Price dispersion $(p_h - p_l)$ is highest for the no return case and lowest for full returns, with an intermediate value for partial returns. Regarding the retailer's investment, expected effort $\bar{e} = \lambda e_l + (1 - \lambda)e_h$ is greatest when the manufacturer does not offer returns, but it stays the same for partial and full returns, so the provision of full returns does not appear to reduce expected effort. Effort dispersion $(e_h - e_l)$, in contrast with price dispersion, reaches the lowest level with no returns and the highest point with full returns. Without returns, the retailer uses the highest price dispersion in conjunction with the lowest effort dispersion to maximize its profits. As the manufacturer increases the return price (from partial to full returns), the price and effort dispersions move in opposite directions. Intuitively, as the return price increases, the retailer should price items higher under the low demand outcome, which decreases price dispersion. In contrast, because the return policy reduces the incentive for the retailer to invest in extra effort, its optimal effort in a low demand condition declines, which leads to greater effort dispersion.

We again note that partial returns do not offer adequate incentive to the retailer to increase its stocking level compared with the no returns case. In agreement with the traditional view, our analysis confirms that the retailer's expected effort is the highest without returns, though it remains the same between the partial and full return conditions. The retailer's effort and pricing decisions contrast, such that as the return price increases (decreases) and effort dispersion increases (decreases), pricing dispersion decreases (increases). A higher return price enables the retailer to adjust its level of investment in selling effort while still maintaining stable prices in different demand outcomes.

Returns model with manufacturer investment in quality/brand

In this section, we describe a case in which the manufacturer invests in product quality or brand name, which improves the demand potential of the product. In contrast with the retailer's effort investment, the manufacturer typically invests in its product quality or brand name prior to the realization of demand uncertainty. That is, demand $d_i = \alpha_i + \theta - \beta p_i$, where i = l and i = h with probability λ and $(1 - \lambda)$, respectively, and θ is the manufacturer's investment at cost $\theta^2/2$, which enables us to model the diminishing return of the quality investment for demand.

The optimal contract offered by the manufacturer features the wholesale price (w), return price (r), and investment in quality (θ) . We summarize the expressions for the partial return case in Table 4, compared with those for the no and full returns cases.

Manufacturer profits again are highest in the partial returns case. In contrast with the other models, the optimal returns price r is higher (equal to $(\alpha_l/2\beta) + ((\bar{\alpha} - \beta c)/(2\beta(4\beta - 1)))$ and depends not only on α_l but also on other demand parameters (α_h, λ) , because the manufacturer's investment occurs before the realization of demand uncertainty and depends on all demand parameters.

Similar to the two previous models, wholesale price is lowest for the no returns case but equally high for the partial and full returns cases. The absolute values of the wholesale and return prices increase when the manufacturer invests in product quality, because the investment improves demand potential, which enables the manufacturer (and retailer) to charge higher prices. The level of manufacturer investment in different scenarios yields interesting results; it is lowest for the no return case (as is the wholesale price), yet it remains the same in the partial and full returns cases (wholesale prices are higher and equal). When the manufacturer decides to offer a return policy, its investment in product quality becomes fixed and does not depend on the returns price.

However, unlike the previous two models, the level of the return price directly affects the retailer's stocking decision, such that this level is lowest for no return case, intermediate for partial returns, and highest for full returns. When the manufacturer invests in demand-enhancing activities and offers a higher return price, it provides incentive for the retailer to choose a higher stocking level, even though the manufacturer's investment remains the same in both the partial and full returns cases.

To summarize our findings, we note that the manufacturer has access to a third decision variable when selecting θ . Because it undertakes in quality investments prior to realizing demand uncertainty, it suffers additional risk. To benefit from its investment, irrespective of realized demand outcomes, it must prompt larger orders from the retailer without comprising its unit profit margin. Therefore, it selects the price parameters (w, r) to ensure that the retailer's order quantity is higher in the partial versus no return condition and that the order size is not so high that it adversely affects profits, which occurs with full returns when the retailer's order is at the highest level. Because returns take place only when the realized demand outcome is low, the manufacturer can benefit from a larger order when the demand outcome is high.

Model with asymmetric demand estimates

To extend our model, we consider the case in which the manufacturer and retailer estimate the nature of demand uncertainty differently, as in a real market space in which the manufacturer has more product-specific knowledge, but the retailer, which is closer to the market, may have better information about market conditions. We derive the optimal expected profits for the manufacturer and retailer and show that though the retailer's estimates influence the expected profits for both the manufacturer and the retailer, the manufacturer's estimate affects only its own profits, because the retailer simply reacts by changing its order quantity.

In the base model in the previous section, we let λ be the probability of a low demand outcome and assume the manufacturer and retailer agree about the value of λ . Here, the manufacturer and retailer have different estimates, because the retailer estimates that the probability of low demand is λ_r whereas the manufacturer's estimate is λ_m . Although the players declare their estimates, they have no reason to agree on a common value for the probability of low demand. Disagreement about mutual beliefs commonly occurs among rational agents, because they have different priors (Aumann, 1976).

The model we consider differs from standard models with asymmetric information. Whereas asymmetric information models typically assume that one side has perfect information, in our research, both players use their own estimates, which are based on the partial information available to them. Thus, both estimates may be incorrect, though each player uses its own "best" estimate to make decisions. Gurnani and Shi (2006) use a similar approach to model a bargaining problem in which the buyer and supplier have different estimates of supply delivery.²

The manufacturer likely has a lower estimate of λ_m (smaller λ_m value implies high demand probability, so the manufacturer should be more optimistic about the chance of success), but we do not require any restriction on the relative ordering of λ_r and λ_m . The qualitative nature of our results does not depend on any assumption of values for λ_r and λ_m .

We start by analyzing the retailer's problem for a given returns policy offered by the manufacturer (w, r). The retailer makes ordering and pricing decisions on the basis of its own estimate of the low demand outcome (λ_r) . Similar to the expressions for the case of equal demand estimates, from Eq. (3), we have

$$\prod^{r} = \lambda_{r} \left[\frac{\alpha_{l}^{2} - \beta^{2} r^{2}}{4\beta} + \left(s - \frac{\alpha_{l} - \beta r}{2} \right) r \right] + (1 - \lambda_{r}) \left[\left(\frac{\alpha_{h} - s}{\beta} \right) s \right] - sw.$$
(8)

 $^{^2}$ In other approaches used in literature on information asymmetry, players update their own beliefs using Bayesian updating. We defer the analysis of updating of beliefs to future research.

The retailer's expected profit function is concave in s, and the optimal order quantity is:

$$s = \frac{(1 - \lambda_r)\alpha_h + \lambda_r\beta r - \beta w}{2(1 - \lambda_r)}.$$
(9)

The retailer's order quantity increases in r and decreases in w, as we expected. Furthermore, the order quantity explicitly depends on λ_r only when λ_m is embedded in the manufacturer's offer (w, r). The overall effect of both estimates on the optimal order quantity depends on their relative values. As we demonstrate subsequently, the retailer may increase the order quantity even in the face of less optimism about demand outcomes if the manufacturer offers a contract with lower wholesale and higher return prices.

For the manufacturer, the expected profit depends on the order quantity s, the number of items returned $(s - d_l)$, and its own estimate of low demand outcomes (λ_m) . According to Eq. (4), the manufacturer's expected profit function is:

$$\Pi^{m} = \left[\frac{(1-\lambda_{r})\alpha_{h} + \lambda_{r}\beta r - \beta w}{2(1-\lambda_{r})}\right](w-c) -\lambda_{m}\left[\frac{(\alpha_{h} - \alpha_{l})(1-\lambda_{r}) - \beta(w-r)}{2(1-\lambda_{r})}\right]r.$$
 (10)

The expected profit function for the manufacturer again is jointly concave in w and r when $\lambda_m > \lambda_r^2$. Using the first-order conditions, we get:

$$r^* = \frac{(1 - \lambda_r)(\lambda_r - \lambda_m)\alpha_h + 2\lambda_m(1 - \lambda_r)\alpha_l - \beta c(\lambda_r - \lambda_m)}{\beta[4\lambda_m - (\lambda_m + \lambda_r)^2]},$$

and (11)

$$w^* = \frac{1}{2\beta} [(1 - \lambda_r)\alpha_h + (\lambda_m + \lambda_r)\beta r^* + \beta c].$$
(12)

The expression for w^* includes r^* ; taking the partial of w^* in Eq. (12) with respect to λ_m , we get $(\partial w^*/\partial \lambda_m) =$ $(1/2\beta)[\beta(\lambda_m + \lambda_r)(\partial r^*/\partial \lambda_m) + (1 + \lambda_r)\beta r^*].$

From the manufacturer's perspective, wholesale and returns prices may play different roles as incentives that prompt the retailer to place appropriate orders. For example, when λ_m increases and the manufacturer is less optimistic about the demand outcome, it likely reduces the wholesale price, because it believes the product has a lower chance of sparking high demand. From the preceding partial derivative, we know that as w^* decreases in λ_m , r^* decreases in λ_m , such that the manufacturer does not offer a higher return price as an incentive to the retailer if it is less optimistic about the demand outcome. The wholesale price also declines, reflecting the smaller probability that the product achieves high demand potential. However, the risk of higher costs due to product returns leads to a lower return price.

Substituting r^* and w^* into Eq. (9), we can compute the retailer's optimal order quantity s^* . Finally, we determine the optimal profits for the retailer and the manufacturer from Eqs. (8) and (10), respectively.

Sensitivity analysis

We determine the effect of various system parameters on the optimal decisions and optimal profits for the manufacturer and retailer. In the base case example, $\alpha_h = 200$, $\alpha_l = 100$, c = 5, $\beta = 5$, $\lambda_r = .4$, and $\lambda_m = .3$; therefore, the manufacturer is more optimistic than the retailer about the demand outcome. Solving for the optimal parameters, we realize $w^* = 18.99$, $r^* = 12.82$, and $s^* = 42.25$. The optimal prices are $p_l^* = 16.4$ and $p_h^* = 31.6$. Finally, the optimal profits are 497.6 for the manufacturer and 240.0 for the retailer.

Impact of manufacturer's estimate

To study the effect of an increase in the manufacturer's estimate of the probability of low demand λ_m for a given value of the retailer's estimate λ_r , we vary λ_m from .2 to .6 in increments of .1 and keep $\lambda_r = .4$ constant. As λ_m increases, the manufacturer infers that the probability of low demand increases, which means the retailer is more likely to return goods. Therefore, the manufacturer reduces the risk of product returns by decreasing the return price r^* , and the retailer decreases the order quantity (even though its estimate of low demand remains unchanged). To influence the retailer to order more, the manufacturer must reduce the wholesale price to offset the reduction in the return price, at least partially.

Regarding retailer prices, we first consider the case of low demand. Because the return price has decreased, the retailer wants to reduce the number of returns and therefore decreases the retail price p_l^* . When demand is high, because the retailer already has diminished its order quantity and set its retail price to clear inventory, p_h^* increases with increasing λ_m . Regarding the pricing margins, because the product has lower market potential (according to the manufacturer's estimate), the manufacturer's margin $(w^* - c)$ decreases, as expected. For the retailer, the margin $(p_i^* - w^*)$ increases when demand is high and decreases when demand is low. Finally, the expected profit for the manufacturer decreases with increasing λ_m , whereas the retailer, with its unchanged estimate, reacts to the manufacturer's returns policy and appropriately changes the size of the order quantity. The expected profit for the retailer is almost flat (decreases marginally) with increasing λ_m at values of .3 or higher. For lower values of λ_m (i.e., manufacturer is optimistic about high demand outcome), the retailer's profits increase, because the optimistic manufacturer offers a higher return price. In Fig. 1, we provide a graphical representation of these observations.

Impact of retailer's estimate

To determine the effect of an increased probability of low demand outcomes, according to the retailer's estimate (λ_r) , we vary λ_r from .2 to .6 in increments of .1 and keep $\lambda_m = .4$ constant. If the retailer infers a greater probability of low demand, it reduces its order quantity, which should prompt the manufacturer to increase the return price (because its estimate is unchanged) and decrease the wholesale price to provoke a larger order. Initially, when λ_r increases, order quantity decreases, but



Fig. 1. Impact of manufacturer's estimate of demand.

the combined effect of a higher return price and lower wholesale price eventually leads to increased order quantity.

Regarding the retail price, when the demand outcome is low, the retail price p_l^* increases because the return price has increased. For high demand outcomes, the retailer sets its price to clear the inventory, which means it first increases and then decreases with increasing λ_r . The margin for the manufacturer decreases as the wholesale price drops, whereas for the retailer, the margins improve. Finally, the expected profits for both the manufacturer and the retailer decrease with increasing λ_r . We illustrate the effect of the retailer's estimate on outcomes in Fig. 2.

To summarize, whereas the retailer's estimate influences the expected profits for both the manufacturer and the retailer, the manufacturer's estimate has a major impact only on its profits, because the retailer changes its optimal order quantity in response to the manufacturer's returns policy.



Fig. 2. Impact of retailer's estimate of demand.

Conclusions

Previous research on returns or buyback models essentially examines two types of demand models: multiplicative and additive. We use an additive demand model, for which the variance of demand is unaffected by the expected demand but the coefficient of variation decreases as expected demand becomes larger. Thus, we show that the manufacturer can maximize profits if it offers partial returns to the retailer, in support of the intuition contained in the review article by Cachon (2005). However, partial returns are not always optimal in other demand models (e.g., Granot and Yin 2005; Song, Ray, and Li, 2006). Intuitively, most manufacturers agree that return policies are beneficial in certain contexts, such as when lead times are high and demand gets realized only after the order is placed. In such a scenario, the appropriate provision of returns should mitigate the retailer's stocking risk and increase profits for the manufacturer.

We examine the role of returns by including partial returns into Padmanabhan and Png's (1997) model of no and full returns. In so doing, we reveal that partial returns do not induce an order quantity beyond that which the retailer would order with no returns. Instead, the benefit to the manufacturer comes in the form of higher profit margins and greater control over the quantity of returned items. When the manufacturer offers partial returns, it charges the same wholesale price as if it were offering full returns, yet the retailer does not stock anymore and orders the same amount as it would have with a no return policy, even though it charges an average retail price equal to that in the full return case. Thus, the partial returns case is not simply an average of the full and no returns cases.

To address the effect of investments in demand-enhancing activities, we create two separate models of retailer effort and manufacturer quality investments. We confirm conventional wisdom that the retailer's expected effort is highest when the manufacturer does not offer returns. Yet this expected effort remains the same with partial or full returns as well. In addition, the retailer makes its effort and pricing decisions in contrasting ways. As the return price increases (decreases), effort dispersion increases (decreases), but pricing dispersion decreases (increases). Thus, an increase in the return price enables the retailer to adjust its investment in selling effort but maintain stable prices, even for different demand outcomes. Although the retailer may exert costly effort, it benefits because it can set higher resale prices. For the manufacturer, the trade-off between selecting wholesale prices and its return policy remains the same, regardless of retailer effort, so providing partial returns does not induce higher stocking quantities from the retailer.

When the manufacturer invests in quality, it does so before it can resolve demand uncertainty. It can benefit from its investment, irrespective of the realized demand outcome, by inducing bigger orders from the retailer but without comprising on the unit profit margin. Therefore, the manufacturer sets the optimal wholesale price and return policy combination to improve the unit profit margin compared with the no returns case and increase the order quantity selected by the retailer by offering a higher return price. Because the retailer makes returns only when the realized demand outcome is low, the manufacturer benefits from inducing higher order quantities when the demand outcome is high. Our partial returns model features the case in which the manufacturer offers a returns price that is strictly lower than the wholesale price but does not impose any upper bound on the quantity of units that can be returned. A possible extension could include a restriction on the number of items that a retailer can return to the manufacturer. In additional research, we hope to examine the use of return policies when the manufacturer offers a return option to the retailer and the retailer also provides customers the option to return their used items. For example, in the textbook publishing industry, bookstores allow students to returns books at the end of the semester; what effect does this policy have on price and demand?

There is a growing stream of literature that deals with pricing issues and emerging trends in retail competition (Ailawadi, Kopalle, and Neslin 2005; González-Benito, Muñoz-Gallego, Kopalle, 2005; Kopalle et al. 2009; Levy et al. 2004). Another extension would be to consider use of returns in a competitive network of multiple manufacturers offering substitute products to multiple retailers. Finally, research should incorporate the role of reverse logistic integrators in models (Mukhopadhyay and Setaputra 2006). These reverse logistic integrators can enhance the efficiency of the supply chain by handling returns better than retailers.

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