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Trade Promotion Decisions Under Demand Uncertainty: A Market Experiment Approach

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In this paper, we examine trade promotion decisions in manufacturer–retailer channels where retailers face consumer demand uncertainty. We first present the theoretical analysis for two types of markets where trade promotion discounts are offered either as off-invoices or as scan-backs. We derive propositions by comparing wholesale and retail prices, retailer order quantities, and profits given the same trade promotion discount. Next, we extend the basic model so that the amount of trade promotion discount influences market expansion and solve for the optimal discount level. To test our theory, we then employ market experiments where we manipulate demand uncertainty and market expansion. Consistent with our theoretical predictions, we find that wholesale and retail prices are higher and retailer order quantities lower when the same amount of trade promotion discount is allocated to scan-backs versus off-invoices. In the market expansion condition, we find that manufacturers offer deeper discounts when trade promotions are allocated to off-invoices versus scan-backs. Overall, our research suggests that market experiments can shed light on trade promotion outcomes for which industry data are sparse or nonexistent.

Key words: channels of distribution; trade promotion; competitive strategy; market experiment
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1. Introduction

Trade promotions comprise a growing category of manufacturer incentives directed to retailers rather than to end consumers. These promotions are designed to influence retailers' sales and prices by providing various inducements. Manufacturers of consumer packaged goods (CPGs) are increasing their trade promotions worldwide. For example, in the United States, CPG manufacturers increased their trade promotions to retailers more than fourfold (from \$71 billion to \$312 billion) between 1996 and 2004 (Joyce 2005). Trade promotion spending of U.S. manufacturers accounted for an unprecedented 18.01% of their gross sales in 2010 (versus approximately 13% in 1998) and was their second largest expense after the cost of goods (The Hale Group 2010).

In spite of their growth, trade promotions often generate conflict in the distribution channel (Ailawadi et al. 2009). Trade promotion budgets may directly impact the effective wholesale price paid by retailers and profit sharing among members of the distribution channel. Moreover, manufacturers and retailers also decide on the budget allocation between two broad promotion types: discount and performance based. A manufacturer may offer a retailer discount-based trade promotions, in which a per-case discount is given for all retailer purchases of a given brand during a limited period of time (off-invoices). Or, a manufacturer may negotiate with a retailer performance-based trade promotions, in which a discount per case is given after a prespecified level of retail sales performance (e.g., target sales volume per week) has been attained and verified by retail sales scanning data (scan-backs).

The economics and marketing literatures have addressed factors that affect design and implementation of trade promotions between manufacturers and retailers. Regarding the manufacturers' decision on the amount of trade promotion discount, there is some empirical evidence that larger trade promotion discounts are associated with decreased brand differentiation (e.g., Mela et al. 1998), suggesting that large trade promotion discounts may be detrimental for manufacturers with strong brands. This indicates that a profit-maximizing manufacturer should offer smaller trade promotion discounts.

Limited research regarding channel members' preferences for trade promotion types seems to suggest that profit-maximizing retailers prefer off-invoices to scan-backs, whereas manufacturers prefer scan-backs to off-invoices. Empirical research by Gómez et al. (2007b) shows that retail companies with larger annual sales, stronger brand positioning, and formal trade promotion policies are able to increase the allocation to off-invoices and to decrease allocation to performance-based trade promotions (such as scan-backs). Similarly, Ailawadi et al. (1999) demonstrated that off-invoice allowances allow resellers to make discretionary use of such funds via forward buying (using trade promotions to build stocks for future sales) or simply not completely passing their cost savings on to their customers. Gómez et al. (2007a) used supermarket data to provide empirical evidence that retailers with bargaining power can increase the allocation of funds to off-invoice trade promotions by achieving higher market share for their private labels. Drèze and Bell (2003) developed a theoretical model to compare these two types of trade promotions with respect to retailers' benefits from forward buying and diverting.

However, the effect of demand uncertainty on trade promotion type decisions has not been examined in the prior literature. What is the impact of a trade promotion discount on manufacturer and retailer profits in the off-invoices versus scan-backs market when the agents face demand uncertainty? We answer these questions by developing a theoretical model for a one-manufacturer, one-retailer channel where the retailer faces stochastic demand in the end-consumer market. We compare the optimal behavior of the manufacturer and retailer for two allocation types where trade promotion discounts are offered either as off-invoices or as scan-backs. We derive propositions by comparing wholesale and retail prices, retailer order quantities, and profits given the same trade promotion discount. Next, we extend the basic model so that the amount of trade promotion discount influences market expansion (ME) and solve for the optimal discount level. We show that when there is no forward buying or diverting, off-invoices benefit manufacturers and retailers and the entire channel. Our model contributes to the theoretical literature of trade promotion by demonstrating how off-invoices and scan-backs operate differently when retailers face demand uncertainty.

Based on the setup of the theoretical model, we then simulate manufacturer–retailer dyads in interactive market experiments where we manipulate demand uncertainty and market expansion. In the trade promotion literature, a common problem encountered for empirical tests on the impact of various factors is the difficulty in obtaining expenditure data on trade promotions because they are part of a total firm's marketing expenditures and are inconsistently reported in financial statements (Ailawadi et al. 2009, Skibo 2007). Even when field data can be collected in surveys, it is difficult to ensure that all of the structural assumptions underlying the theories are satisfied. These limitations suggest that controlled laboratory experiments, where costs and values are induced and decision makers are motivated by monetary incentives, might be an appropriate tool to overcome the aforementioned limitations (Lim and Ho 2007). However, a recent assessment by Brown and Dant (2008) found that only a small number of retailing studies employ interactive experiments to examine distribution channel problems. To our knowledge, no prior experimental studies have investigated trade promotion budget and allocation decisions.

Our experiments are also different from typical market experiments where human subjects play against a computer representing the channel partner (e.g., Katok and Wu 2009). Our approach provides a realistic yet controlled trading environment to manipulate channel structure and test theoretical predictions that are difficult to examine using industry data. Consistent with our theoretical predictions, we find that wholesale and retail prices are higher and retailer order quantities lower when the same amount of trade promotion discount is allocated to scan-backs versus off-invoices. In the market expansion condition, we find that manufacturers offer deeper discounts when trade promotions are allocated to off-invoice versus scan-backs. We further validate our experimental results by showing the convergence of observed behavior toward predicted optimal behavior over time and discuss how risk attitudes may have influenced the observed behaviors.

Our theory and experiments combined provide useful insights into how demand uncertainty may play an important role in channels where trade promotions are offered. Our research also suggests that interactive market experiments may provide insights into the trade promotion process beyond the use of industry data. In a broader context, these types of experiments can be valuable means of collecting relevant data to test implications of analytical models.

The rest of this paper is organized as follows. We first develop our theoretical model and state our propositions. Subsequently, we describe the design and implementation of the market experiment and discuss our findings. In a concluding section we discuss managerial and policy implications, the limitations of the study, and topics for future research.

2. Theoretical Analysis

We now present an economic model to illustrate how trade promotions operate in a distribution channel with one manufacturer and one retailer. The manufacturer, an upstream monopolist, produces a product at a constant marginal cost, c. The manufacturer extends a take-it-or-leave-it offer to the retailer and specifies a wholesale price, w. The retailer, a monopolist seller in the end-consumer market, decides how many units, Q, to order from the manufacturer and the retail price, p, to the consumers.

We assume that the retailer faces a stochastic demand function $D = f(p) + U$, where $f(p) = a - bp$ is a downward sloping, concave, deterministic function of the unit retail price p with $a > 0$ and $b > 0$, and U is a continuous random variable. Both the additive demand form and the assumptions about $f(p)$ are common in the pricing literature (e.g., Petruzzi and Dada 1999). For specificity, we assume that U follows a uniform distribution on $[-(a-bp), a-bp]$. As pointed out by Drèze and Bell (2003), it is important to model demand uncertainty retailers face in this context because they may not be able to perfectly predict the demand in the end-consumer market when making the ordering decision. Sometimes they may order too little. In those situations they are not able to satisfy consumer demand beyond Q. It is also possible that a retailer's order quantity exceeds the actual quantity demanded. In that case, we assume that these extra units have no value for the retailer.

To better understand the framework in which trade promotion decisions are made, in March 2010, we conducted interviews with a convenient sample of 15 supermarket buyers and in-depth interviews with 7 buyers from supermarket companies and 8 category managers from consumer goods manufacturers. In these interviews we focused on two questions: (1) Who determines the trade promotion budget (manufacturer, retailer, or both)? (2) Who decides the allocation across trade promotion types (manufacturer, retailer, or both)? According to these responses, in 90% of the cases the manufacturer made the annual promotion budget for each retail account followed by the allocation decisions. The allocation process exhibits high degree of variability: in some cases, either manufacturers or retailers decide how to allocate the funds across trade promotion types, but in other cases this decision is made jointly. In our model, we adopt the sequence of moves such that the manufacturer first decides the wholesale price and the trade promotion budget. Then the allocation decision is made by either the manufacturer or the retailer followed by the retailer's order quantity and retail price decisions.[1]

With this model setup, we first present the theoretical analysis for two types of markets where trade promotion discounts are offered either as off-invoices or as scan-backs. We then derive propositions by comparing wholesale and retail prices, retailer order quantities, and profits given the same trade promotion discount. Finally, we extend the basic model so that the trade promotion discount is related to demand expansion activities and solve for the optimal discount level.

2.1. Basic Model

As the first step, our analysis focuses on the trade promotion type decisions given the trade promotion discount level. This basic model is consistent with practices in many product categories where there exist industry standards for trade promotion discounts. To distinguish the two different types of trade promotion discounts, we use $\alpha(\beta)$ to represent the per-unit off-invoice (scan-back) discount and subscript $O(S)$ to represent the parameters in the market where off-invoices (scan-backs) are offered.

In the off-invoices condition, the trade promotion α is offered by the manufacturer as a price reduction in the normal price of goods and is subtracted from the initial invoice on all units ordered. Therefore, the effective wholesale price to the retailer becomes $w_O - \alpha$. Given the wholesale price, and the stochastic demand specified above, the retailer's profit can be written as

$$\begin{aligned}\Pi_{R_O} &= -Q_O(W_O - \alpha) + P_O \int_0^{Q_O} \frac{t\,dt}{2(a-bP_O)} \\ &\quad + P_O \int_{Q_O}^{2(a-bP_O)} Q_O \frac{dt}{2(a-bP_O)} \\ &= Q_O(P_O - W_O + \alpha) - \frac{P_O Q_O^2}{4(a-bP_O)}. \end{aligned} \tag{1}$$

The second term in the retailer's profit function represents the retailer's revenue when the demand in the end-consumer market is less than the quantity ordered from the manufacturer. As shown in the last term, the retailer will not be able to satisfy consumer demand if it is higher than the quantity ordered. In equilibrium, the retailer should price at a level to sell all the units. We find the optimal order quantity and retail price by solving the following first-order conditions:

$$\frac{\partial \Pi_{R_O}}{\partial Q_O} = (P_O - W_O + \alpha) - \frac{Q_O P_O}{2(a-bP_O)} = 0$$

$$\Rightarrow \quad Q_O = \frac{2(P_O - W_O + \alpha)(a-bP_O)}{P_O}, \tag{2}$$

$$\frac{\partial \Pi_{R_O}}{\partial P_O} = Q_O - \frac{Q_O^2}{4}\frac{a}{(a-bP_O)^2} = 0$$

$$\Rightarrow \quad Q_O = \frac{4(a-bP_O)^2}{a}, \tag{3}$$

[1] We do not consider the case where the allocation decision is made by the manufacturer and retailer jointly because it requires theoretical and experimental examination of bargaining behavior, which is beyond the scope of this research.

where Π_R is retail profit. We solve for the optimal retail price and the order quantity by first equating (2) and (3) to obtain the optimal price and then substitute the optimal retailer price into either (2) or (3). We find that

$$P_O^* = \frac{a+\sqrt{a^2+8ab(W_O-\alpha)}}{4b}, \tag{4}$$

$$Q_O^* = \frac{(3\sqrt{a}-\sqrt{a+8b(W_O-\alpha)})^2}{4} = \frac{5a+4b(W_O-\alpha)-3\sqrt{a^2+8ab(W_O-\alpha)}}{2}. \tag{5}$$

The manufacturer's profit maximization problem can be represented by

$$\max_{w_O} \Pi_{M_O} = \max_{w_O}[(W_O-\alpha-c)Q_O], \tag{6}$$

where Π_M is manufacturer profit. Solving for the optimal wholesale price, we find that

$$W_O^* = \frac{5a+32bc+64b\alpha+3\sqrt{17a^2+64abc}}{64b}. \tag{7}$$

Different from off-invoice discounts, scan-backs involve a per-unit discount the manufacturer offers to the retailer for each unit sold to consumers. This basically changes the effective retail price to $p_S+\beta$, where β represents the per-unit discount. The retailer's profit given the wholesale price and the trade promotion discount offered by the manufacturer can be written as

$$\begin{aligned}\Pi_{R_S} &= -Q_S W_S + (P_S+\beta)\int_0^{Q_S} \frac{t\,dt}{2(a-bP_S)} \\ &\quad + (P_S+\beta)\int_{Q_S}^{2(a-bP_S)} Q_S \frac{dt}{2(a-bP_S)} \\ &= Q_S(P_S-W_S+\beta) - \frac{(P_S+\beta)Q_S^2}{4(a-bP_S)}. \end{aligned}\tag{8}$$

Similar to the off-invoices case, we take the first-order condition with respect to order quantity and retail price:

$$\frac{\partial \Pi_{R_S}}{\partial Q_S} = (P_S+\beta-W_S) - \frac{(P_S+\beta)Q_S}{2(a-bP_S)} = 0$$

$$\Rightarrow \quad Q_S = \frac{2(P_S+\beta-W_S)(a-bP_S)}{P_S+\beta}, \tag{9}$$

$$\frac{\partial \Pi_{R_S}}{\partial P_s} = Q_S - \frac{Q_S^2}{4}\frac{a+b\beta}{(a-bP_S)^2} = 0$$

$$\Rightarrow \quad Q_S = \frac{4(a-bP_S)^2}{a+b\beta}. \tag{10}$$

Next, we equate (9) and (10), we can solve for

$$P_S^* = \frac{a+b\beta+-4b\beta+\sqrt{a+b\beta}\sqrt{a+b\beta+8bW_S}}{4b}. \tag{11}$$

The optimal order quantity can be written as

$$Q_S^* = \frac{5(a+b\beta)+4bW_S-3\sqrt{(a+b\beta)^2+8(a+b\beta)bW_S}}{2} = \frac{(3\sqrt{a+b\beta}-\sqrt{(a+b\beta)+8bW_S})^2}{4}. \tag{12}$$

The manufacturer's profit maximization problem for the scan-backs case can be written as

$$\max_{w_S} \Pi_{M_S} = \max_{w_S}[Q_S(w_S-\beta-c)]. \tag{13}$$

We then solve for the optimal wholesale price as

$$\begin{aligned} W_S^* &= \frac{5a+32bc+37b\beta+3\sqrt{a+b\beta}\sqrt{17a+64bc+81b\beta}}{64b} \\ &= \frac{5(a+b\beta)+32b(\beta+c)+3\sqrt{17(a+b\beta)^2+64(a+b\beta)b(\beta+c)}}{64b}. \end{aligned}\tag{14}$$

Based on the above basic model, we can derive propositions regarding the trade promotion type decisions by comparing the (wholesale and retail) prices, retailer's order quantity, and channel member profits given the same off-invoice and scan-back trade promotion discount.

2.1.1. Wholesale and Retail Prices. We first compare wholesale and retail prices where off-invoices are offered versus where scan-backs are offered. We find the following:

Proposition 1. *Facing consumer demand uncertainty, manufacturers charge a higher wholesale price when the same amount of trade promotion discount is allocated to scan-backs versus off-invoices.*

Proposition 2. *Facing consumer demand uncertainty, retailers charge a higher retail price when the same amount of trade promotion discount is allocated to scan-backs versus off-invoices.*

See Appendix A for the proofs.

It is obvious that when trade promotion budgets are zero ($\alpha=0$; $\beta=0$), wholesale and retail prices in the market with off-invoices and scan-backs are the same ($W_O^*=W_S^*$ and $P_O^*=P_S^*$) and are equal to the prices in a market with no trade promotions (as should be expected). When the trade promotion is allocated to off-invoices, the retailer enjoys lower effective wholesale prices, which allows him/her to lower the retail prices as well. In contrast, scan-backs increase retailer revenue through a higher effective retail price. Taken together, these intuitions imply that wholesale and retail price are higher when the same level of trade promotion discount is allocated to scan-backs than when allocated to off-invoices.

2.1.2. Retailer Order Quantities. As we have discussed in the previous section, in equilibrium, the optimal quantity ordered by retailers equals the expected quantity sold to end consumers. This is associated to an optimal retail price such that $Q_O^* = 4(a - bP_O^*)^2/a$ in the off-invoices case (Equation (3)) and $Q_S^* = 4(a - bP_S^*)^2/(a + b\beta)$ in the scan-backs case (Equation (10)). The difference between these two terms, $Q_O^* - Q_S^* = (4(a - bP_O^*)^2/(a + b\beta))[b\beta/a + 1 - ((a - bP_S^*)/(a - bP_O^*))^2]$, is positive because we know from Proposition 2 that $P_S^* > P_O^*$. The following proposition summarizes this comparison of retailer order quantity decisions regarding trade promotion types:

Proposition 3. *Facing consumer demand uncertainty, retailers order more from the manufacturer when the same amount of trade promotion discount is allocated to off-invoices versus scan-backs.*

By definition, when trade promotions are allocated to off-invoices, retailers receive discounts on all units ordered. Even when the realized demand is unexpectedly low, retailers are still able to sell the products at lower prices because of the discounts they received from the manufacturers. With scan-backs trade promotions, retailers only receive discounts on the units scanned and sold. Therefore, it is risky for retailers to order a large quantity because they may not be able to sell all when facing unexpectedly low demand. Therefore, compared to off-invoices, retailers would prefer to order less and price higher when trade promotion is offered in the scan-back format.

2.1.3. Manufacturer and Retailer Profits. Finally, we compare manufacturer and retailer profits in the off-invoices case versus the scan-backs case for the basic model. As shown in Appendix A, manufacturer and retailer profits are the same when the (off-invoices or scan-backs) trade promotion discount budget is zero. As the level of scan-backs trade promotion discount increases, both manufacturer and retailer profits decrease (i.e., $\partial\Pi_{M_S}^*/\partial\beta < 0$; $\partial\Pi_{R_S}^*/\partial\beta < 0$). However, their profits are not influenced by the level of off-invoices trade promotion discount. Therefore, profits are higher for both channel members when the same amount of trade promotion discount is allocated to off-invoices than to scan-backs. As profit maximizers, they will choose off-invoices rather than scan-backs. We summarize our conclusions regarding trade promotion types and profits in the following propositions:

Proposition 4. *Facing consumer demand uncertainty, manufacturer profits are higher when the same amount of trade promotion discount is allocated to off-invoices versus scan-backs.*

Proposition 5. *Facing consumer demand uncertainty, retailer profits are higher when the same amount of trade promotion discount is allocated to off-invoices versus scan-backs.*

Given that the effective wholesale price is lower when the trade promotion budget is allocated to off-invoices, the retailer is able to lower its retail price and to enjoy a higher consumer demand and a higher profit. Although this is consistent with what empirical research has shown, in our model it is demand uncertainty that drives this result.

Different from trade promotion decisions based on possibilities of forward buying and diverting, manufacturers' interests and benefits are aligned with those of retailers as far as demand uncertainty is concerned. This means that under demand uncertainty offering off-invoices trade promotion benefits both the manufacturer and the retailer and, therefore, the entire channel.

2.2. Model Extension: Market Expansion

In the basic model, we assume there exists an industry standard for trade promotion discount and examine manufacturer and retailer decisions given an exogenous amount of discount. Although trade promotions are often considered by managers as costs of doing businesses (Kopp and Greyser 1987), recent empirical research has documented manufacturers' effective use of trade promotions tied with retailers' market expansion efforts. This is also consistent with findings in the efficient consumer response literature that suggest that the full retail chain can make higher profits via trade promotions by increasing the market size (Ailawadi 2001, Srinivasan et al. 2004). Therefore, in this section we extend the basic model by endogenizing manufacturers' trade promotion discount decisions. By incorporating market expansion effects of trade promotion discounts, we are able to derive optimal discount levels for off-invoices and scan-backs and compare them.

We assume that the amount of trade promotion discount that a manufacturer offers directly influences the baseline market demand. The new market demand becomes $D^{ME} = f^{ME}(p) + U^{ME}$, where $f^{ME}(p) = A - bp$, and U^{ME} follows a uniform distribution on $[-(A - bp), A - bp]$. The new baseline demand A_O or A_S is a function of the trade promotion discount such that $A_O = a + g\alpha^{ME} - h \cdot \alpha^{ME^2}$ when off-invoices are offered and $A_S = a + g \cdot \beta^{ME} - h \cdot \beta^{ME^2}$ when scan-backs are offered with $g \geq 0$ and $h \geq 0$. This quadratic functional form captures diminishing return and degenerates to the basic model when $g = h = 0$.

Under the basic model setting where trade promotions do not have market expansion effects, although it is costly for the manufacturer to offer trade promotion discounts, they still do so because it is a standard practice in the industry. When the baseline market

Table 1 Optimal Decisions When Trade Promotion Discount Leads to Market Expansion

Optimal decision variables	Off-invoice	Scan-back
W^{ME*}	$\dfrac{5A_O+32bc+64b\alpha^{ME}+3\sqrt{17A_O^2+64A_Obc}}{64b}$	$\dfrac{5A_S+32bc+37b\beta^{ME}+3\sqrt{17(A_S+b\beta^{ME})^2+64(A_S+b\beta^{ME})bc}}{64b}$
Q^{ME*}	$\dfrac{5A_O+4b(W_O^{ME}-\alpha^{ME})-3\sqrt{A_O^2+8A_Ob(W_O^{ME}-\alpha^{ME})}}{2}$	$\dfrac{5(A_S+b\beta^{ME})+4bW_S^{ME}-3\sqrt{(A_S+b\beta^{ME})^2+8(A_S+b\beta^{ME})bW_S^{ME}}}{2}$
P^{ME*}	$\dfrac{A_O+\sqrt{A_O^2+8ab(W_O^{ME}-\alpha^{ME})}}{4b}$	$\dfrac{A_S-3b\beta^{ME}+\sqrt{(A_S+b\beta^{ME})^2+8bW_S^{ME}(A_S+b\beta^{ME})}}{4b}$

Note. Here the new baseline consumer demands are $A_O=a+g\cdot\alpha^{ME}-h\cdot\alpha^{ME^2}$ and $A_S=a+g\cdot\beta^{ME}-h\cdot\beta^{ME^2}$.

size increases as the amount of trade promotion discount becomes greater, manufacturers benefit from a higher consumer demand through offering a deeper discount. By weighing the cost and benefit, manufacturers can find the optimal level of off-invoice or scan-back discounts.

Similar to the derivations in the basic model, we first solve for the optimal order quantity and wholesale and retail prices given the trade promotion discount (Table 1 summarizes our analytical results). We find the optimal wholesale price given the trade promotion discount by taking the first-order conditions of manufacturer profits with respect to wholesale prices to solve for $\partial\Pi_{M_O}^{ME}/\partial W_O^{ME}=0$ and $\partial\Pi_{M_S}^{ME}/\partial W_S^{ME}=0$.

As shown in Table 1, the optimal wholesale price as a function of trade promotion discounts equals

$$W_O^{ME*}=\frac{5A_O+32bc+64b\alpha^{ME}+3\sqrt{17A_O^2+64A_Obc}}{64b}$$

when off-invoices are offered, and it equals

$$W_S^{ME*}=\frac{5A_S+32bc+37b\beta^{ME}+3\sqrt{17(A_S+b\beta^{ME})^2+64(A_S+b\beta^{ME})bc}}{64b}$$

when scan-backs are offered. Then we maximize manufacturer profits with respect to trade promotion discounts by solving $\partial\Pi_{M_O}^{ME}/\partial\alpha^{ME}=0$ and $\partial\Pi_{M_S}^{ME}/\partial\beta^{ME}=0$. We find that

$$\begin{aligned}\frac{\partial\Pi_{M_O}^{ME}}{\partial\alpha^{ME}}&=\frac{1}{2}\Big[-5A_O-4b(W_O^{ME}-\alpha_{ME})\\&\qquad+3\sqrt{A_O[A_O+8b(W_O^{ME}-\alpha_{ME})]}\Big]\\&\quad+\frac{(W_O^{ME}-\alpha_{ME}-c)}{2}\Big\{-4b+5g-10h\alpha_{ME}\\&\quad-\frac{3[8A_Ob-2(g-2h\alpha_{ME})[A_O+4b(W_O^{ME}-\alpha_{ME})]]}{2\sqrt{A_O[A_O+8b(W_O^{ME}-\alpha_{ME})]}}\Big\},\end{aligned}$$

$$\begin{aligned}\frac{\partial\Pi_{M_S}^{ME}}{\partial\beta^{ME}}&=\Big(-5(A_S+b\beta^{ME})-4bW_S^{ME}\\&\qquad+3\sqrt{(A_S+b\beta^{ME})(A_S+b\beta^{ME}+8bW_S^{ME})}\Big)\cdot\frac{1}{2}\\&\quad+\Big((b+g-2h\beta^{ME})(c+\beta^{ME}-W_S^{ME})\\&\qquad\cdot\Big[3(A_S+b\beta^{ME})+12bW_S^{ME}\\&\qquad-5\sqrt{(A_S+b\beta^{ME})(A_S+b+8bW_S^{ME})}\Big]\Big)\\&\quad\cdot\Big(2\sqrt{(A_S+b\beta^{ME})(A_S+b+8bW_S^{ME})}\Big)^{-1}.\end{aligned}$$

Because we lose analytical tractability with these two complicated partial derivatives, we have to numerically solve for the optimal trade promotion discounts. We first selected a wide range of values for all the exogenous variables, which include demand factors (a and b), market expansion factors (g and h), and the cost factor c. For each set of parameters, we then numerically search for the optimal trade promotion discounts that satisfy these two equations $\partial\Pi_{M_O}^{ME}/\partial\alpha^{ME}=0$ and $\partial\Pi_{M_S}^{ME}/\partial\beta^{ME}=0$. Given the difficulty in making algebraic comparisons, we also conduct numerical analyses to compare the optimal off-invoice and scan-back trade promotion discounts and summarize our results in the following proposition:

Proposition 6. *When trade promotion discount leads to market expansion, there exists an optimal level of discount that maximizes a manufacturer's profit under demand uncertainty, and this optimal trade promotion discount is larger when it is allocated to off-invoices versus scan-backs.*

Intuitively, would manufacturers offer greater discounts to off-invoice discounts versus scan-backs? To answer this question, we need to consider both the demand uncertainty effect and the market expansion effect. Because of the market expansion effect, manufacturers have incentives to offer greater trade promotion discounts regardless of the format.

However, demand uncertainty affects retailers differently depending on how the trade promotion discount is allocated. When manufacturers offer greater off-invoice trade promotion discounts (to benefit from market expansion), retailers are willing to order more. However, it is more risky for them to do so when the trade promotion discount is allocated to scan-backs. In equilibrium, the optimal trade promotion discount is smaller compared to the off-invoices case.

3. Implementation of the Laboratory Market Experiment

In prior literature, there are very few experimental papers focusing on channel behavior. Dwyer (1980) used a laboratory simulation of a bilateral duopoly to study channel satisfaction. Focusing on contracting theories, Ho and Zhang (2008) and Lim and Ho (2007) found that channel coordination fails with various contracts. In a supplier newsvendor experiment where human subjects play with computers acting as profit maximizers, Katok and Wu (2009) found that buyback and revenue-sharing contracts do not provide full channel efficiency. Using a partner-matching mechanism, Keser and Paleologo (2004) presented the results of an experimental investigation of a simple supplier–retailer wholesale price contract and found that suppliers make lower profits and retailers make higher profits than predicted by the subgame perfect equilibrium solution. Loch and Wu (2008) argued that social preferences may influence economic decision making in supply chain transactions. They provided experimental evidence that supply chain parties deviate from the predictions of profit-maximization theories.

Although these studies examine interaction between channel members, to our knowledge, the literature has not focused on trade promotion budget and allocation in the context of manufacturer–retailer interactions. We simulate an interactive trading environment based on our theoretical models and observe how trade promotion discount and allocation decisions are made.

3.1. Experimental Design and Procedure

The laboratory market experiment was programmed using *Z*-tree,[2] and all the transactions were completed through networked computers. We used a two (with or without market expansion) by two (replications) design to test the theoretical propositions. Consistent with our theoretical models, the amount of trade promotion discount was given to the subjects in the no market expansion (NME) condition versus chosen by the manufacturers in the ME condition. The demand uncertainty was manipulated such that computers revealed realized consumer demand after manufacturers and retailers made pricing and order quantity decisions with the knowledge of the demand distribution.

We recruited 80 MBA students (20 for each session) with an average work experience of 40 months and an average age of 30. Through a brief survey we administered at the end of the experiment, we learned that most subjects had previous work experience on relationships in the distribution channels of goods and services. Thus, we feel confident that the selection of subjects provides a degree of realism for the study.

We simulate manufacturer–retailer dyads where manufacturers maximize their earnings in experimental dollars (EDs) by selling to the retailers, whereas retailers maximize their earnings in EDs by selling to the consumers. At the beginning of each session, half of the subjects were randomly assigned as manufacturers and the other half as retailers, and they remained in the same roles throughout the experiment. Instructions (see Appendix B) were read and questions were answered publicly, followed by a practice period to familiarize subjects with the experimental environment. During the practice period, the experimenter explained the information provided on each screen of the sequence and answered questions from subjects. With this procedure, we feel confident that all subjects understood the details of the experiment.

For approximately 90 minutes, the subjects traded as manufacturer–retailer dyads in a series of market periods. A market period consists of manufacturers and retailers making decisions in the distribution channel (described in detail below) that lead to channel member profits at the end of each period. To avoid end-game behaviors, the subjects were told that the experiment would last about 90 minutes, but could be terminated at any time. The experimenter made the decision to end the experiment after all decisions were made in the last period.[3]

In each period, the computer system first randomly selects a manufacturer (M) and a retailer (R) to form a dyad. The matching was anonymous and unrepeated so that each period in the experiment represents a one-shot game in the theoretical model, and each dyad is independent. The random matching protocol[4] also helps to minimize collusion, reciprocity,

[2] Zurich Toolbox for Readymade Economic Experiments (Fischbacher 2007).

[3] End-of-game effects have been well documented in the experimental economics literature (e.g., Zwick and Chen 1999). To make sure that this effect does not distort the results, researchers either eliminate the last period data for the analysis or choose not to have a fixed number of periods. Because our experiment was fairly complicated with four stages in each period, the amount of time it took to complete each period varied across players. We used the second method to allow more repetitions.

[4] This type of random-matching protocol has been used by many experimental researchers (e.g., Amaldoss and Rapoport 2005, Lim and Ho 2007).

and other dynamic strategic behaviors. Within a dyad, the computer system randomly selects the manufacturer or the retailer to make the trade promotion allocation decisions so that on average there is a 50% chance it is the manufacturer and a 50% chance it is the retailer. This selection is done for each period and each dyad independently and announced to the players at the beginning of each period.

Within each market period there are four stages, shown in Appendix B. In the first stage, given the information about which member in the channel will make the trade promotion allocation decision, the manufacturers decide on the wholesale price P_M (and per-unit trade promotion discount (TP) decision in the ME condition). In the second stage, either the manufacturer or the retailer makes the allocation decision between off-invoices and scan-backs.[5] If the trade promotion budget is allocated to off-invoices, the units used to determine the total amount of trade promotion (Q_{TP}) will be the same as the quantity ordered by the retailer (Q_M). However, if the trade promotion budget is allocated to scan-backs, then the number of units considered in trade promotion (Q_{TP}) is equal to the quantity sold by retailer to the end-consumers (Q_R). In the third stage, retailers decide the number of units to order from the manufacturer (Q_M) and the retail price (P_R) knowing the trade promotion budget and allocation.[6] In the last stage, the computer system generates realized consumer demand and completes the transactions.

Subjects were informed of the transaction outcomes (including realized demand, units sold, the amount and type of trade promotion, and their own profits) in the current period before they moved on to the next period. The profits in EDs were accumulated throughout the periods then converted into real dollars. At the end of the experiment, each subject was privately paid $5 for participation and an additional $5–$10 depending on performance. As an additional incentive, the subject with the highest accumulated profit at the end of the experiment in each session received a $200 gift certificate from a national chain of electronic stores.[7]

[5] This study focuses on the two most popular types: scan-backs and off-invoices. However, in reality there are other trade promotion types such as cooperative advertising, market development funds, and billbacks. In addition, our experiment does not consider EDLP (everyday low price) retailers, such as Walmart, which do not accept trade promotions from manufacturers but request every day low purchase prices.

[6] To examine whether fairness plays an important role in this context, we allowed retailers to end the transactions by ordering zero units. In that case, both the manufacturer and the retailer in the dyad earn zero ED.

[7] The average payment in our experiment was about $13, which is comparable to the existing experimental studies in the literature. For example, the average earning were $12 in the study by Lim and Ho (2007), $13 in the study by Ho and Zhang (2008), and E7 in the study by Loch and Wu (2008).

As a manipulation check, we also asked respondents to fill out an online survey after the experiment was completed. Questions were related to decision strategies and purpose of the study. None of the respondents had discovered the actual purpose of our study. The majority of respondents indicated profit maximization as their ultimate goal. As an additional check, we gave subjects a blank piece of paper at the beginning of the session without indicating its purpose. At the end of the experiment we collected these pieces of paper and found that most respondents used them to track their profit performance. Therefore, we are confident that the respondents engaged in a deliberate and thoughtful process during the experiment.

3.2. Parameter Selection and Point Estimates

To facilitate subject learning throughout the periods, the parameters of the experiments were carefully selected to satisfy two main criteria: first, that the theoretical predictions for the key variables are different enough for the off-invoice and scan-back conditions, and second, that the induced costs and benefits are relatively easy for subjects to understand.

With the demand factors $a = 100$ and $b = 5$ and manufacturer cost $c = 1$, Table 2 summarizes theoretical predictions for wholesale prices, retail prices, retailer order quantities, and channel member profits given specific amounts of trade promotion discounts for the basic model. These numbers help illustrate how our model performs with the specific set of parameters that we use in our market experiments. To ensure that the experimental settings and outcomes are somewhat realistic and comparable to real market conditions, we chose the trade promotion discount to be 2 EDs (with a percentage discount of 24.17% for the off-invoices and 23.67% for the scan-backs) for the NME experimental sessions. We highlighted the theoretical predictions for the selected parameters.

Similar to the NME case, the optimal wholesale prices, retail prices, order quantities, and channel member profits in both off-invoice and scan-back cases for different demand factors a and b (where $c = 1$) and market expansion factors g and h are shown in Table 3. To facilitate comparisons across the two experimental conditions, the same demand factors and manufacturer cost are used for the two experimental sessions in the ME condition (i.e., $a = 100$, $b = 5$, and $c = 1$). The demand expansion factors $g = 6$ and $h = 1$ were chosen so that the optimal trade promotion discounts in the off-invoice and scan-back cases are substantially different. We have highlighted the set of selected parameters in Table 3.

With these parameter values, we conduct market experiments to test Propositions 1–5 regarding channel members' pricing and ordering decisions and profits when trade promotion discounts are allocated

Table 2 Predictions of the Theoretical Model with No Market Expansion ($a = 100$; $b = 5$; $c = 1$)

Trade promotion discount	Wholesale price		Retail price		Order quantity		Manufacturer profits		Retailer profits	
	Off-invoices	Scan-backs	Off-invoices	Scan-backs	Off-invoices	Scan-backs	Off-invoices	Scan-backs	Off-invoices	Scan-backs
0.00	6.28 (0%)[a]	6.28 (0%)	14.37	14.37	31.72	31.72	167.35	167.35	128.33	128.33
0.50	6.78 (7.38%)	6.83 (7.32%)	14.37	14.43	31.72	30.22	167.35	160.93	128.33	122.50
1.00	7.28 (13.74%)	7.37 (13.57%)	14.37	14.50	31.72	28.86	167.35	155.02	128.33	117.23
1.50	7.78 (19.29%)	7.91 (18.96%)	14.37	14.55	31.72	27.63	167.35	149.56	128.33	112.44
2.00	**8.28 (24.17%)**	**8.45 (23.67%)**	**14.37**	**14.60**	**31.72**	**26.52**	**167.35**	**144.50**	**128.33**	**108.05**
2.50	8.78 (28.49%)	8.98 (27.83%)	14.37	14.64	31.72	25.49	167.35	139.79	128.33	104.02
3.00	9.28 (32.34%)	9.52 (31.53%)	14.37	14.69	31.72	24.55	167.35	135.39	128.33	100.30
3.50	9.78 (35.80%)	10.04 (34.85%)	14.37	14.73	31.72	23.68	167.35	131.27	128.33	96.86

[a]Trade promotion as a percentage of wholesale prices.

to off-invoices versus scan-backs in NME markets. We simulate ME markets to test Proposition 6 regarding manufacturers' optimal trade promotion budget decisions. Furthermore, when we compare profits in Tables 2 and 3, we find that manufacturer and retailer profits are higher with ME (compared to NME), although they would both prefer off-invoices to scan-backs in NME and ME markets. Finally, to verify the validity of our market experiment, we statistically compare the predicted values for manufacturer and retailer decision variables (as in Tables 2 and 3) with observed behavior in the experiments.

Table 3 Optimal Decisions in Market Expansion Model ($c = 1$)

Demand factors (a, b)	Expansion factors (g, h)	Trade promotion discount		Wholesale price		Retail price		Order quantity		Profit	
		Off-invoices	Scan-backs	Off-invoices	Scan-backs	Off-invoices	Scan-backs	Off-invoices	Scan-backs	Off-invoices	Scan-backs
(80, 5)	(5, 1)	2.50 (31.13%)[a]	0.78 (12.72%)	8.03	6.13	12.42	12.09	26.59	23.93	120.78[b] 92.38[c]	104.04 80.67
(80, 6)	(5, 2)	1.25 (21.37%)	0.23 (4.86%)	5.85	4.73	10.09	9.86	24.58	23.24	88.54 67.42	81.39 62.25
(80, 7)	(5, 3)	0.83 (17.11%)	0.06 (1.50%)	4.85	4.01	8.60	8.43	23.29	22.47	70.35 53.35	66.27 50.32
(100,5)	**(6,1)**	**3.00 (30.71%)**	**1.24 (15.88%)**	**9.77**	**7.81**	**15.62**	**15.27**	**35.03**	**31.12**	**201.96 155.09**	**173.43 135.41**
(100, 6)	(6, 2)	1.50 (21.22%)	0.45 (7.60%)	7.07	5.92	12.57	12.34	32.38	30.35	148.06 113.27	135.54 104.39
(100, 7)	(6, 3)	1.00 (17.12%)	0.20 (4.03%)	5.84	4.96	10.69	10.51	30.87	29.55	118.42 90.29	111.07 84.98
(120, 5)	(7, 1)	3.50 (31.76%)	1.71 (17.92%)	11.02	9.54	18.82	18.53	43.50	38.49	306.49 236.00	251.47 193.73
(120, 6)	(7, 2)	1.75 (21.08%)	0.68 (9.55%)	8.30	7.12	15.08	14.86	40.31	37.55	223.89 171.83	204.35 158.12
(120, 6)	(7, 3)	1.17 (17.13%)	0.35 (5.90%)	6.83	5.93	12.78	12.61	38.57	36.70	179.62 137.45	167.91 129.12

[a]Trade promotion as a percentage of wholesale prices.
[b]Manufacturer profit.
[c]Retailer profit.

4. Results from the Experiments

On average, subjects played seventeen periods in 90-minute sessions. Because our unit of observation is the manufacturer–retailer dyad, our data comprise 298 observations for the NME condition and 258 observations for the ME condition. The mean wholesale price, retail quantity ordered, and retail price were 7.09 EDs, 49.47 units, and 17.12 EDs in the NME condition and 7.28 EDs, 48.02 units, and 17.10 EDs in the ME condition, respectively. When manufacturers were asked to make trade promotion discount decisions in the ME condition, the mean trade promotion discount offered by them was 2.43 EDs.

4.1. Testing Theoretical Propositions

First, using the 298 observations from the NME data, we test the directional predictions from the theoretical model by comparing wholesale price, retail price, retailer order quantity, and manufacturer and retailer profits. Specifically, we created a dummy variable for allocation type and employed single-equation ordinary least squares using the White (1980) correction for heteroscedasticity for testing the propositions regarding wholesale price and profits. To account for potential simultaneity in the decisions retailers make on the order quantity and retail price, we employed the seemingly unrelated regression method by Zellner (1960). We summarize our results in Table 4.

When we compare the wholesale prices, we find that wholesale prices are higher when the same amount of trade promotions are allocated to scan-backs than when they are allocated to off-invoices. The difference is also statistically significant, which supports Proposition 1.

Also consistent with what we predicted, we find that given the same trade promotion discount (2 EDs), retail prices are significantly higher ($z = 3.36$; $p = 0.001$) when trade promotions are allocated to scan-backs than to off-invoices. These results provide support for our Proposition 2.

When we compare the number of units that the retailers order from the manufacturers, we find that when knowing the manufacturers are offering a 2 EDs trade promotion discount, the retailers order on average 11 units more when the trade promotion is allocated to off-invoices than when it is allocated to scan-backs. This difference is statistically significant, which provides strong evidence for Proposition 3. These results regarding manufacturer and retailer decisions in the NME market confirm our intuition that retailers order less and wholesale and retail prices are higher when trade promotions are allocated to scan-backs than to off-invoices. Although manufacturers share some costs via offering off-invoice trade promotions when consumer demand is unexpectedly low, this loss is completely borne by the retailer when the trade promotion discount is allocated to scan-backs. This is also consistent with the trade promotion allocation choices we observe in the experiment. Out of 298 observations in the NME condition, computers randomly assigned manufacturers to make the allocation decisions 160 times and retailers 138 times. We find that manufacturers choose off-invoices 87 times (54.38%), whereas retailers choose off-invoices 100 times (72.46%).

To test Propositions 4 and 5, we compare profits for the manufacturers and the retailers. We find that manufacturer profits are much higher when trade promotions are allocated to off-invoices than to scan-backs, and the difference is statistically significant ($t = 2.62$; $p = 0.009$). This provides strong support for Proposition 4. Similarly, retailer profits are also higher when off-invoices are chosen (mean, 356.62 EDs) versus when scan-backs are chosen (mean, 300.50 EDs), with $t = 1.45$ and $p = 0.149$. We therefore conclude that it provides weak support for Proposition 5.

Consistent with our theoretical model, in the NME condition, the amount of trade promotion was given to the subjects as an industry standard. What happens in the ME condition where the manufacturers are allowed to choose the amount of trade promotion discount they offer? To test Proposition 6, we compare the amount of trade promotion discount for 258 observations in the ME condition and find that manufacturers offer a deeper off-invoice trade promotion discount than scan-back trade promotion discount, and the difference is significant ($t = 1.99$; $p = 0.048$).

Table 4 **Testing Theoretical Propositions**

		Off-invoices		Scan-backs		Analysis		
Proposition	Variable	Mean	SD	Mean	SD	Stat.	Sig.	Supported?
1	*Wholesale price*	6.76	1.91	7.32	2.00	$t = 2.43$	$p = 0.016$	Yes
2	*Retail price*	16.40	3.40	17.63	2.93	$z = 3.36$	$p = 0.001$	Yes
3	*Retailer order quantity*	55.76	26.32	44.93	21.39	$z = 3.92$	$p = 0.000$	Yes
4	*Manufacturer profit*	222.95	149.23	181.49	123.05	$t = 2.62$	$p = 0.009$	Yes
5	*Retailer profit*	356.62	227.57	300.50	222.09	$t = 1.45$	$p = 0.149$	Yes, weakly
6	*Trade promotion discount*	2.57	1.11	2.32	0.88	$t = 1.99$	$p = 0.048$	Yes

Table 5 Tests for Differences Between Subject Decisions and Predicted Values (t-Values with p-Values in Parentheses)

No market expansion condition				Market expansion condition				
Period (number of observations)	Wholesale price	Retail price	Retail orders	Period (number of observations)	Wholesale price	Retail price	Retail Orders	Trade promotion discount
12 ($N=16$)	−2.46 (0.03)	3.50 (0.00)	3.50 (0.00)	7 ($N=17$)	−2.06 (0.06)	−0.03 (0.98)	2.05 (0.06)	2.11 (0.05)
13 ($N=16$)	−2.45 (0.03)	3.93 (0.00)	3.51 (0.00)	8 ($N=17$)	−1.06 (0.31)	0.82 (0.42)	2.99 (0.01)	1.83 (0.09)
14 ($N=18$)	−3.44 (0.00)	2.90 (0.01)	2.33 (0.03)	9 ($N=17$)	−1.13 (0.28)	1.61 (0.13)	4.05 (0.00)	1.80 (0.09)
15 ($N=16$)	−1.61 (0.13)	5.57 (0.00)	3.28 (0.01)	10 ($N=17$)	−1.75 (0.10)	2.34 (0.03)	4.10 (0.00)	1.83 (0.09)
16 ($N=18$)	−3.08 (0.01)	3.98 (0.00)	2.84 (0.01)	11 ($N=17$)	−1.09 (0.29)	0.86 (0.40)	0.96 (0.35)	1.03 (0.32)
17 ($N=17$)	−2.26 (0.04)	4.25 (0.00)	3.43 (0.00)	12 ($N=17$)	−1.90 (0.08)	3.40 (0.00)	1.03 (0.32)	1.29 (0.22)
18 ($N=9$)	0.03 (0.98)	11.11 (0.00)	2.09 (0.07)	13 ($N=18$)	−1.57 (0.13)	3.52 (0.00)	0.78 (0.45)	1.43 (0.17)
19 ($N=9$)	0.65 (0.54)	11.43 (0.00)	1.67 (0.13)	14 ($N=17$)	−1.60 (0.13)	2.08 (0.05)	1.56 (0.14)	0.96 (0.35)

4.2. Validity of Experimental Data

In addition to the empirical tests for the directional predictions of our theoretical model, we compare the observed behavior in the experiment with the optimal decision predicted by the theoretical analysis highlighted in Tables 2 and 3. In Table 5, we present the t-statistics and the corresponding p-values for these comparisons. For the NME markets, we take the observations from the last eight periods. Because there are fewer periods completed in the ME sessions and very few data points in the last five periods, we use the observations from period 7 to period 14.

Overall, these tests indicate statistically significant inequality between predicted and actual decisions in the initial periods of the experimental sessions. Nevertheless, these differences tend to decrease over periods. In the last period, for instance, the t-tests fail to reject inequality between the theoretical predictions and the experimental data for all decision variables at the 5% level of significance, except in the case of retail prices in NME markets. This suggests that subjects learned to make profit-maximizing decisions, and the market converges to equilibrium over time. This is consistent with what we show in Figure 1 (for NME markets) and Figure 2 (for ME markets).

Our results from Table 5 and Figures 1 and 2 also suggest that retailers seem to consistently order more and price higher than the optimal levels predicted by the models. If these retailers are indeed risk neutral, they should price lower when ordering more and price higher when ordering less because those two decisions are made simultaneously. One possibility is that the retailers are rather risk seeking than risk neutral, which is what the models assume. In other words, they intentionally order more and price higher hoping that the demand will turn out to be higher than what they expected. To investigate whether our subjects engage in this kind of risk-seeking behavior, we use retailers' actual pricing decisions to construct their expected demand[8] and compare it with actual order quantity. We find that retailers order significantly more than their expected demand given retail prices both in the NME condition ($t=18.21$; $p=0.000$) and in the ME condition ($t=7.93$; $p=0.000$). This result indicates that retailers are indeed more risk seeking than risk neutral.

5. Conclusion and Discussion

We developed an analytical model and implemented market experiments to examine optimal channel member behavior regarding trade promotion decisions, in the context of consumer demand uncertainty. Our results suggest substantial differences in trade promotion outcomes (pricing, ordering, and profits) between discounts allocated to scan-backs and off-invoices. Specifically, we show analytically that, due to demand uncertainty effects, wholesale and retail prices are higher, retailer order quantities are lower, and profits are lower when the same amount of trade promotion discount is allocated to scan-backs and to off-invoices. Moreover, manufacturers offer deeper off-invoice versus scan-back trade promotion discounts when there exists a market expansion effect

[8] Retailers are provided the information about how their retail prices influence the demand distribution and are reminded of that before they make pricing and ordering decisions.

Figure 1 Convergence in Subject Decisions, No Market Expansion Case

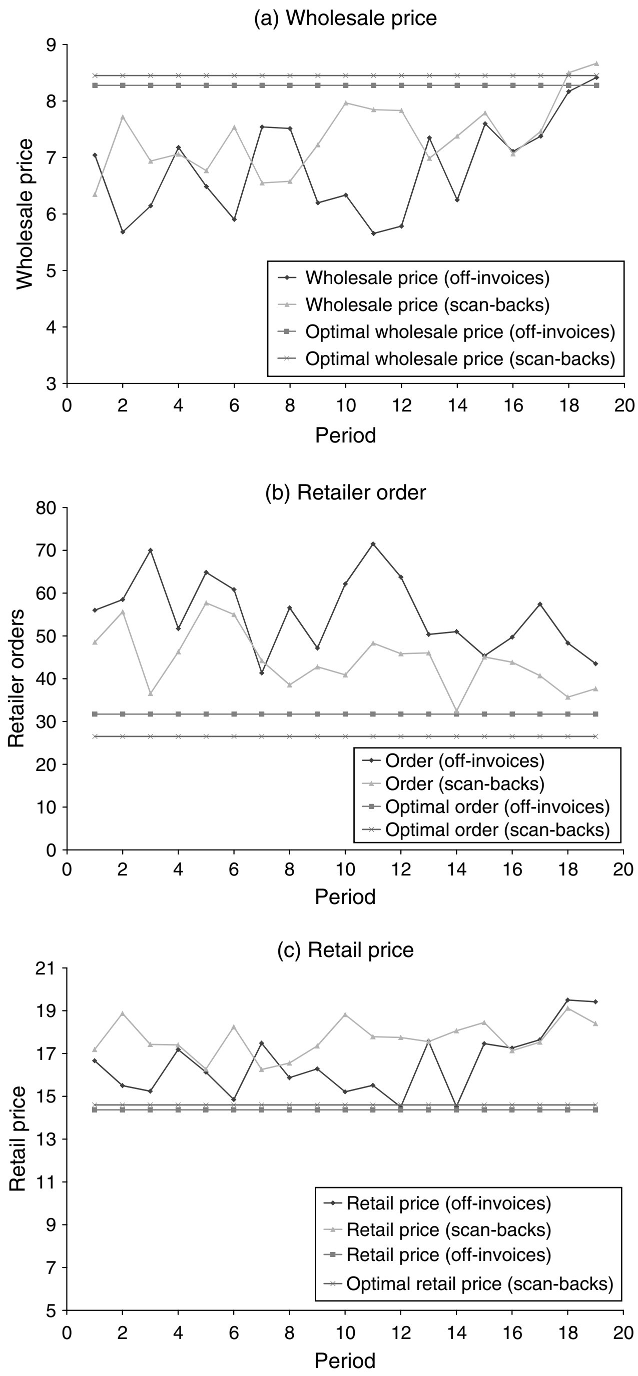
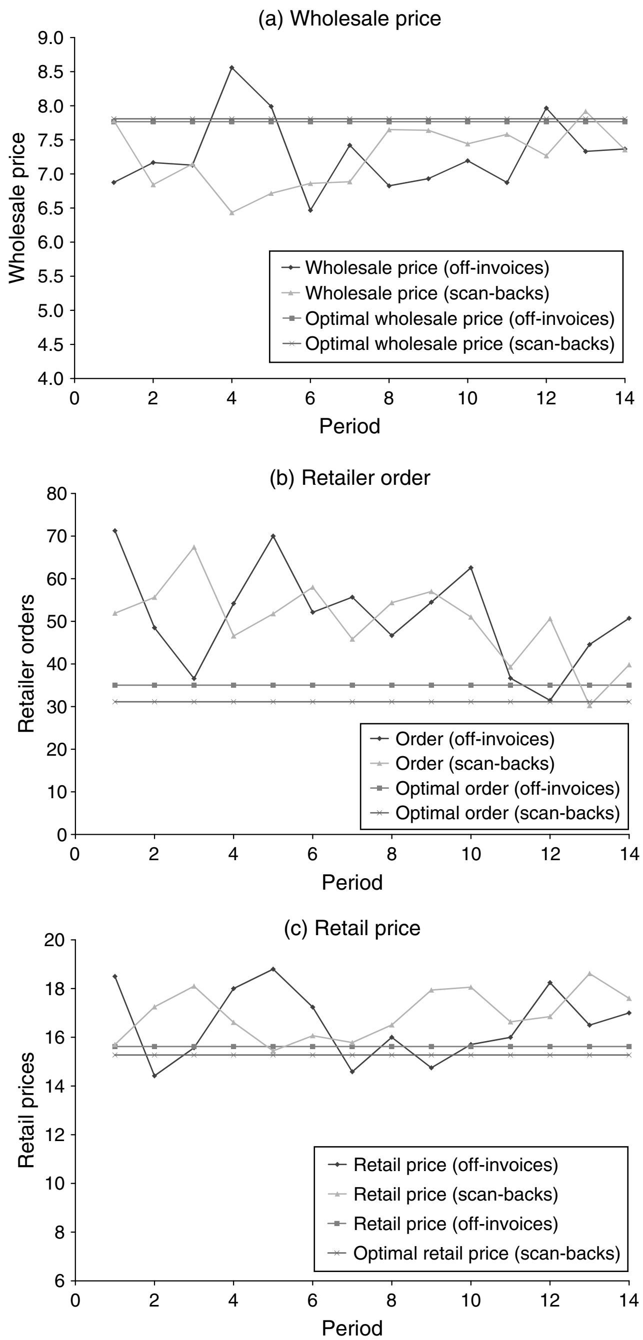


Figure 2 Convergence in Subject Decisions, Market Expansion Case



tied to the depth of the discount. Using market experiments where we manipulate demand uncertainty and market expansion, we are able to find empirical support for all of our six propositions derived from the analytical model (with strong support for the four of them).

We also examined the validity of our data by comparing theoretical predictions regarding optimal wholesale price, retail price, and retailer order quantity with the behaviors we observed in the experiments. We find that, in general, the market behavior converges to the predicted equilibrium conditions.

The experimental approach used in this paper allows us to examine the effects of key variables in a context-free environment and is particularly valuable in situations where primary data are not available. This is the case for trade promotions because they are not systematically reported by firms in certain industries. Our study provides evidence that market experiments may be a useful approach to examine trade promotion decisions in the supply chain, taking into account that companies are often reluctant to share data on their trade promotion practices, or they simply do not have a unified consistent procedure to report these expenditures.

However, the stylized setting of our experiment means that other important factors did not receive full consideration. For example, we only selected one set of parameters. Our empirical results may be limited in their generalizability. Using multiple sets of parameters in the experiment may show the robustness of the results and enable us to test other model implications. For instance, it is obvious from Equation (7) that manufacturers will charge the same effective wholesale price regardless of the amount of off-invoice trade promotion discount they are offering (i.e., $\partial W_O^*/\partial\alpha = 1$). We can also show that as the amount of scan-back trade promotion discount increases, optimal wholesale price increases too ($\partial W_S^*/\partial\beta > 0$). When we compare the effects of trade promotion discounts on optimal wholesale prices, we can show analytically that as trade promotion discount increases, wholesale price increases more when trade promotion is allocated to scan-backs than to off-invoices.[9] This is consistent with the numerical examples shown in Table 2. Further tests with multiple trade promotion discounts can be a topic for future research.

We also assume channel members to be risk neutral in our model. As we have discovered in our experiments, it may not be the case. Although risk is not the focus of this paper, there has been research in the literature that specifically examines risk and other behavioral aspects in a channel setting (e.g., Ho and Zhang 2008). It will be interesting in future research to explicitly model risk attitudes of the channel members and empirically test behavioral implications on trade promotion decisions and profits in the channel.

Another limitation of our experiment is that the markets were formed randomly each period, which is representative of a one-shot game. Although it is consistent with our model setup, this type of experimental design does not allow us to examine how past period trade promotion performance influences current period budget decisions.

Furthermore, the simplified procedures in our experimental design do not allow competitions among manufacturers or retailers, or negotiations between manufacturers and retailers. Although competitions and channel negotiations have been studied in the literature (e.g., Dwyer and Walker 1981, Eyuboglu and Buja 1993), future research can further examine how retailers and manufacturers behave in a competitive environment using bargaining-game approaches. Although fairness did not play an important role in our experiments, it may become a very important factor when we examine negotiations in the experiment.

Finally, our experiment can be extended to study relationships between trade promotions and other important channel characteristics, such as brand power and information asymmetries between trade partners, as well as to institutional and legal contexts. We expect that future research will be conducted to pursue these methodologies and to test implications of various analytical models of interagent behavior.

[9] We first write $\partial W_S^*/\partial\beta - \partial W_O^*/\partial\alpha = (3/64)[(49a+32bc+81b\beta - 9\sqrt{(a+b\beta)(17a+64bc+81b\beta)})/\sqrt{(a+b\beta)(17a+64bc+81b\beta)}]$. The numerator $49a+32bc+81b\beta \geq 9\sqrt{(a+b\beta)(17a+64bc+81b\beta)} \geq 0$. This is because if we square both sides and take the difference, we have $1{,}024(a-bc)^2 \geq 0$. Therefore, we can conclude that $\partial W_S^*/\partial\beta - \partial W_O^*/\partial\alpha \geq 0$.

Acknowledgments
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Appendix A. Proofs for Propositions 1, 2, 4, and 5

Propositions 1 and 2: Wholesale and Retail Prices

Proposition 1. *Wholesale prices*: $W_S^* \geq W_O^*$. We first compare the wholesale prices by taking the differences. We find that

$$W_S^* - W_O^* = (-64b\alpha - 3\sqrt{17a^2+64abc} + 37b\beta + 3\sqrt{17(a+b\beta)^2+64(a+b\beta)b(\beta+c)}) \cdot (64b)^{-1}.$$

Given the same trade promotion discount $\alpha = \beta$, the numerator becomes

$$-3(\sqrt{17a^2+64abc} - 9b\beta + \sqrt{17(a+b\beta)^2+64(a+b\beta)b(\beta+c)}).$$

We then compare

$$\sqrt{17a^2+64abc} - 9b\beta \quad \text{and} \quad \sqrt{17(a+b\beta)^2+64(a+b\beta)b(\beta+c)}$$

by squaring both sides and taking the difference. We find that

$$17(a+b\beta)^2+64(a+b\beta)b(\beta+c) - (\sqrt{17a^2+64abc} - 9b\beta)^2 = 2b\beta(49a+32bc-9\sqrt{17a^2+64abc}).$$

Because

$$(49a+32bc)^2 - (9\sqrt{17a^2+64abc})^2 = 1{,}024(a-bc)^2 \geq 0,$$

we can conclude that $W_S^* \geq W_O^*$.

Proposition 2. *Retail prices*: $P_S^* \geq P_O^*$. Since $P_O^* = (a + \sqrt{a^2+8ab(W_O^*-\alpha)})/(4b)$ and $W_O^* = (5a+32bc+64b\alpha + 3\sqrt{17a^2+64abc})/(64b)$, it is obvious that the optimal retail price is not a function of the trade promotion discount α in the off-invoice case.

In the scan-back case, we have that $P_S^* = (a+b\beta+\sqrt{(a+b\beta)^2+8b(a+b\beta)W_S^*})/(4b) - \beta$.

Let $\sqrt{17a+64bc+81b\beta} = x$ and $\sqrt{a+b\beta} = y$. We can write the optimal wholesale price as

$$W_S^* = \frac{5a+32bc+37b\beta+3\sqrt{a+b\beta}\sqrt{17a+64bc+81b\beta}}{64b} = \frac{x^2+6xy-7y^2}{128b}. \tag{A1}$$

After replacing W_S^* in P_S^* with the expression in (A1), we can simplify the expression of optimal retail price as

$$P_S^* = \frac{y(x+7y)}{16b} - \beta. \tag{A2}$$

Then we take the derivative of price with respect to trade promotion budget for the scan-back case:

$$\frac{\partial P_S^*}{\partial \beta} = \frac{1}{32}\left[-18 + \frac{81y}{x} + \frac{x}{y}\right] = \frac{(x-9y)^2}{32xy} \ge 0.$$

Therefore, when $\beta = 0$, P_S^* reaches a minimum of $(a+\sqrt{a^2+8abW_S^*})/(4b)$. Because we know that $W_S^* > W_O^*$, it is straightforward that $(a+\sqrt{a^2+8abW_S^*})/(4b) > (a+\sqrt{a^2+8ab(W_O^*-\alpha)})/(4b)$. In other words, the minimum P_S^* is greater than P_O^*.

To summarize, we have just shown that $\partial P_O^*/\partial\alpha = 0$ and $\partial P_S^*/\partial\beta > 0$. We also have shown that optimal retail prices are higher in the scan-back than the off-invoice case even when the scan-back trade promotion budget is zero (when $\beta = 0$). Therefore, we can conclude that $P_O^* \le P_S^*$.

Propositions 4 and 5: Manufacturer and Retailer Profits

1. We prove Proposition 4 by comparing manufacturer profits ($\Pi_{M_O}^*$ and $\Pi_{M_S}^*$).

First of all, one can easily show that manufacturer profits are the same in the baseline case where the trade promotion discounts are zero. In other words, when $\alpha=\beta=0$ we have $\Pi_{M_O}^* = \Pi_{M_S}^*$.

It is also obvious that manufacturer profit $\Pi_{M_O}^* = Q_O^*(W_O^* - \alpha - c)$ is not a function of the trade promotion discount α in the off-invoice case.

In the scan-back case, the effect of trade promotion budget on manufacturer profit can be expressed as $\partial\Pi_{M_S}^*/\partial\beta = (\partial Q_S^*/\partial\beta)(W_S^* - c - \beta) + Q_S^*(\partial(W_S^* - c - \beta)/\partial\beta)$. We will use the same intermediate variables we used in the proof of Proposition 2 (i.e., $\sqrt{17a+64bc+81b\beta} = x$ and $\sqrt{a+b\beta} = y$) to simplify the notations. Now we have $W_S^* - c - \beta = (-x^2+3xy+27y^2)/(128b)$, and the optimal retailer order quantity becomes

$$Q_S^* = \frac{(9y-x)^2}{64}. \tag{A3}$$

The effect of trade promotion budget on retailer's order quantity becomes

$$\frac{\partial Q_S^*}{\partial\beta} = \frac{-9b(9y-x)^2}{64xy} < 0. \tag{A4}$$

We can also write $\partial(W_S^* - c - \beta)/\partial\beta = (3/256)(-36 + (81y)/x + x/y)$. Therefore, we can write the effect of trade promotion budget on manufacturer's profit as

$$\begin{aligned}\frac{\partial \Pi_{M_S}^*}{\partial\beta} &= \frac{\partial Q_S^*}{\partial\beta}(W_S^* - c - \beta) + Q_S^*\frac{\partial(W_S^* - c - \beta)}{\partial\beta} \\ &= \frac{-9b(9y-x)^2}{64xy} * \frac{-x^2+3xy+27y^2}{128b} \\ &\quad + \frac{(9y-x)^2}{64} * \frac{3}{256}\left(-36 + \frac{81y}{x} + \frac{x}{y}\right) \\ &= -\frac{3(9y-x)^3(7x+9y)}{16{,}384xy}.\end{aligned}$$

Since $64(a-bc) > 0$, we can easily show that $81y^2 - x^2 > 0$, which means $(9y-x) > 0$. Therefore, we can conclude that $\partial\Pi_{M_S}^*/\partial\beta < 0$. As a result, $\Pi_{M_S}^*$ reaches the minimum when $\beta = 0$. Because we have shown that when $\alpha=\beta=0$ manufacture profits are the same $\Pi_{M_O}^* = \Pi_{M_S}^*$, we can conclude that $\Pi_{M_O}^* \ge \Pi_{M_S}^*$.

2. Next, we prove Proposition 5 by comparing retailer profits ($\Pi_{R_O}^*$ and $\Pi_{R_S}^*$).

First of all, one can easily show that retailer profits are the same in the baseline case where the trade promotion discounts are zero. In other words, when $\alpha=\beta=0$ we have $\Pi_{R_O}^* = \Pi_{R_S}^*$.

From Equation (1), we know that retailer profit is $\Pi_{R_O}^* = Q_O^*(P_O^* - W_O^* + \alpha) - P_O^* Q_O^{*2}/(4(a-bP_O^*))$. Because we have also shown in the proofs of Propositions 1 and 2 that optimal retail price P_O^* and retailer order quantity Q_O^* are not influenced by the trade promotion discount α, we can conclude that retailer profit is not a function of the trade promotion discount α in the off-invoice case.

According to Equation (8), in the scan-back case, retailer's profit can be written as $\Pi_{R_S}^* = Q_S^*(P_S^* - W_S^* + \beta) - (P_S^* + \beta)Q_S^*/(4(a-bP_S^*))$. According to Equation (10), we can replace Q_S^* with $Q_S^* = 4(a-bP_S)^2/(a+b\beta)$, which leads to $\Pi_{R_S}^* = Q_S^*[b(P_S^*+\beta)^2/(a+b\beta) - W_S^*]$.

We will use the same intermediate variables $\sqrt{17a+64bc+81b\beta} = x$ and $\sqrt{a+b\beta} = y$ to simplify the notations. According to Equations (A1) and (A2),

$$W_S^* = \frac{x^2+6xy-7y^2}{128b} \quad \text{and} \quad P_S^* = \frac{y(x+7y)}{16b} - \beta.$$

Therefore, we have

$$\frac{b(P_S^*+\beta)^2}{a+b\beta} - W_S^* = \frac{-x^2+2xy+63y^2}{256b}.$$

According to Equation (A3), $Q_S^* = (9y-x)^2/64$. Therefore, retailer profit when trade promotion is allocated to scan-backs can be expressed by

$$\Pi_{R_S}^* = Q_S^*\left[\frac{b(P_S^*+\beta)^2}{a+b\beta} - W_S^*\right] = \frac{(9y-x)^3(x+7y)}{16{,}384b}.$$

And the effect of trade promotion budget on retailer's profit is $\partial\Pi_{R_S}^*/\partial\beta = -(9y-x)^3(5x+27y)/(8{,}192xy)$. Since $(9y-x) > 0$, we can conclude that $\partial\Pi_{R_S}^*/\partial\beta < 0$. As a result, $\Pi_{R_S}^*$ reaches the minimum when $\beta = 0$. Because we have shown that when $\alpha=\beta=0$ retailer profits are the same $\Pi_{R_O}^* = \Pi_{R_S}^*$, we can conclude that $\Pi_{R_O}^* \ge \Pi_{R_S}^*$.

Appendix B. Instructions for the Experiment

This is an experiment to study how manufacturers and retailers decide on the trade promotion discount and allocation. In this experiment, half of you will be randomly assigned as manufacturers and the other half as retailers in a sequence of market trading periods.

In each period, the computers will randomly match retailers and manufacturers to form dyads (pairs). Each dyad consists of one manufacturer trading with one retailer, who faces a market of consumers. Each dyad is independent. Although you remain in the same role as a manufacturer (or a retailer) throughout the experiment, you may be matched with different retailers (or manufacturers) in different periods.

The type of currency in this market is experimental dollars. All transactions will be in terms of EDs. You will accumulate your earnings in EDs throughout the periods. Your objective is to earn as much as you can. You can raise your hands if you have any questions during the experiment. *Please do not talk to others*.

Definitions

Trade promotions are manufacturer incentives directed to retailers (rather than to consumers) to increase sales. The negotiation of trade promotions usually involves two major decisions: the *discount* and its *allocation*:

(1) *Discount*. *Discount* refers to the amount of per-unit discount (in dollars) a manufacturer gives to a retailer based on the wholesale price. There is usually an industry standard for trade promotion discount. In this experiment, the trade promotion discount in EDs is TP.

(2) *Allocation*. In this experiment we consider two types of trade promotions:

- *Off-invoices*. The manufacturer pays the retailer a per-unit trade promotion discount TP for all units ordered by the retailer.
- *Scan-backs*. The manufacturer pays the retailer a per-unit trade promotion discount TP for all items sold (scanned) by the retailer.

In this experiment, the trade promotion discount has to be allocated entirely to either *off-invoices* or to *scan-backs*.

Market Information

1. *Consumer demand.* Consumer demand in each market will be generated by computers in the following way: the potential demand lies between 0 units and a maximum of $2(A - B \cdot P_R)$ units, with each value having equal chance of being selected. Here A represents the highest potential demand, P_R represents retail price, and B represents how retail prices influence consumer demand.

2. *Manufacturer decisions*. Each manufacturer only produces and sells one brand to fulfill the retailer's order. It costs a manufacturer C to produce a unit. The manufacturer makes profits by selling to the retailer. The higher the (per unit) wholesale price (P_M) the higher the manufacturer profit.

3. *Retailer decisions*. Retailers make decisions on the number of units to order from the manufacturer and the retail price to consumers. Retailers cannot perfectly predict consumer demand when making pricing and order decisions. If at the end of each period realized consumer demand is lower than retailer's order quantity, there will be no residual value or inventory cost associated with the unsold products. On the other hand, a retailer will not be able to satisfy consumer demands beyond what he/she has ordered from the manufacturer.

Procedure

There are four stages in each period. The sequence of these stages is as shown in Figure B.1.

At the beginning of each period, the computers will randomly select a manufacturer or a retailer in each dyad to make the trade promotion allocation decision and inform you.

1. *In the first stage*, the manufacturer sets a wholesale price P_M (per-unit prices paid by retailers to manufacturers) given the per-unit trade promotion discount (TP) in the industry.

2. *In the second stage*, either the manufacturer or the retailer within a dyad makes the allocation decision between off-invoices and scan-backs. The units considered in trade promotion (Q_{TP}) and, consequently, the total amount of trade promotion ($B = TP * Q_{TP}$) depend on the allocation decision.

If the trade promotion is allocated to off-invoices, the units considered in trade promotion (Q_{TP}) will be the same as the quantity *ordered* by the retailer (Q_M). The manufacturer will give the retailer $B_{\text{off-invoices}} = TP * Q_M$ as trade promotion allowance. In this case, the allocation to scan-backs is zero ($B_{\text{scan-backs}} = 0$).

If the trade promotion budget is allocated to *scan-backs*, then the units considered in trade promotion (Q_{TP}) is equal to the quantity *sold* by retailer to the end consumer (Q_R). The TP allowance should be calculated as $TP * Q_R$. In this case, the allocation to off-invoices is zero ($B_{\text{off-invoices}} = 0$).

3. *In the third stage*, retailers make decisions on the order quantity (Q_M) and retail price (P_R).

4. *In the fourth stage*, the consumer demand realizes and the computers will complete the transactions and display the decisions and profits in this period.

Profit Calculation

Manufacturer profit depends on (1) revenue and (2) trade promotion discount and its allocation. It can be calculated as

$$\underbrace{Q_M * (P_M - C)}_{\text{Revenue}} - \underbrace{(TP * Q_{TP})}_{\text{Trade Promotion}},$$

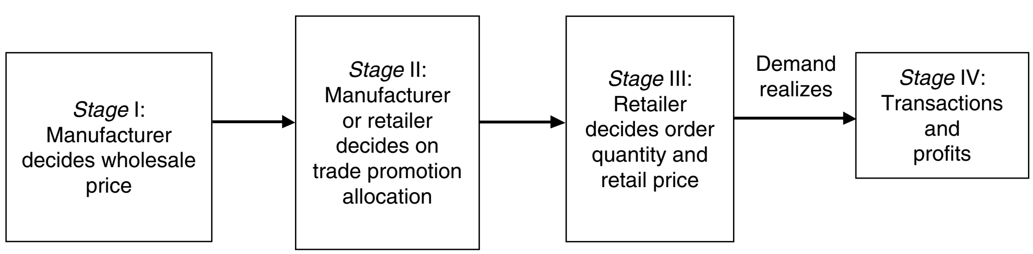
where $Q_{TP} = Q_M$ if *off-invoices* and $Q_{TP} = Q_R$ if *scan-backs.*

Retailer profit depends on (1) revenue, (2) cost of order, and (3) trade promotion discount and its allocation. It can be calculated as

$$\underbrace{(P_R * Q_R)}_{\text{Revenue}} - \underbrace{(P_M * Q_M)}_{\text{Cost of Order}} + \underbrace{(TP * Q_{TP})}_{\text{Trade Promotion}},$$

where $Q_{TP} = Q_M$ if *off-invoices* and $Q_{TP} = Q_R$ if *scan-backs.*

Figure B.1 Experimental Procedure



You will find out your profits for the current period before you move on to the next period. Your goal in this experimental setting is to maximize your profits across all periods.

In this experiment, the input parameter values are as follows:

Trade promotion discount: $\underline{TP = 2 \text{ EDs}}$

Manufacturer production cost: $\underline{C = 1 \text{ ED}}$

Consumer demand factors: $\underline{A = 100 \text{ EDs} \quad B = 5 \text{ EDs}}$

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