University of Alberta

Experimental Study of Price Competition in Distribution Channels and Promotions

by

Sung Chul Choi ©

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Experimental Study of Price Competition in Distribution Channels and Promotions submitted by Sung Chul Choi in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Marketing.

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Dr. Wilfred Amaldoss

Dedication

To my whole family in Korea and Canada.

ABSTRACT

The primary contribution of this thesis is to add to the experimental work on price competition in various market structures. In particular, I examine whether the predicted outcomes of one-shot games hold up in more realistic repeated contexts and whether human cognitive and instinctual reactions match with theoretic predictions. Toward this objective, I develop three related experimental studies on price competition. In particular, I study (a) power relations in the context of channel consisting of two manufacturers and a common retailer, (b) competitive price promotional strategies in a market consisting of two competing firms, and (c) competitive pricing behavior among firms in different channel structures.

In the first essay of the thesis, I conduct a laboratory experiment to test the applicability of competing possible channel models (Manufacturer Stackelberg leadership, Retailer Stackelberg leadership, Vertical Nash, or channel coordination) and to examine deviations of individual pricing behavior from optimal reactions in the context of Choi's (1991) analysis of two manufacturers and a common retailer. I also study the impact on channel power of three additional variables—market information, the degree of product substitutability, and asymmetric cost structure.

In the second essay, I conduct another laboratory experiment to examine boundary conditions that influence the applicability of the mixed-strategy predictions of the loyal/switcher model of competitive price promotions by

Narasimhan (1988). This essay sheds light on criticisms of mixed strategy equilibria as being too complex for humans, inherently unintuitive, and of questionable applicability and robustness. In addition, the second essay tests whether promotional depth and frequency outcomes are more consistent with Narasimhan's (1988) model or with competing hypotheses, and examines whether a "chat" condition which allows communication between competitors facilitates cooperation.

The third essay examines the nature of competitive interactions among channel members in two different distribution channels: (a) A single-manufacturer / single-retailer bilateral monopoly channel model; (b) Two manufacturers interact with a common retailer. For the single-manufacturer/single-retailer bilateral monopoly channel, I examine vertical strategic interactions (VSI). For the two manufacturers and a common retailer channel, I examine both vertical strategic interactions (VSI) and horizontal strategic interactions (HSI).

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Chapter 1

Introduction

A growing body of research is devoted to modify and test basic economic predictions; moreover, economic research relies increasingly on data collected in the laboratory rather than in the field. This research has its roots in two distinct, but currently converging, areas: the analysis of human judgment and decision-making by cognitive psychologists, and the empirical testing of predictions from economic theory by experimental economists (Press Release: The Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel 2002). As evidence of this widely growing research stream, Vernon Smith was awarded the Nobel Prize 2002 in Economics along with Daniel Kahneman. Vernon Smith was given this award "for having established laboratory experiments as a tool in empirical economic analysis, especially in the study of alternative market mechanisms." In addition, recently, more attention has been giving to experimental studies of marketers' strategic activities predicted from theoretical marketing models (Zwick and Chen 1999, Amaldoss et. al. 2002, Srivastava et. al 2000, Messinger and Chen 2000, Amaldoss and Jain 2002) and many strategic models of competitive behavior are open to such study.

From a theoretic perspective, however, most extant game theoretic models of competition are one-shot games, whereas institutional applications are repeated situations. I wonder whether the predicted outcomes hold up in more realistic repeated contexts and whether human cognitive and instinctual reactions match with theoretic predictions. I accordingly believe it is of interest to examine whether humans will use competitive strategies, as predicted by theory, and the extent to which the predictions of one-shot game models are descriptive of outcomes of repeated game interactions. To investigate this issue, I experimentally test the two-manufacturer/one-retailer channel model of Choi (1991) in the first essay. Current research differs as to whether the most applicable equilibrium under this structure is Manufacturer Stackelberg (MS) or Vertical Nash (VN). The earliest models began by assuming MS, but much subsequent work (beginning with Jeuland and Shugan 1983) has used VN. These models are typically proposes as one-shot games, and with the folk-theorem, both (and many other) outcomes are possible in repeated contexts. The primary question is how enduring the MS first-mover advantage is when the retailer has the ability to counter to try to influence the manufacturer in the subsequent period.

In the second essay, I experimentally test the loyal/switcher pricing model of Narasimhan (1988) to examine whether human subjects really can and do, indeed, carry out mixed strategies. Yet mixed strategy equilibria have been criticized as being of questionable robustness, too complex for humans, and inherently unintuitive. I therefore examine the applicability of these criticisms in the context of Narasimhan's (1988) model of competitive price promotions.

Finally, in the third essay, I investigate the nature of competitive interactions among channel members in two different distribution channels using experimental data: (a) a single-manufacturer/single retailer bilateral monopoly channel and (b) two-manufacturer/one-retailer channel.

The thesis is organized as follows. Chapter 2 examines channel power relations in the context of Choi"s (1991) model. Chapter 3 shed light on criticisms that mixed strategy equilibria are too complex for humans and inherently unintuitive in the context of Narasimhan's (1988) model. Chapter 4 estimates of competitive pricing behavior among channel members. Lastly, Chapter 5 discusses the implication and delineates several further research areas.

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Chapter 2

Essay 1: An Experimental Study of Power Relations in a Two-Manufacturer/One-Retailer Channel

Because of changing distribution systems and development of competing modeling approaches to describe these systems, practitioners and academics have increasingly studied channel coordination and power. Two principal research streams of the last two decades utilize behavioral and game-theoretic methods. Gaski (1984) summarized behavioral research on channel power, dating back to El-Ansary and Stern (1972), based on both cross-sectional surveys of industry participants and laboratory experiments. Economics-based modeling of channel relationships started with Spengler (1950) and has been developed considerably by marketing scholars.

The earliest channel models assume leader-follower behavior with the manufacturer acting as price leader and the retailer, as price follower (Spengler 1950, McGuire and Staelin 1983, Coughlan 1985, Choi 1991, Lee and Staelin 1997). According to this approach, manufacturers set wholesale prices strategically knowing that these prices will influence retailers' decisions, and retailers follow in predictable fashion by selecting margins that constitute optimal reactions to the manufacturers' wholesale prices. Such manufacturer-retailer interaction constitutes a form of Stackelberg leadership, with the manufacturer playing the role as leader. An alternate form of leader-follower relationship involves the retailer playing the role of leader (Choi 1991, Lee and Staelin 1997).

Such an approach may reflect the growing belief among practitioners that retailers are gaining power in the channel.

Several authors have considered a more symmetrical relationship between manufacturers and retailers (Jeuland and Shugan 1983, Choi 1991, Lee and Staelin 1997). According to this approach, manufacturers and retailers move simultaneously. Thus, manufacturer wholesale prices and retailer margins are assumed to be optimal reactions to each other in a single-period, simultaneous-move context. Choi (1991) calls such manufacturer-retailer interaction as Vertical Nash, which he contrasts with Manufacturer Stackelberg leadership, Retailer Stackelberg leadership, and a fully coordinated channel (the outcome of an integrated monopoly).

In the last two decades, most modeling work has utilized Manufacturer Stackelberg leadership, although some analyses have assumed a Vertical Nash structure. Despite the proliferation of such models, there really is little consensus about which approach is a more accurate representation of marketing channels. Most studies to date have assumed a given theoretical model, and relatively little empirical work has been done to ascertain which model structure is most applicable.

The empirical work that has been done testing competing channel structures has used market and laboratory data. Kadiyali, Chintagunta and Vilcassim (1996) test competing channel market structures using time-series data from a pharmaceutical channel. Experimental tests of a single-manufacturer/single-retailer channel have been performed by Srivastava, Chakravarti, and Rapoport (2000), who consider a particular sequential bargaining model under one-sided uncertainty and opportunity cost of delay, and by Messinger and Chen (2000) who consider several competing non-cooperative models.

The intended contribution of the current essay is to add to the empirical work on channel structure by providing a laboratory experiment designed to test which channel power structure is more applicable in the context of Choi's (1991) model of a channel consisting of two manufacturers and a common retailer: Manufacturer Stackelberg leadership, Retailer Stackelberg leadership, Vertical Nash, or channel coordination. I also study deviations of individual pricing behavior from optimal reactions to better understand the behavioral reasons for the observed market outcomes. In addition, I consider the impact on channel power of three additional variables—market information, the degree of product substitutability, and asymmetric production costs—the latter two of which have not been previously considered in experimental channel research.

Concerning the first of these variables, Chu and Messinger (1997) examine the impact of market information acquisition on the distribution of channel profits. They find that improved information about demand always results in greater absolute profits. Desiraju and Moorthy (1997) also show that performance requirements on price and service improve channel performance when the retailer is better informed about demand conditions than the manufacturer. In debriefing surveys in pilot runs, I also found that participants felt that knowledge of competitors' costs and profits could be particularly interesting. Thus, I consider whether channel coordination is facilitated when players know competitors' costs and profits.

Concerning the second variable, McGuire and Staelin (1983) examine the effect of product substitutability associated with cross-price elasticity on Nash equilibrium distribution structures. They find that the degree of substitutability is a crucial component of linear duopoly demand function, and has a critical influence on the channel coordination. A smaller value of the degree of product substitutability implies more product differentiation (i.e., a price difference between the two products has less of an impact on the demand for the competitor's product; see Choi 1996). In this context, Choi (1991) shows that greater product substitutability leads to greater relative profits for the retailer (as compared to the manufacturers), although all channel participants gain in absolute terms. I accordingly examine a treatment condition in which there is high substitutability between the two manufacturers' products.

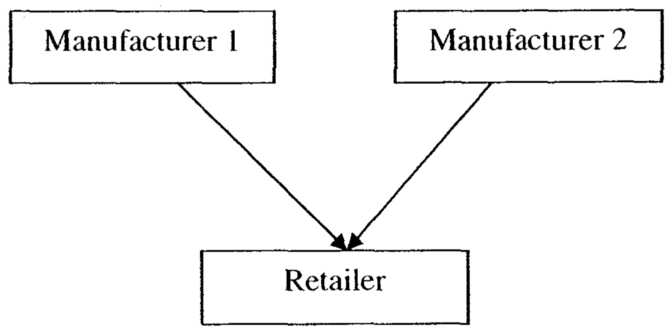
Concerning the production cost differences between manufacturers, I examine whether firms exploit cost advantages or cope with cost disadvantages through pricing. In particular, I investigate the impact of cost advantages in a market with differentiated products. This relaxes the simplifying assumption made in past studies of equal manufacturer variable production cost (Choi 1991, 1996, Lee and Staelin 1997).

Note that the last two issues—product differentiation and cost reduction—constitute the two most important "generic strategies" commonly listed in the management literature (Porter 1980), and thus constitute important issues for experimental consideration.

2.1 Review of Two-Manufacturer/One-Retailer Channel Structure

Several channel models have been considered in the literature, involving one manufacturer and one retailer (Spengler 1950, Jeuland and Shugan 1983, Desiraju and Moorthy 1997), two parallel dyads of one manufacturer and one retailer (McGuire and Staelin 1983), one manufacturer and two retailers (Ingene and Parry 1995), two manufacturers and one retailer (Choi 1991), and two manufacturers and two retailers (Choi 1996, and Lee and Staelin 1997). Most work in this area has focused on theoretical models. Although there have been a couple of empirical studies of these models using the New Empirical Industrial Organization approach (Kadiyali, Chintagunta and Vilcassim 2000 and Sudhir 2001), there have been few empirical studies using the experimental economics approach. One exception concerns the one-manufacturer/one-retailer setting (Messinger and Chen 2000). The current essay reports on an experimental study of the more strategically complex environment of two manufacturers and one retailer (see Figure 2.1).

Figure 2.1 Common Retailer Channel Structure



Following Choi (1991), the two-manufacturer/one-retailer model can be described as follows. Suppose there are downward sloping demand functions:

$$q_i = a - bp_i + \gamma p_j, \quad i,j = 1,2, \quad i \neq j, \quad a > 0, \quad b > \gamma > 0 \qquad (2.1)$$

where q_i is the demand for brand i at retail price p_i (given that the retail price of the other brand j is p_j) and γ describes the degree of substitutability between the two products (McGuire and Staelin 1983, Jeuland and Shugan 1988, Choi 1991, Ingene and Parry 1995). When $\gamma = 0$, the model represents two (independent) single-manufacturer/single-retailer bilateral monopoly channels. The higher the γ, the greater the cross-price effects between the two products. It is also assumed that the own-price effect exceeds the cross-price effect (so that $b > \gamma$).

The profit functions for manufacturer 1, manufacturer 2, and the retailer, respectively, are

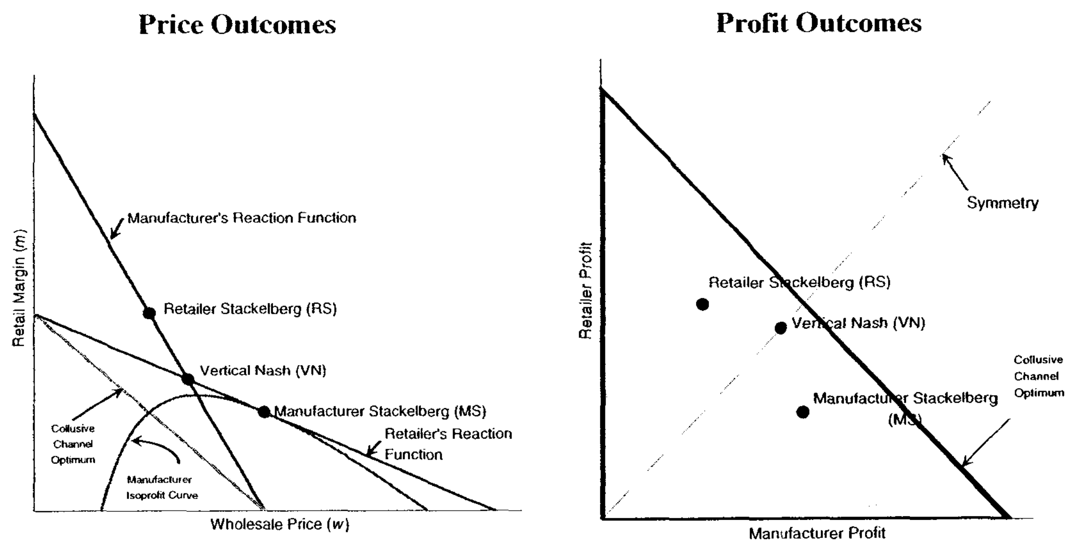
$$\Pi_{M_1} = (w_1 - c_{m1})q_1,\ \Pi_{M_2} = (w_2 - c_{m2})q_2,\ \text{and}\ \Pi_R = \sum_{i=1}^{2}(m_i - c_{ri})q_i \equiv \sum_{i=1}^{2}\Pi_{R_i} \quad (2.2)$$

where w_i is manufacturer i's wholesale price, m_i is the retail margin on product i ($m_i = p_i - w_i$), c_{mi} is manufacturer i's variable cost of producing its product, and c_{ri} is the retailer's handling cost for product i. The inclusion of the retailer's handling cost is a minor addition to Choi's (1991) assumptions (I will assume these handling costs to be equal for both products).

Equilibria for a single-period game are calculated by maximizing the three profit functions in Equation (2.2). A different sequence of optimization calculations is used to compute three of the competing equilibrium concepts (see Choi 1991).

The Vertical Nash (VN) equilibrium is calculated by simultaneously optimizing the three profit functions in Equation (2.2). (That is, Manufacturer 1 sets w_1 to maximize Π_{M_1}, Manufacturer 2 sets w_2 to maximize Π_{M_2}, and the Retailer sets m_1 and m_2 to maximize Π_R.) For the simplifying case of no cross-price effects (γ=0), the VN equilibrium (for either Product 1 or Product 2) can be graphed in Figure 2.2 (left panel) as the intersection of the reaction functions (first-order conditions) of one manufacturer and the retailer.

Figure 2.2 Different Possible Equilibria



*Symmetric case with $c_{m1} = c_{m2}$ and $c_{r1} = c_{r2}$.

The Manufacturer Stackelberg leadership (MS) equilibrium assumes that the manufacturers move first and the retailer, second. I solve this problem backwards, first maximizing the retailer's profits, and then simultaneously maximizing the two manufacturers' profits. (That is, I begin by solving for the values of m_1 and m_2 that maximize Π_R , conditional on w_1 and w_2. I then simultaneously solve for w_1 to maximize Π_{M_1} and w_2 to maximize Π_{M_2} , factoring into the calculations how the manufacturers' choices of w_1 and w_2 influence the retailer's choice of m_1 and m_2.[1]) The MS equilibrium is graphed in Figure 2.2 as the point on the retailer's reaction function that provides the highest manufacturer profit. Note that wholesale price under MS is greater than or equal to that under VN and retail margin under MS is less than or equal to that under VN.

[1]Thus, Manufacturer Leadership involves anticipating the retailer reactions.

The Retailer Stackelberg leadership (RS) equilibrium assumes that the retailer moves first and the manufacturers, second. I solve this by first simultaneously maximizing the two manufacturers' profit functions, and then maximizing the retailer's profits (factoring into the retailer's optimization how its choice of retail margins will influence the two manufacturers' choices of wholesale prices). The RS equilibrium is shown in the left panel of Figure 2.2 analogously to the MS equilibrium. Note that VN, MS, and RS yield retail prices above the Collusive Channel Optimum (i.e., the values of p_1 and p_2 that maximize $\sum_{i=1}^{2}(p_i - c_{ri})q_i$).

The right-hand panel of Figure 2.2 depicts the retail and manufacturer profits for the MS, RS, and VN cases. The retail profit is greatest under RS and least under MS, and manufacturer profit is the reverse. Consequently, each channel member has a direct incentive to become a leader (Choi 1991, Lee and Staelin 1997).

In an infinitely repeated game, according to the folk-theorem (see Fudenberg and Tirole 1991, chapter 5), all profit combinations in each period in the triangular region of the right-hand panel of Figure 2.2 can be supported as (subgame perfect) equilibrium outcomes. In a finitely repeated game, it is less recognized that the Manufacturer Stackelberg (MS) outcome in each period is the unique (subgame perfect Nash) equilibrium outcome (Messinger and Chen 2000). Formally, this latter outcome is the maintained hypothesis because the experiment uses a finite-move game. RS and VN are two alternative hypotheses. RS is a particularly interesting alternative hypothesis because the presence of two manufacturers would seem to give the retailer the opportunity to take a price leadership role by "playing" the manufacturers off against each other.

When $\gamma>0$, the equilibrium wholesale prices, retail margins, and profits under RS, VN, and MS for both Products 1 and 2 will all be shifted upwards relative to what is shown in Figure 2.2. The resulting distribution of channel profits is more favorable to the retailer. Although a general description of the retailers' and manufacturers' reactions requires more than two dimensions, the equilibrium points can still be graphed in Figure 2.2, and when I assume symmetry of costs and demand, it turns out that a single point describes both Products 1 and 2 under each hypothesis. The exact equilibrium points are shown later in the essay. (See Figure 2.5a for the case of moderate substitutability; Figure 2.5b for the case of high product substitutability; and Figure 2.5c for the case of asymmetric costs.)

The purpose of the experiments is to ascertain which of these theoretical outcomes is most applicable and to assess whether individual pricing behavior conforms to optimal reactions (shown in Figure 2.2).

2.2 Research Hypotheses

I summarize the specific research hypotheses in Table 2.1 and give further explanation in the discussion that follows.

Table 2.1 Summary of the Research Hypothesis

Hypothesis	Verbal Description of Experimental Manipulation	Expected Outcomes	Background Literature
1. Channel Structure	Treatment 1: Each channel member knows the opponents' costs and profits; the two products are moderately differentiated; and both manufacturers have the same production costs (equal to $8.00).	Manufacturer Stackelberg*	Choi (1991) Lee and Staelin (1997) Messinger and Chen (2000) Sudhir (2001)
2. Imperfect Information on Costs and Profits	Treatment 2: Each channel member does not know the opponents' costs and profits; the two products are moderately differentiated; and both manufacturers have the same production costs (equal to $8.00).	Lower total channel profit Relative profits unaffected Higher dispersion of outcomes	Chu and Messinger (1997) Desiraju and Moorthy (1997)
3. Low Product Differentiation	Treatment 3: Each channel member knows the opponents' costs and profits; the two products are less differentiated; and both manufacturers have the same production costs (equal to $8.00).	Retail margins and profits much higher. Manufacturer net prices and profits somewhat higher.	Shugan and Jeuland (1988) Choi (1991)
4. Asymmetric Production Costs	Treatment 4: Each channel member knows the opponents' costs and profits; the two products are moderately differentiated; and the manufacturers have different production costs (equal to $10.00 and $8.00, respectively).	Higher net prices and profits for the low-cost manufacturer Greater benefits for the retailer	Choi (1991)
5. Interaction Effect	Treatment 5: Each channel member knows the opponents' costs and profits; the two products are less differentiated; and the manufacturers have different production costs (equal to $10.00 and $8.00, respectively).	The combined effect of Treatments 3 and 4 is greater than the sum of the two individual effects.	Choi (1991)

* Manufacturer Stackelberg is the subgame perfect equilibrium in a finite move game such as this experiment. Competing Hypotheses are Retail Stackelberg, Vertical Nash, Collusion, and Symmetric Prices and Profits.

2.2.1 Hypothesis 1

As suggested earlier, there is no theoretical consensus as to which model applies in a repeated or one shot setting with many manufacturers selling through a common retailer—indeed, that is the motivation for this study. The competing models are MS, VN, RS, collusion, symmetric outcomes, or something else. Formally, the unique (subgame perfect) equilibrium to the finitely repeated game is Manufacturer Stackelberg (MS); so MS is the formal maintained hypothesis.

To examine this hypothesis, Treatment 1 creates a setting that embodies the structure of the two-manufacturer/one-retailer game. In particular, I have designed Treatment 1 to include (a) full information on all players' parts about opponents' costs and profits, (b) moderately differentiated products (γ=75), and (c) symmetric production costs between the two manufacturers.

2.2.2 Hypothesis 2: Incomplete Cost and Profit Information

The foregoing discussion of competing hypotheses assumed full cost and profit information. In practice, however, channel participants may have imperfect information about each other's costs and profits. Previous research suggests that channel profits will be higher under full information than under incomplete information (Chu and Messinger 1997; Desiraju and Moorthy 1997) due to the informed channel member's ability to "fine tune" prices in response to changes in demand conditions. I, thus, hypothesize that total channel profits will be higher under full information about competitor's costs and profits. However, since cost and profit information are symmetric, I hypothesize that the share of channel profits obtained by the two manufacturers and the retailer will be unaffected. Furthermore, since there is more guesswork under incomplete information, I hypothesize that there will be greater dispersion in outcomes across participants. To examine this hypothesis, Treatment 2 incorporates incomplete information for all players' about opponents' costs and profits.

2.2.3 Hypothesis 3: Product Differentiation

The analyses of Choi (1991) and Shugan and Jeuland (1988) suggest that high product substitutability implies higher relative prices and profits for the retailer than for the manufacturers (see Figures 2.5b and 2.5f). Less intuitively, both wholesale and retail prices increase and everyone's profits increase. To examine these conclusions, Treatment 3 incorporates high substitutability between the competing products (γ=200, which describes less product differentiation).

2.2.4 Hypothesis 4: Product Cost Differences

Choi (1991) argued that a low-cost manufacturer benefits, not only from a larger contribution margin, but also from a larger market share due to the lower price. But while the manufacturers compete to sell more of their respective products by transferring part of the cost savings to wholesale prices, the common retailer lacks an incentive to reduce its margins. I therefore hypothesize that asymmetric production costs yield higher net prices and profits for the low-cost product, for both the manufacturer and the retailer, than for the high cost product (as compared to the case of symmetric production costs). I also hypothesize that the retailer's benefit is greater than the manufacturers' from asymmetric production costs. To examine these hypothesis, Treatment 4 includes asymmetric production costs for the two manufacturers (cm1 = 10 and cm2 = 8).

2.2.5 Hypothesis 5: Interaction of Product and Cost Differences

Choi's (1991) model predicts a small interaction effect under the presence of both high product substitutability and asymmetric production costs (see Figures 2.5d and 2.5h).[2] In particular, the combined effect is greater than the sum of the two individual effects. To examine such interaction of product and cost differentiation, Treatment 5 includes asymmetric production costs (c_{m1} = 10 and c_{m2} = 8) and high product substitutability (γ=200).

2.3 Experiment 1

2.3.1 Subjects

Three hundred MBA and undergraduate (mostly business) students from a large university in North America participated in a session that lasted about 90 minutes. Subjects were recruited through advertisements and class announcements. In return for participating, subjects were given class credit, a fixed payment of $5, and a further payment contingent upon performance.

2.3.2 Game Setup and Procedures

[2] A small interaction effect arises for all three equilibrium concepts considered by Choi (Manufacturer Stackelberg, Vertical Nash, Retail Stackelberg).

Subjects were randomly assigned the roles of manufacturer and retailer, and engaged in multiple rounds of interaction. As shown in Figure 2.3, each round has three steps reflecting the institutional reality of the sequence of the game. In the first step, each manufacturer chooses its own wholesale price w_1 and w_2 within sixty seconds, respectively. In the second step, the retailer chooses gross margins m_1 *and* m_2 for the two products within sixty seconds. In the third step, market demands for the two products, q_1 and q_2, and each player's profits are realized (according to Equation (2)). The play proceeds for thirty rounds, each round lasting a maximum of 2 minutes, and the entire game lasts a maximum of about 60 minutes.

The experimental procedure began by giving subjects' detailed instructions and a quiz (Appendix 2.1). The quiz consisted of ten questions to ascertain the understanding of the instructions and subjects were awarded 10 cents for each correct answer.[3] Subjects then played at a computer terminal with a randomized, anonymous partner for seven 'practice' rounds. No compensation was provided for practice rounds. The parameters of the model were then changed and each subject was randomly reassigned to a different partner but each subject's role was not changed. Subjects then engaged in 30 rounds of play and subject fees were earned based on the game profits earned. Subjects then filled out a survey about their strategies they applied in the game. They were then paid subject fees in private, and debriefed. The payment formula was as follows: each

[3] The average quiz score was 8.73/10, which indicated that players understood the game well, even before playing the practice rounds.

Figure 2.3 Game Set-up

Beginning of Round	Step 1 (60 seconds)	Step 2 (60 seconds)	Step 3
	Manufacturer 1 sets w_1 **Manufacturer 2 sets w_2**	**Retailer sets** **m_1 and m_2**	**Demands and** **Profits Realized**
	Sent to Retailer	Sent to Market $P_1 = w_1 + m_1$ $P_2 = w_2 + m_2$	Manufacturer 1 gets: $q_1(w_1 - c_{m1})$ Manufacturer 2 gets: $q_2(w_2 - c_{m2})$ Retailer gets: $q_1(m_1 - c_{r1}) + q_2(m_2 - c_{r2})$

subject was paid $5.00 automatically, plus the quiz payment (maximum of $1.00), plus the total accumulated profit over the thirty rounds divided by the collusive profit multiplied by two rounded to the nearest 10,000. I limited the maximum payment to $25.00. Adding these three components together, the average actual payment for all runs of the experiment was $17.91.

The manufacturers and the retailer computer screens in steps 1 and 2 are shown in Figure 2.4. In the example of this figure, both manufactures chose their own wholesale price in Round 7 to be $20.00 respectively. The retailer received those prices and then selected retail gross margins of $15.00 and $17.00, respectively, for Products 1 and 2 in Round 7. (Note that, before making a final decision, the retailer sees a calculation of the retail prices and net margins associated with its gross margin selections in the upper right hand corner. The traffic signal shows a yellow light until the player confirms, "OK.") All players see a running tally of market outcomes for the last five rounds of play including wholesale prices, retail margins, retail prices, quantities demanded, and profits accruing to them.

2.3.3 Experimental Design

I employed a partial-factorial, between-subjects design involving three variables, each set at two possible levels (full information/incomplete information, moderate product substitutability/high product substitutability, and symmetric production cost/asymmetric production cost). See Table 2.2.

Figure 2.4 (a) Typical Manufacturer Screen in Stage 1

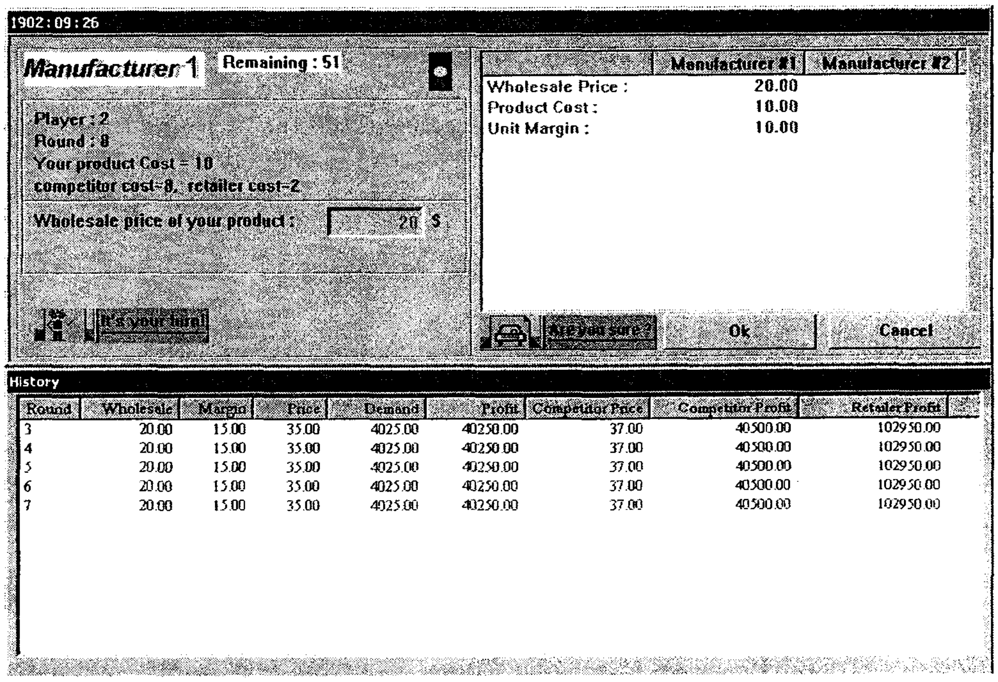
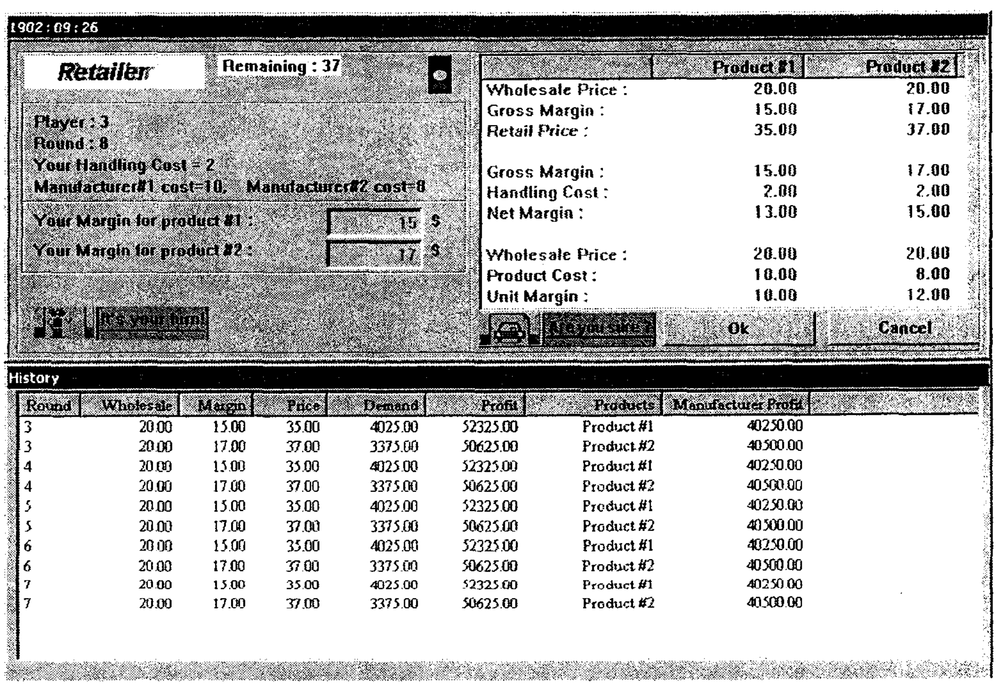


Figure 2.4 (b) Typical Retailer Screen in Stage 2



Treatment 1 is the full information condition. In this condition, the computer screens inform the players of the pricing decisions, costs, and profits of the other players (all players know their own pricing decisions, costs, and profits, of course).

Table 2.2 Experimental Design
(Number of experimental runs in parentheses)

	Incomplete Information	Full Information	
	Moderate Degree of Substitutability ($\gamma = 75$)	Moderate Degree of Substitutability ($\gamma = 75$)	High Degree of Substitutability ($\gamma = 200$)
Symmetric production cost ($c_{m1} = c_{m2}$)	Treatment 2 (20)	Treatment 1 (20)	Treatment 3 (20)
Asymmetric production cost ($c_{m1} \neq c_{m2}$)	N.A.	Treatment 4 (20)	Treatment 5 (20)

In particular, each manufacturer is informed of the competing manufacturer's wholesale price decisions, production cost, and profit, and the retailer's margin decisions, handling cost, and profit; and the retailer is informed of both manufacturers' wholesale price decisions, production costs, and profits. The demand and cost parameters used in this condition are shown in the first row of Table 2.3. [4]

Treatment 2 is the incomplete information condition. In this condition, all parameters are the same as in Treatment 1—the only difference is that the players' do not known (and the game screens do not show) the costs and profits of

[4]To provide external validity, players are not told the parameters of the demand function under which they are operating, but must infer the demand relation through the evolving history of play. Messinger and Chen (2000) find that the outcomes of such a case are very close to a similar case in which subjects are provided the actual demand parameters, in addition to pricing decisions, costs, and profits.

the other players. In particular, manufacturer i knows its own wholesale price, production cost (c_{mi}), and profits, but not the other manufacturer's wholesale price, production cost, and profit, or the retailer's handling costs and profit. The retailer knows its handling costs (c_{r1} and c_{r2}), and profits (for both products), but not the production costs and profit of either manufacturer. All players know the retail prices of both products.

Table 2.3 Parameter values used in the experiment

Treatment	a	b	γ	c_{m1}	c_{m2}	$c_{r1} = c_{r2}$
1. Full Information	10,000	250	75	8	8	2
2. Incomplete Information	10,000	250	75	8	8	2
3. Product Differentiation	10,000	250	200	8	8	2
4. Production Cost Differences	10,000	250	75	10	8	2
5. Interaction Effect (3 and 4)	10,000	250	200	10	8	2

Treatments 3, 4, and 5 are full information conditions. For Treatment 3 (high product substitutability), I set γ= 200, leaving the other parameters the same as in Treatments 1 and 2. For Treatment 4 (asymmetric production costs), I set c_{m1} = 10 and c_{m2} = 8 (the screens in Figure 4 show this treatment). For Treatment 5 (interaction effect of high substitutability and asymmetric production costs), I set γ = 200, cm1 = 10, and cm2 = 8.

2.4. Experimental Results

I summarize the experimental manipulations, expected outcomes, and actual findings in Table 2.4 below.

Table 2.4 Summary of the Hypothesis Tests

Hypothesis	Experimental Manipulations*	Expected Outcomes	Actual Findings
1. Channel Structure	Treatment 1: Full information Moderate substitutability ($\gamma = 75$) Symmetric production costs ($c_{m1} = c_{m2} = 8$)	Manufacturer Stackelberg**	Symmetric Outcomes
2. Imperfect Information on Costs and Profits	Treatment 2: Incomplete information (about competitors' costs and profits)	Relative profits unaffected (Manufacturer Stackelberg). Lower total channel profits. Higher dispersion of outcomes.	Manufacturer profits slightly higher (not reject MS or Symmetry). Total channel profits unaffected. Higher dispersion of outcomes.
3. Low Product Differentiation	Treatment 3: High substitutability ($\gamma = 200$)	Retail margins and profits much higher. Manufacturer net prices and profits somewhat higher.	Retailer margins and profits lag model predictions (but still exceed Symmetric Outcome). Manufacturer net prices and profits are consistent with model predictions.
4. Asymmetric Production Costs	Treatment 4: Asymmetric production costs ($c_{m1} = 10$ and $c_{m2} = 8$)	Higher net prices and profits for the low-cost manufacturer Greater benefits for the retailer	Higher net prices and profits for the low-cost manufacturer Greater benefits for the retailer
5. Interaction Effect	Treatment 5: Asymmetric production costs ($c_{m1} = 10$ and $c_{m2} = 8$) High substitutability ($\gamma = 200$)	The combined effect of Treatments 3 and 4 is greater than the sum of the two individual effects.	The combined effect of Treatments 3 and 4 is approximately equal to the sum of the two individual effects.

*If not explicitly stated, Treatments 2-5 parameters are the same as for Treatment 1.
**The maintained hypothesis for mean outcomes for all treatments is Manufacturer Stackelberg.

This section discusses experimental findings in detail, by describing analyses of mean game results, heterogeneity across respondent dyads, and respondent behavior over time. I begin with a graphical summary of the experimental results (see Figure 2.5).

Figure 2.5 presents mean price/margin and profit outcomes for the five treatment conditions.[5] This figure shows mean outcomes for each treatment across subject dyads and across all 30 rounds and compares these results with the predictions of competing equilibrium concepts. For each treatment condition, I find the following.

2.4.1 Treatment 1: Full Information

For this treatment, the maintained hypothesis is the Manufacturer Stackelberg outcome (because this is a finitely repeated game in which the manufacturers move first in each round). In Figures 2.5a and 2.5e, however, the price outcomes lie closest to the Symmetric Outcomes hypothesis and the manufacturers and retailer tend to share channel profit equally.

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[5]To avoid extreme prices being too influential, if a player chose a value of w or m greater than \$57.5 for the moderate degree of substitutability cases and \$200 for the high degree of substitutability cases in a given round, then NA was recorded for (i) that player's value of w or m, (ii) the associated p, (iii) both product quantities (q_1 and q_2), and (iv) all players profits.

Figure 2.5. Mean Game Results

Pricing and Profit Outcomes for the Five Treatments

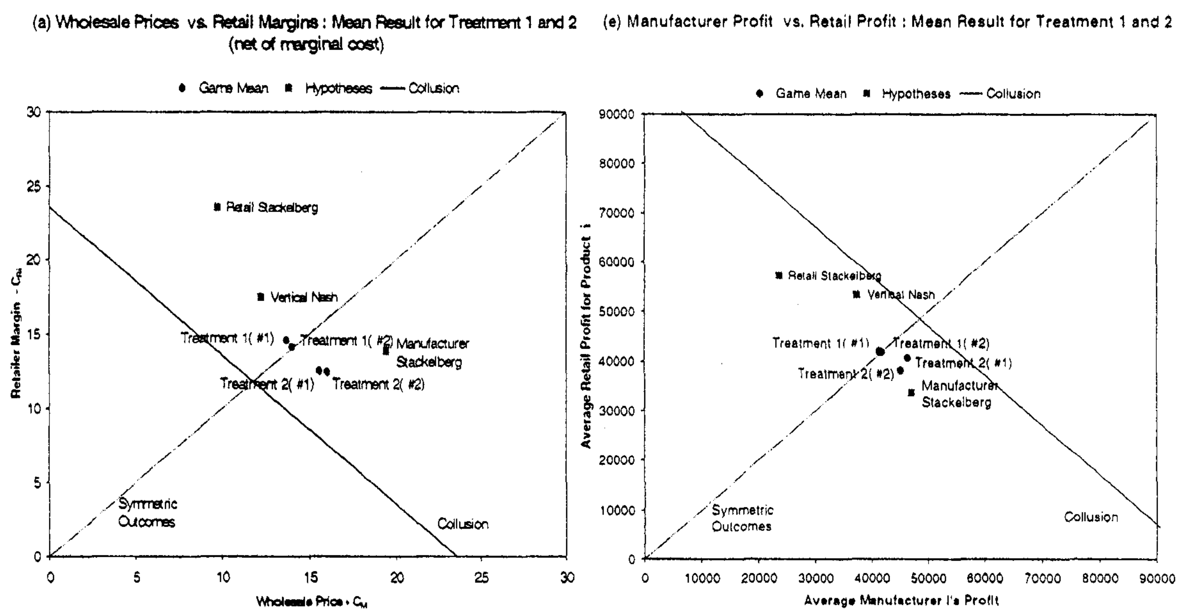


Figure 2.5. Continued

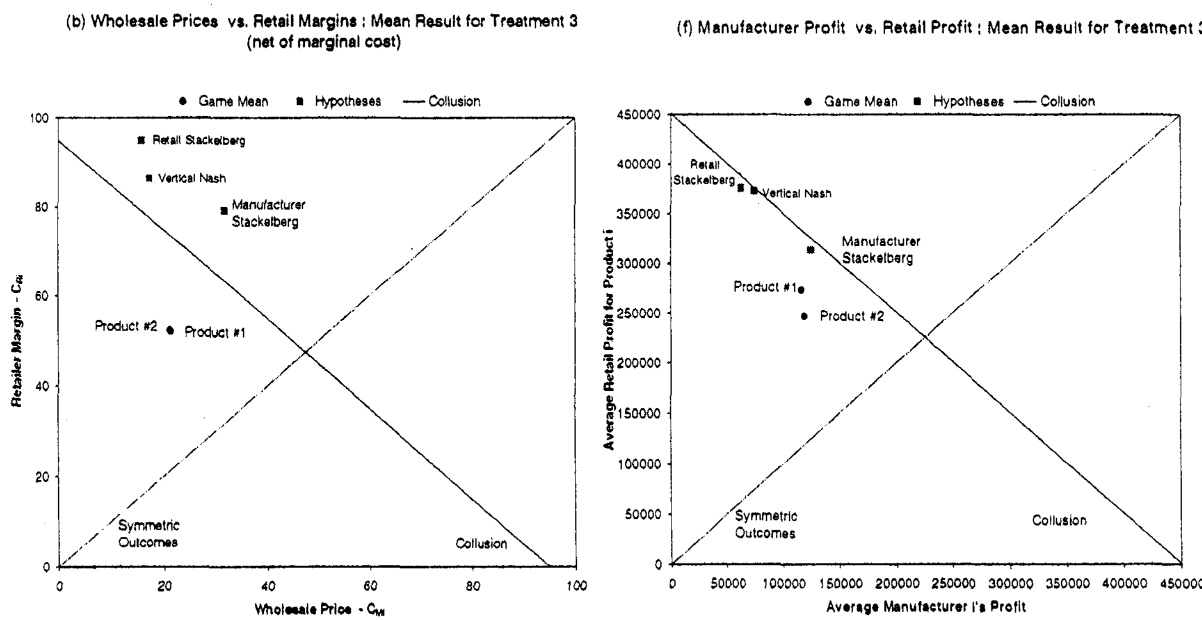
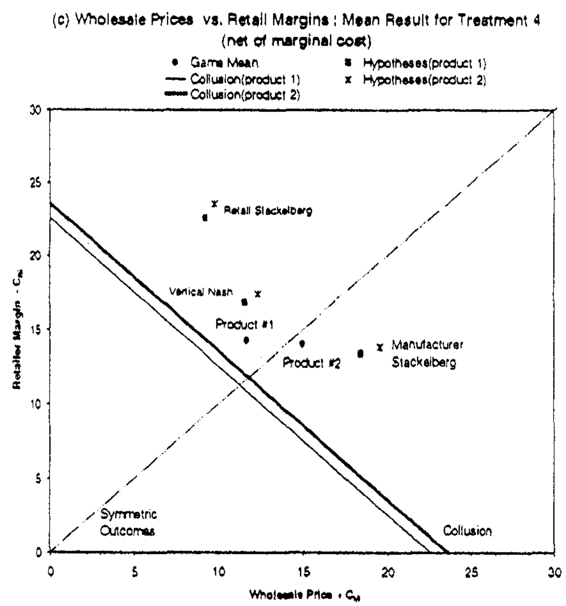


Figure 2.5. Continued



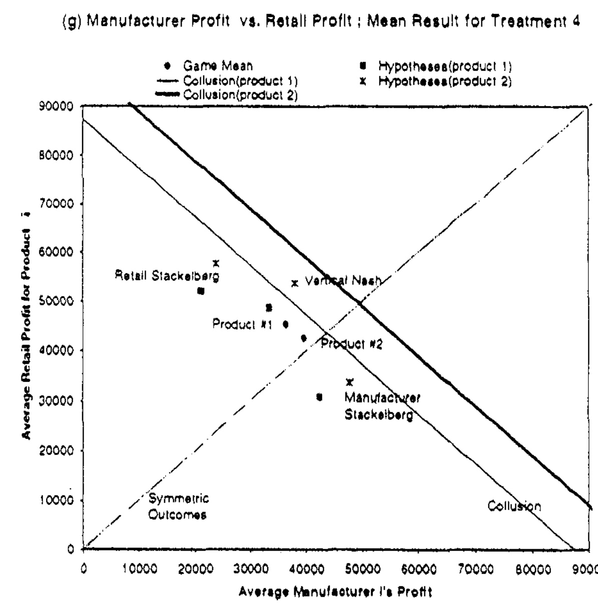
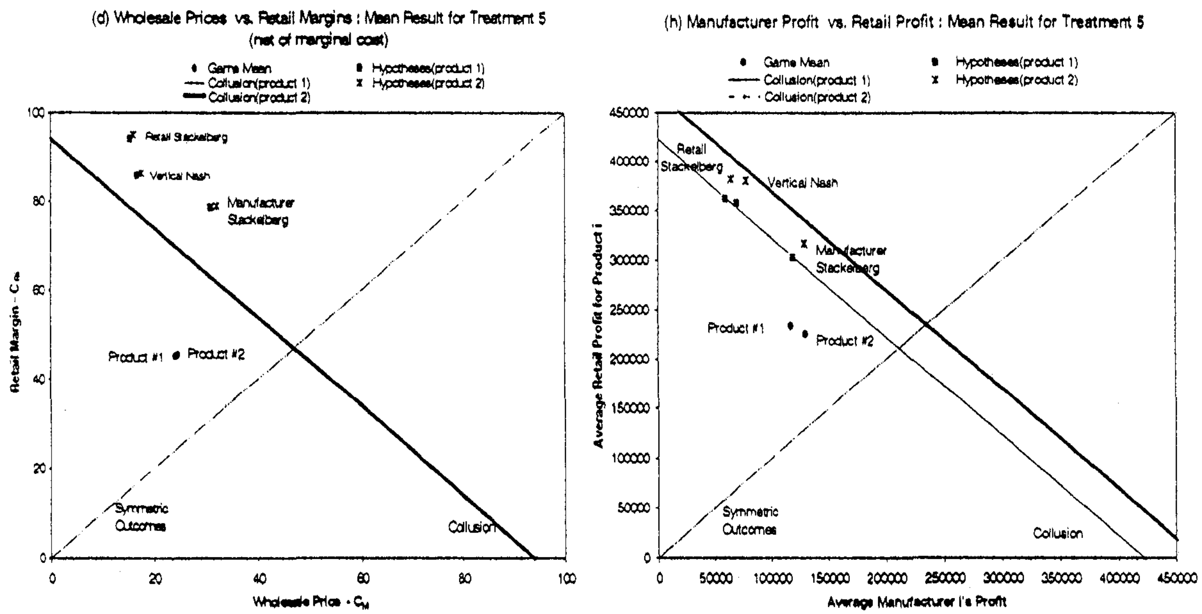


Figure 2.5. Continued



I formally test whether the symmetric outcomes hypothesis applies in Table 2.5. This table contains t-tests of the two linear hypotheses of Symmetric Outcomes and Collusive Channel Optimum Pricing and F-tests of three single-point hypotheses (Vertical Nash, Manufacturer Stackelberg, and Retail Stackelberg).[6] Row 1, indeed, verifies that the price and profit data for both products in Treatment 1 are not significantly different from the Symmetric Outcomes hypothesis (although I do not reject the Manufacturer Leadership hypothesis for the profit data for Product 2).

Overall, Treatment 1 supports an "equity heuristic" wherein, for each product, the manufacturer and retailer tend to share profit equally. I do not get Manufacturer leadership; and the manufacturers' "first-mover" advantage in each

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[6]The t-tests for symmetry are standard (two-sided) tests of equality for Products 1 and 2. The t-test for collusive pricing are standard (two-sided) tests against the hypothesis that retail prices are $33.57 for Treatments 1 and 2; $105 for Treatment 3; $34.57 and $33.57 for Products 1 and 2 for Treatment 4; and $106 and $105 for Products 1 and 2 for Treatment 5, respectively. The t-test on channel profits is a standard (one-sided) test against the hypothesis that channel profits are $97,231 for Treatments 1 and 2; $451,250 for Treatment 3; $87,465 and $98,999 for Products 1 and 2 for Treatment 4; and $423,000 and $470,250 for Products 1 and 2 for Treatment 5, respectively (this is a one-sided test because I know that channel profit cannot be higher than this value). The F-tests in Table 5 are likelihood-ratio tests of the null hypothesis that $\mathrm{E}(x_1,x_2)=(x_1^0,x_2^0)$, where the variance $\mathrm{V}\begin{pmatrix}x_1\\x_2\end{pmatrix}=\Sigma$ is unknown. Assuming (x_1,x_2) follows a multivariate normal distribution, the test statistic $\frac{n-2}{2}\mathbf{d}'\mathbf{S}^{-1}\mathbf{d}$ follows an $F_{2,n-2}$ distribution, where $\mathbf{d}=(\bar{x}_1-x_1^0,\bar{x}_2-x_2^0)$, $\bar{x}_i=\frac{1}{n}\sum_{r=1}^{n}x_{ri}$, and $s_{ij}=\frac{1}{n}\sum_{r=1}^{n}(x_{ri}-\bar{x}_i)(x_{rj}-\bar{x}_j)$ (see Mardia, Kent, and Bibby, 1979, chapter 5). In particular, for each product, I test whether $\mathrm{E}(w,m)=(w^0,m^0)$ and $\mathrm{E}(\Pi_{M_i},\Pi_{R_i})=(\Pi_{M_i}^0,\Pi_{R_i}^0)$, where (w^0,m^0) and $(\Pi_{M_i}^0,\Pi_{R_i}^0)$ describe the predicted values from the various equilibrium hypothesis, VN, MS, or RS.

round, appears to be dissipated when there are thirty rounds. However, I also do not get an outcome where the common retailer takes advantage of its strategic position of being able to play the manufacturers off against each other. Even the Vertical Nash outcome, which factors in some strategic advantage to the common retailer, is rejected.

Table 2.5. Tests of Channel Hypotheses

Test of **Net Prices** Test of **Profits**		**Null Hypothesis** (*Reject at .05 level. ** Reject at .01 level.)				
Treatment		Symmetric Outcomes (t-stat)	Collusive Pricing (t-stat)	Vertical Nash (F-stat)	MS (F-stat)	RS (F-stat)
1. Full Info ($c_{m1} = c_{m2}$) ($\gamma = 75$)	Product 1	0.48 0.11	14.46** -4.59**	4.26* 6.67**	15.04** 3.84*	42.12** 20.96**
	Product 2	0.39 -0.01	13.34** -4.52**	7.04** 5.71*	12.18** 3.16	56.32** 21.89**
2. Incomplete Info ($c_{m1} = c_{m2}$) ($\gamma = 75$)	Product 1	-1.73 -1.52	13.06** -3.65**	28.43** 16.04**	12.75** 3.14	147.18** 77.06**
	Product 2	-2.36* -1.61	12.88** -5.73**	32.23** 12.91**	9.42** 1.06	157.18** 58.86**

2.4.2 Treatment 2: Incomplete Cost and Profit Information

On the basis of theory, I expect relative profit for Treatment 2 to be the same as for Treatment 1 (and the maintained hypothesis for both Treatments 1 and 2 is Manufacturer Leadership). But because an environment of incomplete information may cause players to misinterpret competitor's actions, I also expect lower total individual and channel profits and greater dispersion of profits across subject groups.

I actually find that price and profit outcomes for Treatments 2 and 1 are somewhat different, as shown in Figure 2.5 (a and e), and that Treatment 2 profit outcomes appear closer to the hypothesis of Manufacturer Leadership. I formally test for differences between Treatments 2 and 1 using a one-way MANOVA (multivariate analysis of variance)[7] and find that the outcomes for Treatment 2 are not significantly different from those of Treatment 1 for both net prices and profits ($F(4, 35) = 0.810$ and 0.600, respectively, which is not significant at the .05 level). So the manufacturer advantage in price and profit outcomes (shown graphically in Figure 2.5a and 2.5e) is not large enough to be statistically significant. This result is consistent with Row 2 of Table 2.5, which indicates that the profit data for Treatment 2 are close to Manufacturer leadership, but that I also cannot reject the Symmetric Outcomes hypothesis.

I also find that Treatment 2 yielded slightly higher average total channel profits per round than Treatment 1 (see Table 2.6, Row 3), but that this difference is not significant at the .05 level. A separate analysis (not shown) indicated that

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[7]The one-way MANOVA model is given by $X_{ik} = \mu + \alpha_k + \varepsilon_{ik}$, i = 1, 2, ..., n_k, and k = treatment condition. To test whether net-prices changed across treatment conditions, I modeled $X_{ik}^T = [w_{i1k} \quad w_{i2k} \quad m_{i1k} \quad m_{i2k}]$, $\mu^T = [\mu_{w_1} \quad \mu_{w_2} \quad \mu_{m_1} \quad \mu_{m_2}]$, $\alpha_k{}^T = [\mu_{w_{1k}} - \mu_{w_1} \quad \mu_{w_{2k}} - \mu_{w_2} \quad \mu_{m_{1k}} - \mu_{m_1} \quad \mu_{m_{2k}} - \mu_{m_2}]$, and $\varepsilon_{ik}{}^T = [w_{i1k} - \mu_{w_{1k}} \quad w_{i2k} - \mu_{w_{2k}} \quad m_{i1k} - \mu_{m_{1k}} \quad m_{i2k} - \mu_{m_{2k}}]$. To test whether profits changed across treatments, I used $X_{ik}^T = [M.profit_{i1k} \quad M.profit_{i2k} \quad R.profit_{i1k} \quad R.profit_{i2k}]$, $\mu^T = [\mu_{M.profit_1} \quad \mu_{M.profit_2} \quad \mu_{R.profit_1} \quad \mu_{R.profit_2}]$, $\alpha_k{}^T = [\mu_{M.profit_{1k}} - \mu_{M.profit_1} \quad \mu_{M.profit_{2k}} - \mu_{M.profit_2} \quad \mu_{R.profit_{1k}} - \mu_{R.profi_1} \quad \mu_{R.profit_{2k}} - \mu_{R.prof_2}]$, and $\varepsilon_{ik}{}^T = [M.profit_{i1k} - \mu_{M.profit_{1k}} \quad M.profit_{i2k} - \mu_{M.profit_{2k}} \quad R.profit_{i1k} - \mu_{R.profit_{1k}} \quad R.profit_{i2k} - \mu_{R.profit_{2k}}]$. I tested the hypotheses $H_o : \mu_k = \mu_l$, where $k \neq l$, k=1,2,..,5, and l=1,2,..,5.

profits for the two cases were not statistically different for either the manufacturer or the retailer.

Table 2.6. Actual Total Channel Profit Outcomes for Five Treatment Conditions*

	Treatment 3	Treatment 5	Treatment 2	Treatment 1	Treatment 4
Collusion Hypothesis	902500	893250	194463.4	194463.4	186464.2
Vertical Nash Hypothesis	895035	885812.9	181394	181394	173869
Experimental Channel Profit	**755983.6 (45627.7)**	**706954.7 (32990.9)**	**170614.3 (4003.5)**	**167102.2 (5368.4)**	**164167.9 (5121.9)**
Manufacture Leadership Hypothesis	877409.4	868351.6	161455.1	161455.1	154767
Retaier Leadership Hypothesis	877409.4	868351.6	161455.1	161455.1	154767

*Total Channel Profit Per Round Averaged Across All Groups in Treatment Condition; Standard Errors in Parentheses.

Lastly, I calculate variance ratio tests to examine whether there is greater dispersion of outcomes for Treatment 2 than for Treatment 1. I, indeed, find greater dispersion for the following variables (which describe outcome differences between Products 2 and 1): (a) wholesale price difference, $w_2 - w_1$ ($F(19, 19) = 7.43$, significant at .01 level), (b) retail margin difference, $m_2 - m_1$ ($F(19, 19) = 2.06$, significant at .10 level), (c) manufacturer profit difference, $\Pi_{M_2} - \Pi_{M_1}$ ($F(19, 19) = 2.04$, significant at .10 level), and (d) retail profit difference, $\Pi_{R_2} - \Pi_{R_1}$ ($F(19, 19) = 4.07$, significant at .01 level). The data, thus, indicate more variation in outcomes between the two products for Treatment 2 than for Treatment 1.

Overall, the strategic advantage for the retailer from playing off the two manufacturers against each other appears to be counterbalanced by the manufacturer's first-mover advantage (perhaps a bit more than counterbalanced). The profit and price outcomes for Treatment 2 are not statistically different from Treatment 1. The total channel profits are also not statistically different. The only affect apparently present is that there is greater variation in profits between Products 1 and 2 for Treatment 2. To the extent that manufacturer profits exceed retail profits, the first movers (i.e., manufacturers) may gain from an "open high" tactic in the hope of anchoring pricing behavior advantageous to them (Siegel and Fouraker 1960; Srivastava, Chakravarti, and Rapoport 2000), but such an advantage is only partially supported by the data (i.e., by the profit data, which do not reject the Manufacturer Stackelberg outcome).

2.4.3 Treatment 3: Low Product Differentiation

Choi's model (1991) predicts that high product substitutability ($\gamma = 200$) implies much higher relative prices and profits for the retailer than moderate substitutability ($\gamma = 75$), as one might expect, and somewhat higher prices and profits for the manufacturer, which is perhaps less intuitive.

To examine these predictions, I first conduct a one-way MANOVA to verify that net prices and profits for Treatment 3 differ significantly from Treatment 1 ($F(4, 35) = 10.434$ and 64.085 for Net Prices and Profits, which were both significant at the .01 levels). Examination of Figures 2.5b and 2.5f, however, indicates that the results from Treatment 3, while very different from

Treatment 1, do not unambiguously support any of the competing hypotheses. In particular, the substantial advantage to the retailer implied by the maintained hypothesis fails to materialize, and mean retail prices and profits (in particular, the retail profit for product 2) fall far below Manufacturer Stackelberg predictions.[8] By contrast, manufacturer profits are close to the Manufacturer Stackelberg outcome.[9]

For the channel as a whole (see Table 2.6), I find that channel profits are significantly higher in Treatments 3 than Treatment 1 (Means = \$755,984 vs. \$167,102, $t=12.818$, $p<0.001$), or any of the other treatments, but significantly lower than the Manufacturer Stackelberg hypothesis ($t = 2.661$, $p< 0.015$).

Overall, the results of Treatment 3 diverge from the equilibrium analyses of Choi (1991) and Shugan and Jeuland (1988), which predict higher wholesale prices and much higher retail margins. Wholesale prices are a bit higher and net retail margins are, indeed, about triple those of Treatments 1 and 2. But even with this sizeable shift, the retailer fails to fully capitalize on its inherent strategic advantage under this treatment. An "equity heuristic" may be compelling

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[8]Mean net retail margins for Products 1 and 2 are \$52.09 and \$52.39, which are significantly below the Manufacturer Stackelberg predictions of \$79.17 and \$79.17; $t = 3.709$ and 3.598, $p<0.002$, respectively. Mean retail profit for Product 2 is \$246,823, which is significantly below the Manufacturer Stackelberg prediction of \$313,354; $t = 3.259$, $p<0.004$. However, mean retail profit for Product 1 is \$273,136, which is not significantly below the Manufacturer Stackelberg predictions of \$313,355 ($t=1.190$).

[9]Mean manufacturer profits for Products 1 and 2 are \$116,692 and \$119,333, which are not significantly below the Manufacturer Stackelberg predictions of \$125,350 and \$125,350 ($t=0.725$ and 0.480), respectively. However, mean net wholesale prices for Products 1 and 2 are \$21.38 and \$21.22, which are significantly below the Manufacturer Stackelberg predictions of \$31.67 and \$31.67; $t = 4.454$ and 4.244, $p<0.001$, respectively.

resistance from manufacturers (or restraining opportunism from retailers). As a result, manufacturers manage to maintain profits comparable to the Manufacturer Stackelberg level, but the retailer accrues profits that (though greater than those of Treatments 1 and 2) fall below what would be possible even by behaving as a Stackelberg follower (see Figure 5(f)).

2.4.4 Treatment 4: Asymmetric Production Costs

Choi's model (1991) predicts that asymmetric production costs (c_{m1}=10; c_{m2}=8) yield higher net prices and profits for the low-cost product, for both the manufacturer and the retailer, than for the high-cost product (as compared to the case of symmetric production costs, $c_{m1}=8=c_{m2}$), as one might expect. Less intuitively, the low-cost manufacturer's advantage can be shown to be greatest under the Manufacturer Stackelberg outcome and least under Retail Stackberg outcome (see Figures 2.5c and 2.5g).

To consider these issues, I first perform a one-way MANOVA comparing Treatment 4 with Treatment 1 and find that net prices are significantly different in the two treatments ($F(4, 35)$ = 3.600 and 1.495 for Net Prices and Profits, the first of which is significant at the .05 level).

To explore this further, I see in Figures 5c and 5g almost no change in mean net retail margins for Treatment 4 as compared to Treatment 1, but the low-cost manufacturer (of Product 2) benefits from a higher wholesale price and profit (than the high cost manufacturer of Product 1).[10]

Formally, I find that Manufacturer 1 (which is high cost) has lower net wholesale price and profit than Manufacturer Product 2 (Means net wholesale prices of $11.67 vs. $14.97; $t = -3.439$, $p<0.003$; mean profit of $36,441 vs. $39,675, $t= -1.313$). Manufacturer 1 also earns lower profits than the Retailer for Product 1 ($36,441 vs. $45,453, $t=-1.96$, $p<0.065$). Thus, the high cost manufacturer is at a disadvantage relative to both the other manufacturer and the retailer. The retailer appears to be behaving much as it did under Treatment 1 (including charging nearly equal margins for both products ($t= .584$, which is not significant in showing a difference), but ends up as the overall winner—earning more on Product 1, alone, than the manufacturers of both Products 1 and 2.

Overall, the manufacturers appear to be closer to matching gross wholesale prices than net wholesale prices. This is reasonable behavior on the part of the manufactures, since demand is unchanged, so that the net incidence of high costs falls mostly on the higher-cost manufacturer. But unlike the Stackelberg hypotheses, the high cost manufacturer appears unable to get either the retailer or the other manufacturer to absorb part of the profit reductions from its high costs.

---

[10] Note that Products 1 and 2 are hypothesized to have different net prices and profits under asymmetric costs. Thus a single point does not suffice (in Panels c, d, g, and h) to represent both products (as it does in Panels a, b, e and f). The higher cost product has lower net wholesale prices, retail margins, manufacturer profits, and retail profits for the Vertical Nash, or either Stackelberg equilibrium.

2.4.5 Treatment 5: Interaction of Product and Cost Differentiation

Choi's (1991) model predicts a small interaction effect under the presence of both high product substitutability and asymmetric production costs.

To consider this, I first examine Figures 2.5d and 2.5h, which appear very similar to Figures 2.5c and 2.5g, except that Product 2 appears to have slightly higher mean retailer margins and profits. This suggests little interaction beyond a simple combination of Treatments 3 and 4.

To formally consider this issue, I show a two-way MANOVA in Table 2.7. This indicates that there is not a significant interaction between Low Product Differentiation and Asymmetric Production Costs. (It also confirms a significant effect for Low Product Differentiation in general, but does not confirm a general Asymmetric Production Cost effect.)

Table 2.7. Two-Way MANOVA (using Treatments 1, 3, 4, & 5)

Manipulation	F-Test of **Net Prices** F-Test of **Profits**
Low Product Differentiation ($\gamma = 200$ vs. $\gamma = 75$)	20.018** 122.934**
Asymmetric Production Costs ($c_m = 10 \neq 8 = c_{m2}$ vs. $c_m = 8 = c_{m2}$)	1.290 .743
Interaction	.711 .371

*Reject at .05 level. ** Reject at .01 level.

2.4.6 Player Outcomes versus Reaction Function Predictions

The above conclusions raise the question of why the game outcomes differ from the maintained hypothesis of Manufacturer Stackelberg equilibrium. To help understand this, I examine the responses of players to other players' moves.

In Figure 2.6, the left panels indicate the difference between actual wholesale prices and the predictions of the reaction function, averaged over all groups within a treatment condition. The right panels indicate the difference between actual retail margins and the predictions of the reaction function, averaged over all groups within a treatment condition. Thus, positive (negative) values indicate wholesale prices and margins above (below) the players' best response function. In particular, Figure 2.6 describes Treatments 1 and 2, and part of Treatments 3 and 4. (Treatment 5, not shown, showed a very similar pattern to Treatment 3.)

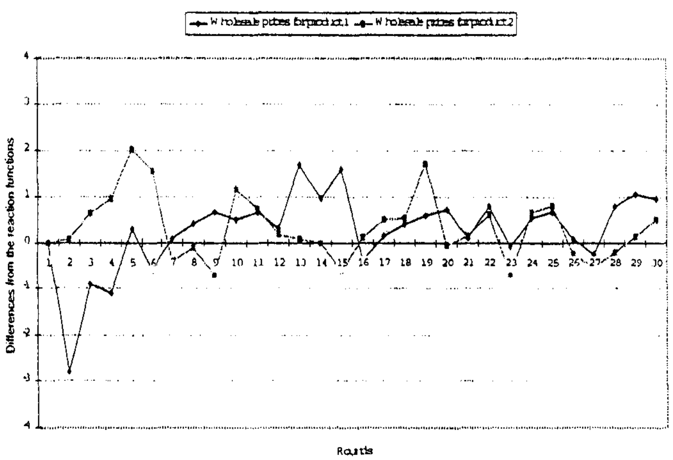
Figure 2.6 shows at least three things. First, manufacturers are setting their wholesale prices above their best responses, and retailers are setting their margins below their best responses, especially in the first half of the game. When products are less differentiated (Figure 2.5 (b3) containing Treatment 3), retailers play far below their best responses. Second, retailers show higher deviation from the best responses than manufacturers in the first half of the game, and, as time passes, retail margins rise to approach the Manufacturer Stackelberg level. This strong positive trend indicates that retailers are learning to price in a profit-maximizing—but reactive—fashion.

Figure 2.6 Deviation for Reaction Function*

*The left (right) panels show the average deviations of the actual wholesale prices (retail margins) from behavior predicted by the manufacturers' (retailers') reaction function. The graphs show the outcomes, averaged over all 20 groups in each treatment. Note that since the manufacturers select the wholesale price before retailers select the retail margin in each round, there are no manufacturer deviations in Period 1. The first panel, thus, indicates that the average wholesale price of Product 1 in Period 2 was approximately $2.8 below what would be predicted by Manufacturer 1's optimal reactions to the retailer's margin in Period 1.

Wholesale Prices

(a1) Treatment 1: Full Information



Retailer Margins

(b1) Treatment 1: Full Information

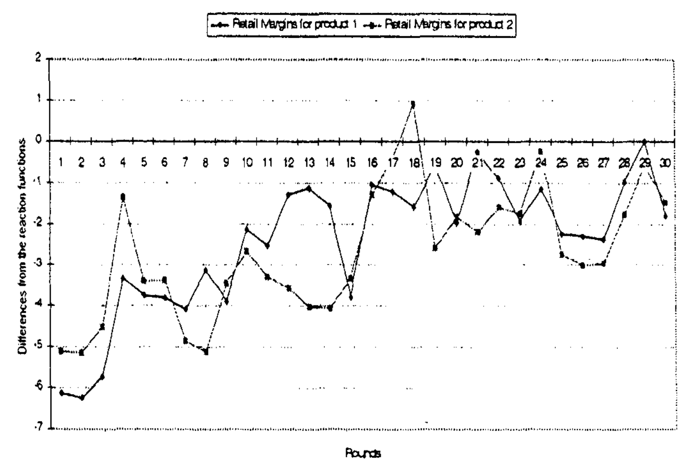
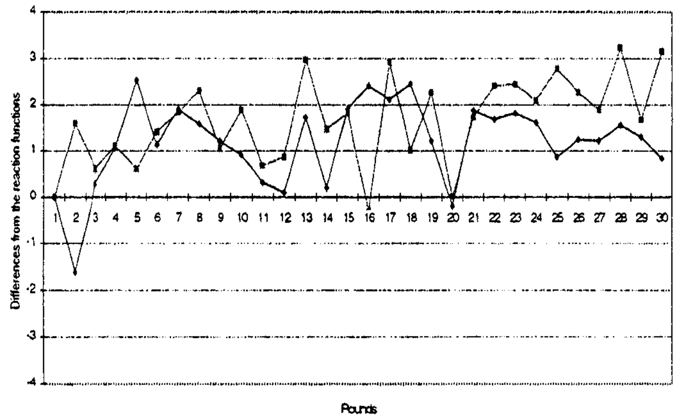


Figure 2.6 Continued

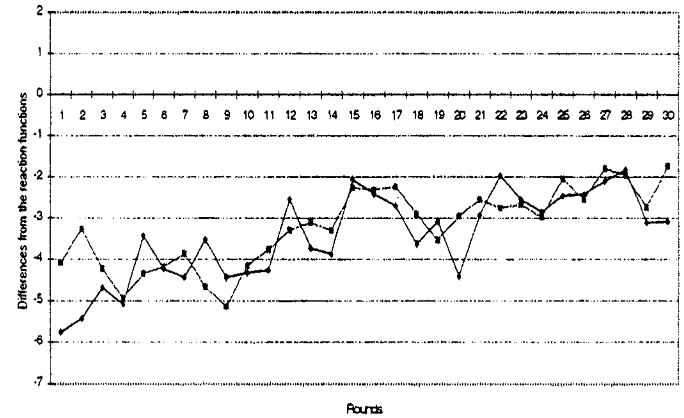
Wholesale Prices

Retailer Margins

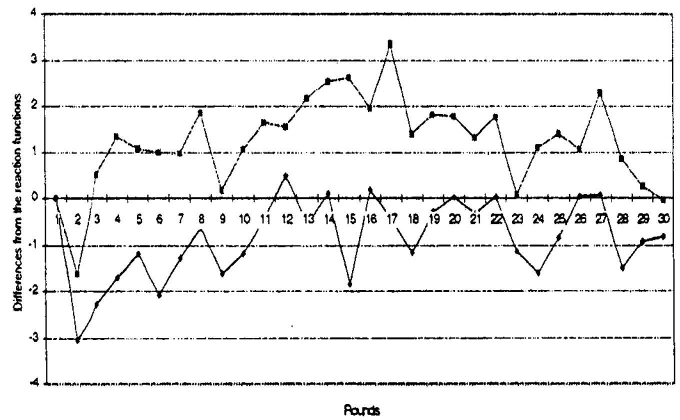
(a2) Treatment 2: Incomplete Information



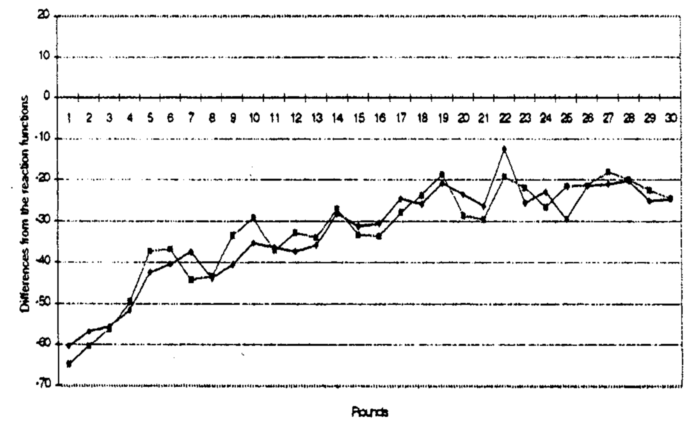
(b2) Treatment 2: Incomplete Information



(a3) Treatment 4: Asymmetric Production Costs



(b3) Treatment 3: Low Product Differentiation



Third, in Treatment 4, the low-cost manufacturers are consistently setting their net wholesale prices higher than the high-cost manufacturers [mean deviations from the manufacturers' reaction function = 1.28 vs. -.89, t=14.255, p<0.001; see Figure 2.6(a3)], and higher than their best responses. This outcome suggests greater strategic power for the player with a cost advantage.

In Figure 2.7, I examine more precisely the possibility that the game is converging to Manufacturer Stackelberg leadership. This figure shows the mean absolute difference between wholesale prices and the Manufacturer Stackelberg equilibrium wholesale prices, and the mean absolute difference between retail margins and the retailer's best responses (both averaged over all groups within a treatment condition and over Products 1 and 2).

Figure 2.7 shows two things. First, over the 30 rounds, the mean absolute differences for retail margins are greater than the mean absolute differences for wholesale prices.[11] Second, the mean absolute differences of retail margins decrease throughout the 30 rounds, as retailers learn about the game. This suggests that manufacturers complete their learning early in the game, whereas retailers continue learning throughout the thirty rounds of the game.[12]

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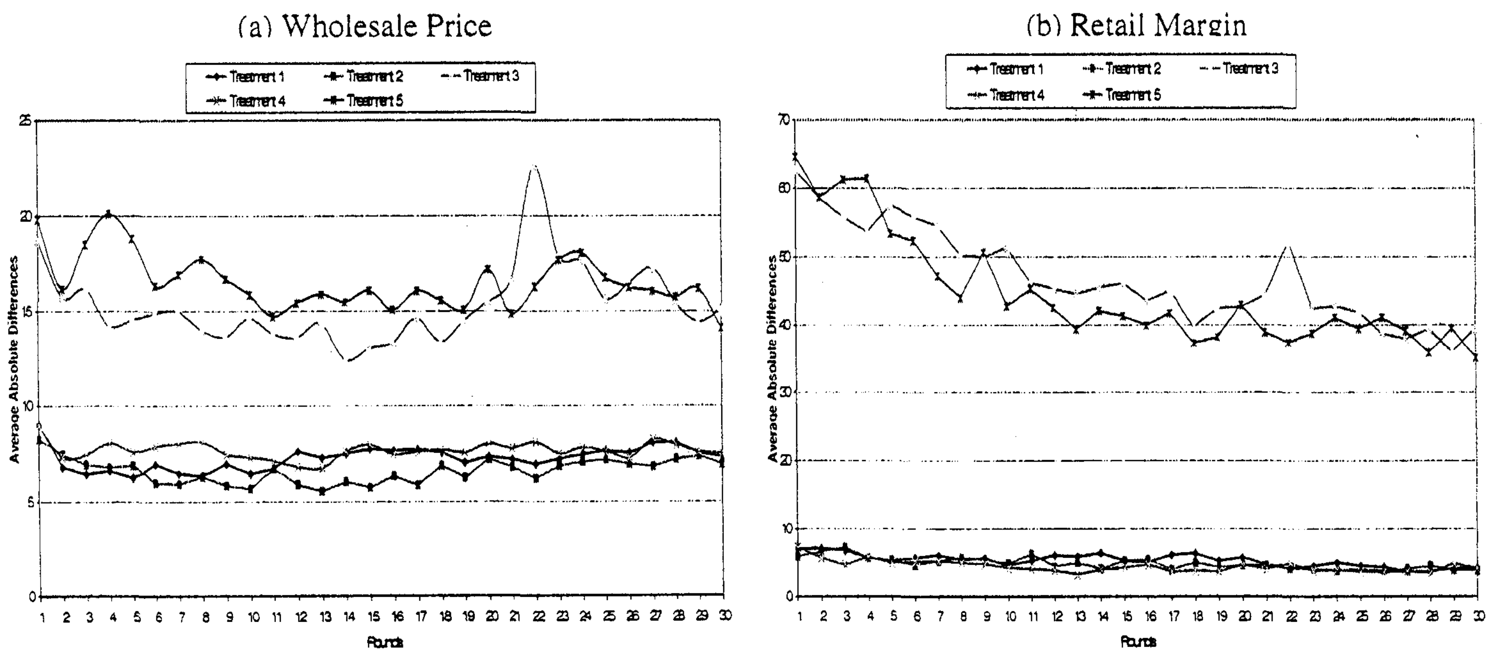
[11]For Treatments 1 through 5, the mean absolute retail margin differences from equilibrium were 17%, 18%, 18%, 28%, and 32%, respectively, which exceed the corresponding mean absolute wholesale price differences from equilibrium of 8%, 10%, 8%, 26%, and 15%.
[12]Figure 2.7 also indicates that the mean absolute differences are greater for both manufacturers and retailers when the products are highly substitutable (Treatments 3 and 5).

Figure 2.7. Average Absolute Deviation from Maintained Hypothesis*

*The left panel shows the average absolute values of the differences between the actual wholesale prices and the equilibrium wholesale prices predicted by the Manufacturer Stackelberg hypothesis. The right panel shows the average absolute values of the differences between the actual retail margins and the retail margins predicted by the retailer reaction functions. (Note that the Manufacturer Stackelberg hypothesis stipulates that the retailer will choose margins on its reaction function.) For each of the five treatment conditions, the graphs show the outcomes, averaged over all 20 groups in each treatment and averaged over Products 1 and 2.



Overall, retail behavior diverges more, on average, from the Manufacturer Stackelberg hypothesis and shows more variation over time than manufacturer behavior. During the initial period, especially, the retailer makes large adjustments as it learns about the game and about its opponents. The retailer often must try margins completely out of range to learn where the profitable part of the demand function is, and then the game generally settles down.

2.5 Discussion and Conclusion

This essay describes an experiment that replicates some of the essential incentives present in a channel of distribution involving two manufacturers and a common retailer. The objectives of the essay are to ascertain which channel structure is more applicable, to examine the impact on channel power relationships of several important variables, and to consider how players' behavior deviates from their best responses. I find that the game results are closest to the Symmetric Outcomes hypothesis when products are moderately differentiated (regardless of knowledge of competitors' costs and profits). This means that the profit distribution between the players is very equal, suggesting the applicability of an "equity heuristic." Thus, the manufacturers' "first-mover" advantage in each round appears to be dissipated. Similarly, retailers do not appear to be exercising their power as the "common retailer" in this game structure.

For the incomplete information treatment condition, I also find more variation in outcomes between the two products than under full information. This indicates that there is more guesswork than under full information, and that an "equity heuristic" is somewhat harder to achieve. In addition, the share of channel profits obtained by channel members is unaffected even though each channel member could not observe the competitors' costs and profits.

For the high degree of substitutability treatment conditions, I find higher net prices and profits for all players (consistent with Choi 1991 and Shugan and Jeuland 1988), but the retailer is unable to fully capitalize on its inherent strategic advantage under this treatment. Manufacturer net prices and profits are consistent with Manufacturer Stackelberg predictions, but retailer margins and profits (though much higher than other treatments) fall below what would be possible even by behaving as a Stackelberg follower. An "equity heuristic" appears to be compelling resistance from manufacturers or restraining opportunism of retailers.

For the asymmetric production costs treatment conditions, I find that the low-cost manufacturer's net wholesale prices and profits are significantly higher than those of the competing manufacturer when products are moderately differentiated. This result indicates that low-cost players recognize their strategic advantages and attempt to exploit them (similar to Zwick and Chen 1999). Moreover, I find that the retailer benefits more from asymmetric production cost than the manufacturers.

With respect to individual players' behavior, I find that manufacturers are setting their wholesale prices above their best responses, and retailers are setting their margins below their best responses in most cases. This means that manufacturers are exercising leadership in pricing, and retailers are playing more passively than a Stackelberg follower. I also find that retail behavior diverges more, on average, from the Manufacturer Stackelberg hypothesis and shows more variation over time than manufacturer behavior. On this latter point, the deviation of retail margins from optimal reactions declines throughout the game. This suggests that retailers continue learning throughout the game, whereas manufacturers appear to complete their learning earlier in the game. (Incidentally, it is worth noting that an advantage of experimental methodology is that it facilitates this type of analyses of individual-level behavior.)

Overall, the results suggest that actual competitive behavior may be described by a combination of the predictions of the Manufacturer Stackelberg model and an "equity heuristic." In particular, manufacturer behavior often appears consistent with playing a leadership role (or at least pricing somewhat more aggressively than the best response). Retailer behavior is less aggressive. Under most treatment conditions, the net effect lies near the Symmetric Outcomes line, reflecting an "equity heuristic," between the Vertical Nash and Manufacturer Stackelberg outcomes. Under treatment conditions that significantly favor the retailer, the net effect appears to lie between the Symmetric Outcomes line and the Manufacturer Stackelberg outcome.

Such considerations may have implications for how to interpret the conclusions of one-shot, game-theoretic models intended to describe repeated-move contexts. In such repeated-move contexts, the considerations of the folk theorem suggest a range of possible outcomes. Within this range, the outcome may be influenced by behavior based on social norms that factor in what players believe is “fair.” In the experiments, a norm associated with an “equity heuristic” seems to have an influence. Nevertheless, the equilibria of one-shot games indicate strategic advantages inherent in the game structure influencing net outcomes in a way that is more predictable than the wide range of possible outcomes supported by the folk theorem.

Appendix 2.1: Instruction and Quiz for the full information condition

In this experiment we will ask you to make managerial decisions on key economic and marketing variables for a simulated company in a competitive environment. We will pay you subject fees at the end of the experiment based on the decisions you take and the decisions that your competitors take in a simulated market. The basic goal of the research is to determine patterns of economic outcomes that emerge in markets where competing firms are mutually dependent on each other. All the responses will be confidential throughout the research and the reporting of the research results will be anonymous.

The minimum subject fee for this experiment will be $5 and the majority of subjects should earn subject fees between $8.00 and $20.00 for participation in an experiment that will last between 1 and 2 hours.

I give my consent to participate in this experiment. I realize that at any time during the experiment I may withdraw from the experiment. In the event that I withdraw from this experiment, I will still receive $5.00 plus compensation for the quiz ($0.10 per answer correct answer, with a maximum payment of $1.00).

Signed ____

Instructions

Thank you for your participation in this experiment.

This is an experiment in manufacturer and retailer decision-making. These are the instructions for the experiment. You will be paid at the conclusion of the experiment. Feel free to earn as much as you can.

All aspects of this experiment will be conducted through the use of computer terminals. No special skills are required and the instructions that follow will provide all the information you need to participate. Be sure to ask any questions that you might have during the presentation of the instructions, and ask for assistance, if needed, once you

Here is a list of today's activities:

1. An overview of these written instructions.
2. A quiz based on the instructions (you will be paid for $0.10 for each correct answer).
3. A review of the quiz.
4. Instructions on how to use the computer (including 7 warm-up rounds).
5. The actual experiment followed by a written questionnaire.
6. Cash payment of your earning from the actual experiment and the quiz.

Please keep these instructions with you until the experiment is complete, you may need to refer to them.

Important Note: This experiment is being conducted over a period of several days. Please do not discuss the specifics of the experiment with other students. Please return the instructions after the experiment.

All the participants will be divided into three groups: *manufacturer #1, manufacturer #2*, and *retailer*. During the experiment you will engage in business with a participant in the other group. These transactions will involve real money.

At the end of the experiment, you will be paid in cash. The amount you are paid depends on your decisions and the decisions of the other participants.

At the end of the experiment, you will be paid in private so that other participants will not know how much money you made. Also at the end of the experiment you will be asked to complete a questionnaire concerning your strategies and experiences during the experiment.

The Structure of The Experiment

Participant Roles

1. Manufacturers. There are two manufacturers in each game. Each person managing a manufacturer will offer a wholesale price, w, to the *retailer*. Each *manufacturer* incurs a product cost of c_m. Each *manufacturer* earns a unit margin of $w-c_m$ and a profit of $(w-c_m)$ times the quantity sold q. That is, each *manufacturer's* profit will equal the formula $(w-c_m)\,q$. *(Note that, since there are two manufacturers, there are two wholesale prices set in each round and each manufacturer will have a different quantity demanded and profit.)*

2. *Retailer.* This person will receive the wholesale prices, w_1 *and* w_2, from *manufacturer #1* and the *manufacturer #2* and choose the retailer gross margins, m_1 *and* m_2. The final retail prices, p_1 *and* p_2, are defined as the sum of the wholesale price and the retail margins (i.e., $p_1 = w_1 + m_1$ and $p_2=w_2+m_2$.) The *retailer* has the retailing unit handling costs, c_{R1} *and* c_{R2}, for the product #1 and the product #2 respectively (in addition to the wholesale price paid to the manufacturers). Thus the *retailer* earns the net margin of m_1-c_{R1} for the product #1 and the net margin of m_2-c_{R2} for the product #2 respectively, and the profit of (m_1-c_{R1}) times the quantity sold q_1 for the product #1 and the profit of (m_2-c_{R2}) times the quantity sold q_2 for the product #2 respectively . That is, the *retailer's*

profit will equal the formulas $(m_1 - c_{R_1})q_1$ for the product #1 and $(m_2 - c_{R_2})q_2$ for the product #2 respectively .

The quantities sold are functions of the two retail prices. Participants will not know these functions. The quantities sold, q_1 *and* q_2, will be calculated by computer.

The *manufacturers* will be told each other's wholesale price, product cost, and profit. The *manufacturers* also know the *retailer's* handling cost and profit. The *retailer* knows the *manufacturer's* product costs and profits.

Rounds

A round consists of the following steps

Step 1. The *manufacturer #1* chooses the wholesale price, w_1, and sends it to the *retailer.* The *manufacturer #2* also chooses the wholesale price, w_2, and sends it to the *retailer.*

Step 2. The *retailer* decides the gross margins, m_1 *and* m_2, after receiving the wholesale prices, w_1 and w_2, from the *manufacturer #1* and the *manufacturer #2* respectively.

Step 3. The computer calculates the quantities sold, q_1 *and* q_2, based on the retail prices, p_1 *and* p_2, which equal $w_1 + m_1$ and $w_2 + m_2$, and allocates profit to each role.

Each *manufacturer* will be given the information of the last five previous rounds. The information includes the variables w_1, p_1, q_1, w_2, p_2, q_2, and their profits and the profits of the other two players.

The *retailer* will be given the information of the last five previous rounds. The information includes the variables w_1, m_1, p_1, q_1, w_2, m_2, p_2, q_2, and the *retailer* profit of the round, and the profits of the two manufacturers.

Time Limit

Each role will be given 60 seconds in each round to make a decision.

For the *manufacturers*, the timer begins at the end of last round.

For the *retailer*, the timer begins when the *retailer* receives both wholesale prices, w_1 and w_2, from the *manufacturer #1* and *the manufacturer #2* respectively.

If no decision is made before time over, the computer will use your decision in the last round as the default decision. If there is no last period, no business will be done and each role will get zero profit for that round.

Experiment Quiz

Circle the best answer

True* False 1. If your role is the *retailer*, you will play the experiment with people who take the role of *manufacturer*.

True* False 2. If your role is the *manufacturer*, you will only make decision on wholesale price in each round.

True* False 3. If your role is the *retailer*, you will know the *manufacturer's* unit product cost.

True* False 4. If your role is the *manufacturer #1*, and you know the retail price, p_1, the wholesale price, w_1, then you can figure out retailer gross margin, m_1.

True* False 5. The quantities sold depend only on the retail price.

True False* 6. The variables c_{R_1} *and* c_{R_2} include the wholesale price.

True* False 7. You have one minute to make a decision in each round.

* Correct answers.

True False* 8. The *retailer's* timer begins at the end of last round.

True* False 9. If you time out, your decision will be your decision in the last round.

True False* 10. You will personally be paid cash equaling your total profit / 50,000.

Number Correct ________________

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Chapter 3

Essay 2: An Experimental Study of Competitive Price Promotional Strategies

Mixed strategy pricing is a growing part of the competitive modeler's toolkit. For marketing problems, mixed strategy models have been applied to price discrimination between informed and uninformed consumers (Varian 1980), high/low pricing to loyals and switchers (Narasimhan 1988), variable pricing to two segments with lock-in (Raju *et al.* 1990), competition between store and national brands (Rao 1991), informative advertising with trade promotions (Rao and Ranran 2001), co-location at Internet malls (Iyer and Pazgal 2003), markets with infomediaries (Jeuland *et al.* 2003), competition under limited supply problems (Cui and Ho 2003), and other contexts (Agrawal 1996, Simester 1997, Lal and Villas-Boas 1998, Chen *et al.* 2001, Rajiv *et al.* 2002, Shaffer and Zhang 2002). Such pricing policies are attractive from a managerial perspective because they constitute a means of balancing multiple marketing objectives (including targeting multiple segments) and from an empirical perspective because they offer an explanation for markets with stable price variability.

But for all their advantages at the market level, mixed strategy models nevertheless appear to put substantial burdens on individual agents. Since their inception, scholars have sought to interpret mixed strategies[13]; and some analysts

[13] Luce and Raiffa (1957, pp. 72-76) discuss early interpretations and criticisms of mixed (or random) strategies, and initial (independent parallel) contributions in the 1920s and 1930s by J. Von Neumann, E. Borel, and R.A.Fisher.

still criticize mixed strategy equilibria as too complex for humans and inherently unintuitive.[14] A further limitation is that many mixed strategy models are one-shot games (some with multiple stages, but played out only once), in spite of the intended applicability to marketing situations involving repeated interactions.

I accordingly believe it is of interest to examine whether humans will use mixed strategies, as predicted by theory, and the extent to which the predictions of one-shot mixed-strategy models are descriptive of outcomes of repeat game interactions. Such tests can be particularly informative if subjects follow model predictions, under certain experimental conditions, but violate them, under others. The current essay, accordingly, examines an early and particularly interesting loyal/switcher model in a laboratory setting to ascertain when model predictions apply and breakdown.

3.1 Past Literature

I focus on the model of Narasimhan (1988), which builds on Varian's (1980) mixed-strategy analysis of pricing to informed consumers (who choose the lowest-priced brand) and uninformed consumers (who choose at random). Narasimhan (1988) reformulates and extends Varian's model to apply to firms selling to switcher (who choose the lowest-priced brand) and loyal consumers (who, if any, choose only their preferred brand). This reinterpretation ties in

[14] Rubinstein (1991, p. 913) considered mixed strategies as "against our intuition." Rubinstein goes on to state, "one of the reasons that mixed strategies are popular in both game and economic theory, in spite of being so unintuitive, is that many models do not have an equilibrium with pure strategies."

nicely with empirical research in marketing concerning determinants of consumer brand switching behavior (Guadagni and Little 1983, Neslin et al. 1985, Gupta 1988) and drivers of promotional response across brands, categories, or market conditions (Bolton 1989, Fader and Lodish 1990, Raju 1992, Narasimhan et al. 1998, Bell et al. 1999, van Heerde et al. 2001). Subsequent theoretical work has reconsidered and extended the early mixed-strategy, price-promotions models (Raju et al. 1990, Rao 1991).[15] To my knowledge, my experimental results are the first concerning Narasimhan's (1988) model or the class of simple loyal/switcher price promotion models, generally.

My experimental results complement extant empirical literature on price promotion and other mixed-strategy models based on aggregate and disaggregate market data (Villas-Boas 1995, Agrawal 1996, Raju et al. 1990). Due to the nature of market data, however, the latter work is not able to assess (1) conditions that limit the applicability of the equilibria, and (2) how the market participants attain the equilibria. A further limitation is that the theoretical and empirical definitions of strength of brand loyalty do not always match. The experimental approach avoids these problems.[16]

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[15] Raju et al. find that the brand with the larger loyal segment promotes less often, but with greater discounts than the brand with the smaller loyal segment. Rao predicts that a private label (weaker brand) does not promote, but the national brand does. Other models generalize Narashiman (1988), including Simester (1997), who includes multiple products and general demand functions, and Lal and Villas-Boas (1998), who consider channel settings with two manufactures and two retailers.

[16] Experimental and market data complement each other because the experimental approach has greater internal validity in testing human behavior under known model specifications, whereas the market-based empirical approach has greater external validity concerning market predictions under model specifications that cannot be known with certainty.

This essay also adds to the controlled-laboratory experimental tests of mixed strategy behavior more generally (Rapoport and Boebel 1992, Rapoport and Budescu 1992, Rapoport and Amaldoss 2000, Amaldoss *et al.* 2000, Amaldoss and Jain 2002, Brown and Rosenthal 1990, Ochs 1995). By focusing on the loyal/switcher model of competitive price promotions (Narasimhan 1988, Varian 1980), I believe I am considering a simple, fundamental game structure in marketing deserving of experimental study.

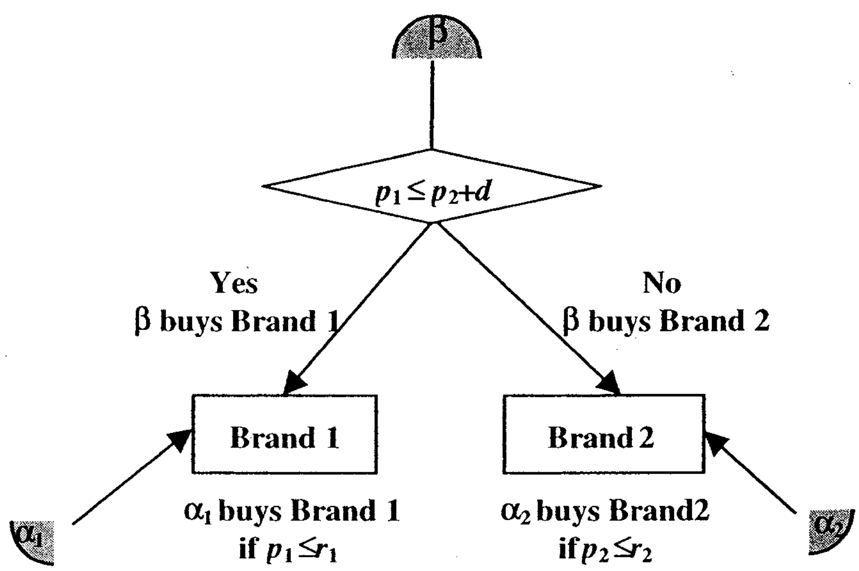
3.1.1 Research Objectives

The specific objectives of this essay are (1) to test the boundary conditions of when firms randomize as hypothesized by theory (Varian 1980, Narasimhan 1988) when the structure is symmetric, when loyal shares are asymmetric, or when switchers prefer one brand over another, (2) to test whether specific depth and frequency outcomes are consistent with Narasimhan's (1988) model, (3) to examine whether allowing communication between competitors (using a "chat condition) facilitates cooperation, and (4) to examine dynamic learning behavior in this game. In the experiments, pairs of subjects interact in a computer-mediated environment and are compensated in proportion to their performance.

3.2 The Model

The model of Narasimhan (1988) was proposed to describe periodic promotions, such as price deals, cents-off labels, coupons, and rebates. In this model, the market is assumed to be a fixed size (so that, for simplicity, promotions induce switching between brands, but do not expand category demand). Consumers are grouped into three segments: the loyal segment for Brand 1 (with market share of α_1), the loyal segment for Brand 2 (with market share of α_2), and the switcher segment (with market share of β), where $\alpha_1+\alpha_2+\beta=1$.

Figure 3.1 The Game Structure



*d is a measure of brand preference, if d=0, no preference.
If $p_1=p_2+d$, $(^1/_2)\beta$ buys Brand 1, and $(^1/_2)\beta$ buys Brand 2.

Each consumer in a loyal segment is assumed to buy one unit of the associated brand so long as the price does not exceed the consumer's reservation price, r; the consumer will not buy at all, otherwise. The reservation prices for both brands are assumed to be the same. In addition, the marginal cost for both brands is assumed the same (Narasimhan 1988 assumes zero marginal costs, but I use positive marginal costs in the experiment and analysis, so that $c_1 = c_2 > 0$).

Much of the action in this model lies with the switcher segment, who buy Brand 1 if $p_1<p_2+d$, Brand 2 if $p_1>p_2+d$, and split half-and-half between the two brands if $p_1=p_2+d$. I can interpret the parameter, d, as the brand preference for product 1. When d=0, the switchers are indifferent between the brands and always buy the lower-priced brand. When d>0, the switchers buy Brand 1 even if it is priced at a premium relative to the price of Brand 2 of up to d.

In this model, firms have an incentive to undercut each other to capture the entire switcher segment. But, by so doing, they leave "money on the table" relative to their loyal segments. Figure 3.1 describes the game structure.

It turns out that the price equilibria for this model necessarily involve mixed strategies wherein firms choose prices according to particular probability distributions that depend on the various parameters, α_1, α_2, and d. When $\alpha_1 = \alpha_2$ and $d = 0$, the two players use identical probability distributions. When $\alpha_1 > \alpha_2$ and $d = 0$, Brand 2 promotes (i.e., prices less than r) more frequently than Brand 1, but both use the same average discount when they do promote. When $\alpha_1 = \alpha_2$ and $d > 0$, the premium Brand 1 promotes more frequently than Brand 2, but when it does, Brand 1 offers a smaller average discount from r than Brand 2 does. Appendix 3.1 provides a general solution for the model, and provides details for these three cases.

3.2.1 Extension to Repeated Games

Narasimhan's (1988) model describes a one-shot game, but it is also relevant to consider the model in repeated-game contexts.

For a finitely repeated game, in which Narasimhan's (1988) model is repeated in each round, it is relatively easy to see that Narasimhan's predicted equilibrium, played in each round is the only subgame perfect equilibrium. In particular, the subgame consisting of the last round is a one-shot game; so Narasimhan's equilibrium applies. Next I consider the subgame consisting of the last two rounds, restricting attention to strategies wherein Narasimhan's equilibrium obtains in the last round. Since play in the second-to-last round, thus, cannot influence strategies in the last round, the equilibrium of the last two rounds must involve Narasimhan's equilibrium obtaining in the second to last round, as well as the last round. According to the logic of subgame perfection, iteration implies that Narasimhan's predicted equilibrium strategies applied to each round of the finitely-repeated game constitutes the only subgame perfect equilibrium.

For an infinitely repeated game, in which Narasimhan's (1988) model is repeated in each round, the same equilibrium exists, but the folk-theorem also indicates a multiplicity of possible outcomes supported by equilibrium punishment strategies. Such equilibria include more cooperative outcomes than those predicted by playing the one-shot equilibrium in each round (see Fudenberg and Tirole 1991, chapter 5). The relevant issue, here, is whether such coordinated outcomes can be attained without explicit communication.

3.2.2 Research Hypotheses

I am interested in experimental examination of four specific issues associated with the above model. First, I am interested in the extent to which humans will play mixed strategies, generally, and whether and when they follow the predictions of Narasimhan's model, in particular. Second, I am interested in the specific directional implications of the model concerning mean price discount and discount frequency for various special cases. Third, I am interested in examining whether allowing direct communication between the players leads to greater cooperation, higher prices, and higher profits, as been suggested in other game settings. Fourth, I am interested in how players learn to play the game through the course of the experiment, an issue that is increasingly being considered in experimental literature. I describe in greater detail below our motivation for examining these issues.

3.2.2.1 Hypothesis 1: Mixed Strategy Equilibrium Play

Mixed-strategy pricing consists of firms choosing price from a probability distribution and not fixing price at a single optimum value. In particular, Varian (1980) demonstrates in his game (of informed and uninformed consumers) that there is no pure-strategy equilibrium, but only a mixed-strategy equilibrium wherein competing stores randomize prices. Narasimhan (1988) likewise shows the nonexistence of a pure-strategy equilibrium. The mixed-strategy equilibrium of his game involves firms independently randomizing prices according to the following cumulative probability distributions (see Appendix 3.1):

$$F_1(p)=\begin{cases}0 & \text{for} \quad p\le \hat{p}, \\ 1+\frac{\alpha_2}{\beta}-\frac{(\alpha_2+\beta)(\hat{p}-d-c_2)}{\beta(p-d-c_2)} & \text{for} \quad \hat{p}\le p\le r, \\ 1 & \text{for} \quad r\le p,\end{cases}$$

$$F_2(p)=\begin{cases}0 & \text{for} \quad p\le \hat{p}-d, \\ 1+\frac{\alpha_1}{\beta}-\frac{(\alpha_1+\beta)(\hat{p}-c_1)}{\beta(p+d-c_1)} & \text{for} \quad \hat{p}-d\le p\le r-d, \\ 1+\frac{\alpha_1}{\beta}-\frac{(\alpha_1+\beta)(\hat{p}-c_1)}{\beta(r-c_1)} & \text{for} \quad r-d\le p\le r, \\ 1 & \text{for} \quad r\le p.\end{cases}$$

Although this (one-shot) equilibrium could be tested in experiments concerning one-shot games[17], my main concern whether these predictions hold up in repeated-game contexts. Since the predictions of the one-shot model, repeated each round, constitute the only subgame perfect equilibrium of the finitely-repeated version of the game (as I discussed in Section 3.2.1), the maintained hypothesis for the experiments is as follows:

H_1: *In a loyal/switcher context, players will randomize prices, particularly according to Narasimhan (1988)'s predictions.*

3.2.2.2 Hypothesis 2: Depth and Frequency of Price Discount

Narasimhan (1988) shows, when $\alpha=\alpha_1=\alpha_2$, d=0, and $c=c_1=c_2$, that the average discounts and the probability of discounting, respectively, are $E(p_1 \mid p_1<r)=E(p_2 \mid p_2<r)=\frac{\alpha(r-c)}{\beta}\ln\left[\frac{(\alpha+\beta)}{\alpha}\right]+c$ and $\Pr(p_1<r)=\Pr(p_2<r)=1$. This suggests that when each brand has the same size

[17]I am currently engaging in one-shot runs of the experiment.

of loyal segment and switchers are indifferent between the two competing products, there are no differences between the two competing firms in terms of depth and frequency of price discount. To test these predictions, I hypothesize that

H_{2a}: *The two competing firms offer the same amount and frequency of price discount under the symmetric market condition.*

Narasimhan (1988) also predicts that when $\alpha_1 > \alpha_2$, $d=0$, and $c=c_1=c_2$, the average discounts are $E(p_1 \mid p_1 < r) = E(p_2 \mid p_2 < r) = \frac{\alpha_1 (r - c_1)}{\beta} \ln\left[\frac{(\alpha_1 + \beta)}{\alpha_1}\right]$, which indicate the same depth of discount for the two firms. However, Narasimhan (1988) also shows that $\Pr(p_1 < r) = \frac{(\alpha_2 + \beta)}{(\alpha_1 + \beta)} < \frac{\alpha_1}{\beta}\left[\frac{(r - c_1)}{(\bar{p} - c_1)} - 1\right] = \Pr(p_2 < r)$, which suggests that a large share brand lowers its price less frequently than a small share brand.[18] I accordingly hypothesize that

H_{2b}. *The larger-share brand lowers its price less frequently than the smaller-share brand and offers the same average discount.*

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[18] This compares with Raju *et al.* (1990), who support the analytical finding of Narasimhan (1988) that the brand with greater loyalty promotes less frequently than the one with lesser loyalty. Regarding the depth of price discount, however, they predict that the stronger brand offers a larger average discount. By contrast, Rao (1991) predicts that the private label ("weaker" brand) never promotes, but the national brand only promotes. Agrawal (1996), on the other hand, finds that the retailer promotes the stronger loyalty brand more often, but provides a smaller price discount for it as compared to the weaker loyalty brand. In addition, he analytically predicts that the weaker brand manufacturer promotes more often, but provides a smaller discount on average than the stronger brand manufacturer.

Although Narasimhan (1988) considers the premium brand case, he always sets $\alpha_1 > \alpha_2$ when $d>0$. For experimental purposes, I think it is important to examine the effect of $d>0$ separately from $\alpha_1 > \alpha_2$. I therefore set $\alpha_1 = \alpha_2$. Following Rao (1991), I interpret d as a price premium commanded by Brand 1 over Brand 2. I predict that when $\alpha = \alpha_1 = \alpha_2$, $d>0$, and $c = c_1 = c_2$, $E(p_1 \mid p_1 < r) > E(p_2 \mid p_2 < r)$ [19] and $\Pr(p_1 < r) > \Pr(p_2 < r)$ [20]. This suggests that when the switchers are not indifferent between the two brands and the two brands have the same size of loyal segment, the premium brand, which is preferred by the switchers at equal prices, promotes more often and offers smaller average discount. I thus hypothesize that

H_{2c}. *The preferred brand by the switchers at equal prices promotes more often and offers smaller average discount.*

3.2.2.3 Hypothesis 3: Direct Communication

A further issue I consider concerns direct communication between players. Costless, nonbonding, and unverifiable communication or signaling about private

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19 $$E(p_1 \mid p_1 < r) = \frac{(\hat{p}_2 - c_2)(r - d - c_2)}{(r - d - \hat{p}_2)} \ln\left[\frac{(r - d - c_2)}{(\hat{p}_2 - c_2)}\right] + d + c_2$$

$$E(p_2 \mid p_2 < r) = \frac{(\hat{p}_2 + d - c_1)(r - c_1)}{r - \hat{p}_2 - d} \ln\left[\frac{(r - c_1)}{(\hat{p}_2 + d - c_1)}\right] - d + c_1.$$

20 $$\Pr(p_1 < r) = \frac{\alpha_2 (r - c_2)}{\beta}\left[\frac{1}{(\hat{p}_2 - c_2)} - \frac{1}{(r - d - c_2)}\right]$$

$$\Pr(p_2 < r) = \frac{(\alpha_1 + \beta)(\hat{p}_2 + d - c_1)}{\beta}\left[\frac{1}{(\hat{p}_2 + d - c_1)} - \frac{1}{(r - c_1)}\right].$$

information and future actions are considered cheap talk in situations of strategic interdependence, and such communication may have no direct payoff implications because of the implicit incentive to deceive (Srivastava et. al. 2000). In experimental research, however, cheap talk has been shown to be effective in coordination and bargaining games (see Croson et. al 2002 for a review). For instance, Dawes, MacTavish, and Shaklee (1977) find that nonbinding group communications generally improve cooperation in prisoners' dilemma games. In a bargaining game involving the acquisition of a company, Valley, Moag and Bazerman (1998) find a greater number of mutually beneficial agreements being reached as communication opportunities increase.

More recently, Aoyagi (2002) find that when players publicly communicate their signals during the course of play, their announcements serve as public signals on which actions can be coordinated. Such a mechanism may lead to more coordinated outcomes similar to those supported by the logic of the folk-theorem. I therefore hypothesize that:

H_3. *Direct communication facilitates cooperation between firms.*

3.2.2.4 Hypothesis 4: Learning Effects

In the experimental economics literature, learning effects are increasingly being used to explain how subjects reach (or fail to reach) equilibrium in the course of playing the game (Salmon 2001). Recently, Zwick and Chen (1999) analyze subjects' bargaining behavior by focusing on adaptive monotonic response. In addition, Zwick and Rapoport (1999) find that the behavior of subjects is significantly influenced by the results of their decision in the most recent iteration of the game, which indicates adaptive behavior. Based on this approach, I examine how players learn the game over the multiple iterations and hypothesize that:

H_4. *Players move toward strategies that are reinforced by positive outcomes.*

Table 3.1 summarizes the research hypotheses. The experimental methodology for testing these hypotheses follows in the next section.

Table 3.1 Summary of the Research Hypotheses

Test of:	Hypothesis Statement:
Mixed Strategy Equilibrium	In a loyal/switcher context, players will randomize prices, particularly according to Narasimhan's (1988) predictions.
Depth and Frequency of Price Discount	Under symmetric market conditions (**$a_1 = a_2$ and d=0**), the two competing firms offer the same amount and frequency of price discount.
	When the loyal segments have asymmetric sizes (**$a_1 > a_2$ and d=0**), the larger-share brand lowers its price less frequently and offers the same average discount.
	When switchers prefer one brand (**$a_1 = a_2$ and d>0**), the preferred brand promotes more often and offers smaller average discount.
Direct Communication	Direct communication facilitates cooperation between firms.
Learning Effects	Players move toward strategies that are reinforced by positive outcomes.

3.3 Experiment 2

3.3.1 Subjects

Three hundred and four undergraduate business students from a large university in North America participated in a session that lasted about 60 minutes.

Participants were recruited from a subject pool and randomly assigned to treatment conditions. In return for participating, subjects were given class credit and payment contingent on performance.

I used a convenience sample of non-expert subjects intentionally: if such subjects can figure out the fairly complex strategies of the theory (and freely choose to follow these strategies), then this provides a strong test of the behavior induced from the model. Experiments with expert subjects are logistically more difficult to carry out, but would also be worthwhile for future research.

3.3.2 Game Setup and Procedures

Subjects were randomly divided into groups of two players, and engaged in multiple rounds of interaction. In each round, the two players simultaneously set prices for their products. The prices of their products determine market demand for each product and the profits accruing to each player. Each player was given 60 seconds in each round to make a decision. If a player took longer than 60 seconds, the player would lose $0.05 per second as a penalty.[21] The final subject fee was proportional to that player's cumulative profits after 30 rounds of the game.

The experimental procedure began by giving subjects' detailed instructions and a quiz. This is a simple game structure and the instructions are

[21] Under the No Chat conditions, no penalties occurred. Under the Chat conditions, only 4 out of 2640 moves involved penalties, and these were relatively small. Thus, players did not appear hampered by time pressure.

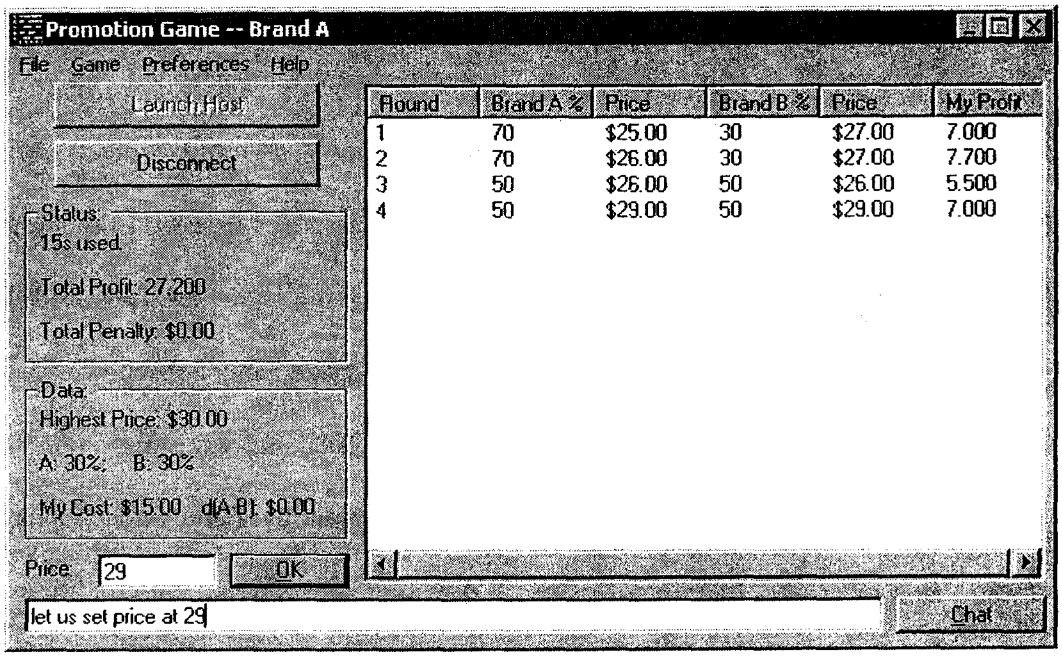
short (see Appendix 3.2). The quiz consisted of ten questions to ascertain the understanding of the instructions and subjects were paid 10 cents for each correct answer.[22] Subjects then played at a computer terminal with a randomized, anonymous partner for seven 'practice' rounds. No compensation was provided for practice rounds. The parameters of the model were then changed and each subject was randomly reassigned to a different partner.[23] Pairs of subjects then engaged in 30 rounds of play and subject fees were awarded based on the game profits earned. Subjects then filled out a survey about the strategies they used in the game. They were then paid subject fees in private, and debriefed. The payment formula was that each subject was paid \$3.00, plus the quiz payment (maximum of \$1.00), plus the total accumulated profit over the thirty rounds divided by a parameter that equalizes profit potential across treatment conditions. The average payment for the experiment was \$10.35.

A typical player's computer screen is shown in Figure 3.2.[24] In this example, the two competing firms both chose prices of \$29.00 in Round 4. Figure 3.2 also shows how firms communicate under the "chat" condition.[25] At the start of the game, players are shown an overhead screen with all parameters of

[22] The average quiz score was 9.03/10, which indicated that players understood the game, even before the practice game.
[23] Since I am interested in the repeated version of Narasimhan's one-shot model, each player is matched with the same player for all 30 periods. This may cause sequential dependence between players' moves. In the future, it also may be desirable to compare fixed paring with random paring.
[24] To make the game more user-friendly, I denoted the two brands as Brand A and Brand B in the game screen. In this paper, I find the mathematical notation easier to refer to these as Brand 1 and Brand 2, respectively.
[25] Under the no-chat condition, the portion of the screen in Figure 2 containing the "chat" button and the space for message entry, instead, appeared blank.

the game for them and their opponents, including brand loyalty percentages (α_1 and α_2), highest prices ($r_1 = r_2$), and costs ($c_1 = c_2$).

Figure 3.2 Typical Screen of the Experiment



All players see a running tally of market outcomes for all previous rounds of play including brand loyalty percentages, highest prices, costs, and profits accruing to them.

3.3.3 Experimental Design

To examine the hypotheses listed in Table 3.1, I employ a between-subjects design involving three variables. See Table 3.2.

The first experimental variable is the size of loyal segments. This variable has two levels: symmetric loyal segments (30% for each brand) and asymmetric loyal segments (40% for Brand 1 and 20% for Brand 2).

Table 3.2. Experimental Design
(Number of groups in parentheses)

	No Preference for the Premium Brand (d=0)		Preference for the Premium Brand (d=3)
	Symmetric Loyal Segments (Each brand has 30% loyal segment.)	Asymmetric Loyal Segments (Brands 1 and 2 have 40% and 20% loyal segments, respectively.)	Symmetric Loyal Segments (Each brand has 30% loyal segment.)
No Chat	Treatment 1 (20)	Treatment 2 (20)	Treatment 3 (24)
Chat	Treatment 4 (27)	Treatment 5 (29)	Treatment 6 (32)

The second experimental variable is the preference for the premium brand by the switcher segment. Consumers in this group switch between the two competing brands according to following rules. Switchers buy Brand 1 if $p_1<p_2+d$, while they buy Brand 2 if $p_1>p_2+d$. If $p_1=p_2+d$, the half of the switchers buy Brand 1 and the other half buy Brand 2. When d=0, the switchers are extremely price sensitive and buy whatever brand has lower price. When d=3, Brand 2 must be priced 3 dollars below brand 1's price to be equally desirable by the switchers. Thus Brand 1 is considered the premium brand.[26]

The last experimental variable is related to communication between players. Under the "no chat" condition (Treatments 1 to 3), players could not

[26] Note that I did not consider the interaction effect of Premium Brand Preference and Asymmetric Size of Loyals because of budget constraints.

send messages to each other, that is, the only way to communicate with each other is by using the prices, themselves. Under the "chat" condition (Treatments 4 to 6), however, players could send and receive digital messages during the experiment (see Figure 3.2).

Table 3.3 lists the parameters used in the experiment for the six treatment conditions.

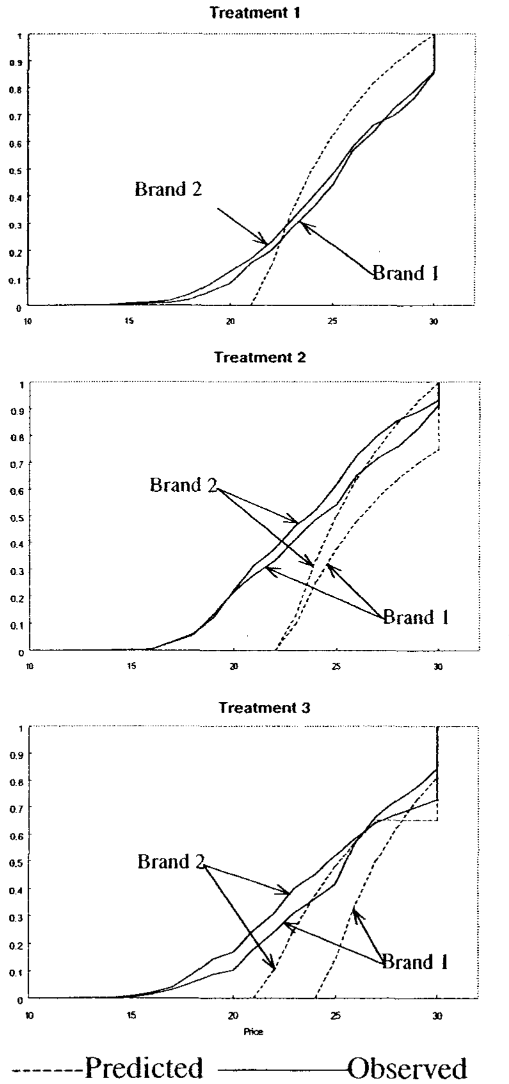
Table 3.3 Parameter Values

	Treatments 1 & 4	Treatments 2 & 5	Treatments 3 & 6
Loyal segment of Brand 1	30%	40%	30%
Loyal segment of Brand 2	30%	20%	30%
Switcher segment	40%	40%	40%
Highest price of Brand 1	\$30	\$30	\$30
Highest price of Brand 2	\$30	\$30	\$30
Cost of Brand 1	\$15	\$15	\$15
Cost of Brand 2	\$15	\$15	\$15
d (switchers' preference for Brand 1)	0	0	\$3

3.4 Experimental Results

I now assess the hypotheses concerning use of mixed strategies, depth and frequency of price discounts, direct communications, and dynamic learning effects.

Figure 3.3 Predicted and Observed Cumulative Probability Distributions of Price Outcomes



3.4.1 Tests of Mixed Strategy Equilibrium Play

Figure 3.3 provides an overview of Treatments 1-3 across all games and rounds for Brands 1 and 2. The graphs compare the observed cumulative probability distributions (solid lines) with theoretical predictions (dotted lines).

3.4.1.1 General Mixed-Strategy Behavior.

Before I consider whether the data conform to the specific predictions of the model, I first consider the extent of price variability used by players. Figure 3.3 certainly indicates substantial price variation in the data, as suggested by mixed strategy play, but the question arises as to whether this price variation is due to individual differences in mean prices across games or price variation within games.

To consider this issue, Table 3.4 indicates the extent to which the total variation in price is due to between-game and within-game effects. For Treatment 1 (Symmetric Market), we see that 72% and 66% of the total variation (i.e., the sum of squares) in Prices 1 and 2, respectively, is due to within-game price variability. Furthermore, the observed standard deviation of prices within games is $3.74 and $3.97 for Products 1 and 2, respectively. For Treatments 2 (Asymmetric Loyal Segments) and 3 (Asymmetric Switcher Preferences), most of the total variation is also due to within-game effects (although these asymmetric conditions generate somewhat greater between-game variation). A preliminary examination of the data, thus, suggests behavior consistent with mixed-strategy play. I next compare the observed outcomes with theoretical predictions.

3.4.1.2 Treatment 1: Symmetric Market

Treatment 1 (Symmetric Market) data in Figure 3.3 indicate that subjects randomize over a wide range of prices and that the empirical game means (graphically, the horizontal center of gravity) are not too far from the predicted mean (this will be examined more precisely below). Indeed, this treatment elicits randomizing behavior not too far from predictions (although the variance appears larger than predicted, indicating that players may have difficulty attaining the optimal variance and range of prices)

I conduct formal tests of whether the observed prices are different from predictions in Table 3.5. Row 1 compares the observed mean in Treatment 1 (Symmetric Market) for Brands 1 and 2 of $24.95 and $24.81, respectively, with

Table 3.4. Mixed Strategy Play Indicated by Within-Game Sum of Squares

Treatment	Source	Price 1				Price 2			
		Sum of Squares	% of Total	Predicted S.D.*	Observed S.D.*	Sum of Squares	% of Total	Predicted S.D.*	Observed S.D.*
1. Symmetric Market	Between Game	2375.04	0.28			3252.64	0.34		
	Within Game	6020.68	0.72	2.38	3.74**	6180.18	0.66	2.38	3.97**
	Total	8395.73				9432.82			
2. Asymmetric Loyal Segments	Between Game	4573.60	0.45			3857.20	0.43		
	Within Game	5626.52	0.55	2.69	4.13**	5024.48	0.57	2.09	3.85**
	Total	10200.12				8881.68			
3. Asymmetric Switcher Preferences	Between Game	4873.62	0.43			6156.65	0.40		
	Within Game	6394.81	0.57	1.97	3.96**	9239.38	0.60	3.24	4.63**
	Total	11268.43				15396.03			

* Standard Deviation ** Significantly greater than predictions at the .01 level.

the predicted mean of $24.53. I find that the average game mean in Treatment 1 is not significantly different from the predicted mean.[27] On the other hand, the Kolmogorov-Smirov (KS) test shows that the aggregate price distributions for both Brands are significantly different from the theoretical predictions (KS for Brands 1 and 2 = 4.483 and 4.654, $p<0.001$, respectively). This difference arises because of greater within-game standard deviations than predicted (Table 3.4) and also because of between-game variation.

Table 3.5. Predicted vs. Observed Price Behavior

		Mean Price		Aggregate	Disaggregate KS Tests[2]	
		Predicted	**Observed**	**KS Stat[1]**	**Individual**	**Combined**
Treatment 1	Brand 1	$24.53	$24.95	4.483**	9/20 (.45)	17/40 (.425)
	Brand 2	$24.53	$24.81	4.654**	8/20 (.40)	
Treatment 2	Brand 1	$26.55	$23.87**	8.083**	5/20 (.25)	8/40 (.20)
	Brand 2	$25.40	$23.32**	9.137**	3/20 (.15)	
Treatment 3	Brand 1	$27.26	$24.71**	9.660**	7/24 (.292)	10/48 (.208)
	Brand 2	$25.96	$24.35*	6.601**	3/24 (.125)	

[1] Kolmogorov-Smirnov distribution statistic using all data in treatment condition.

[2] Kolmogorov-Smirnov distribution tests: Fraction of games in treatment condition confirming theoretical predictions at the .01 level.

* Reject at .05 the level that the average game mean is different from the predicted mean.

** Reject at .01 the level that the average game mean is different from the predicted mean.

[27] This test is based on comparing the mean of the 20 observed game means with the theoretical expected price. I also tested the mean from each game (over thirty rounds) and found that, for Treatment 1, the observed game mean was not significantly different (at the .01 level) from theoretical predictions in 14 games (70%) for Price 1 and 11 games (55%) for Price 2. For Treatment 2, the observed game mean was not significantly different from theoretical predictions in 9 of 20 games (45%) for Price 1 and 10 of 20 games (50%) for Price 2. For Treatment 3, the observed game mean was not significantly different from theoretical predictions in 7 of 24 games (29%) for Price 1 and 4 of 24 games (17%) for Price 2.

To get a better sense of the price distributions across games, I compute Kolmogorov-Smirov (KS) test statistics for each individual game (two players playing 30 moves) under the three treatment conditions (see Table 3.5). Under Treatment 1 (Symmetric Market), Brand 1 exhibited price behavior consistent with theoretical predictions in 9 of 20 games and Brand 2 exhibited consistent price behavior in 8 of 20 games. Overall for Treatment 1 (Symmetric Market), 17 of 40 players (42.5%) display behavior fully consistent with theoretical predictions. I was surprised that so high a number of subjects, who had no previous experience with this game, ended up playing the predicted, rather complex, theoretical equilibrium strategies so closely. In addition, even those who did not follow predictions, tended to counterbalance each other, which is why the average game means were not significantly different from predictions.

3.4.1.3 Treatment 2: Asymmetric Loyal Segments

In this treatment, Figure 3.3 shows that the observed distributions for both players lie to the left of predictions, and are somewhat flatter (higher variance). Row 2 of Table 3.5 confirms that average game means are significantly lower than the theoretic prediction (Mean Price for Brand 1 is \$23.87 vs. \$26.55, $t = -4.233$, $p<0.001$; Mean Price for Brand 2 is \$23.32 vs. \$25.40, $t = -3.567$, $p<0.001$, respectively). I also find that the observed aggregate price distribution is significantly different from the theoretic prediction (KS for Brands 1 and 2 are 8.083 and 9.137, $p<0.001$, respectively). At a more disaggregate level, the Kolmogorov-Smirov distribution tests show that only 8 of 40 players (20%)

behave according to theoretical predictions. All of this evidence suggests that observed pricing differs significantly from theoretical predictions.

A further feature of this treatment is that the predicted price distribution for Brand 1 lies to the right of that for Brand 2 (see Figure 3.3). I also see that the observed distribution for Brand 1 does lie somewhat to the right of Brand 2, but formally there is no significant difference in game means for Brands 1 and 2. If I put this together with the earlier observation that mean pricing is significantly lower than predicted, it appears that the inequality between the players in the predictions has translated itself into lower prices for both players, but players share the lower profit more equally.

3.4.1.4 Treatment 3: Asymmetric Switcher Preferences

The observed data for this treatment display several features similar with those of Treatment 2 (Asymmetric Loyal Segments). I see in Figure 3.3 that the observed distributions for both players lie to the left of predictions, are somewhat flatter (higher variance), and, as before, mean game outcomes are significantly lower than predictions (Mean Prices for Brands 1 is \$24.71 vs. \$27.26, $t = -4.706$, $p<0.001$; Mean Prices for Brands 2 is \$24.35 vs. \$25.96, $t = -2.641$, $p=0.015$, respectively). I also find that the observed price distribution is significantly different from the theoretic prediction (KS statistics for Brands 1 and 2 are 9.660 and 6.601, $p<0.001$, respectively). Further, under Treatment 3 (Asymmetric Switcher Preferences), 10 of 48 players (20.8%) behave according to theoretical predictions. All of this evidence again suggests that observed pricing differs significantly from theoretical predictions.

In addition, Treatment 3 (Asymmetric Switcher Preferences) implies a predicted price distribution for Brand 1 that is to the right of Brand 2. However, the observed distribution for Brand 1 lies only somewhat to the right of Brand 2, and there is no significant difference in game means for Brands 1 and 2.

One feature different from previous treatments is that Treatment 3 (Asymmetric Switcher Preferences) implies a greater mass point at the top price for both Brands (as compared to the symmetric market conditions of Treatment 1). And I, indeed, observe greater mass points for both players than for the other treatments (although both mass points are somewhat smaller than predicted).

Overall, comparing Treatments 1-3, mean pricing behavior is consistent with predictions under the symmetric condition, but not under the two asymmetric conditions. Furthermore, the full distribution of prices is consistent with theoretical predictions about twice as often under symmetric conditions as under asymmetric conditions. Thus, asymmetric game structures seem to limit the applicability of the Narasimhan's predictions. In the asymmetric cases, Brand 1 does not (or is unable to) fully exploit structural advantages; and Brand 2 may be willing to sacrifice profitability in order to gain profits more equal to those of Brand 1.

3.4.1.5 Intuitive Rationale for Mixed Strategies

Since all treatments exhibit mixed strategy behavior, a natural follow-up question concerns whether subjects consciously used dynamic pricing strategies and, if so, why they chose to do so.

I accordingly examined the answers to an open-ended question in the debriefing survey asking, "Please describe the strategy that you used in the experiment." Of the 128 subjects in Treatments 1-3, two coders were in agreement that 89 subjects (70%) explicitly acknowledged using a form of dynamic pricing.[28] Players differed in their exact motivations for such dynamic strategies—82 subjects explained their strategies with reference to the opponent (higher price, lower price, or alternating between these)[29] and 40 subjects explained their strategies with reference to the target segments (switchers, loyals, or alternating between these).[30]

Overall, I believe a clear tension exists in this game between desires (1) to undercut the competitor and (2) to avoid destructive competition. At another level, tension exists between desires (1) to attract the switchers and (2) to avoid

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[28] Inter-judge reliability measures were only fair, with coefficient of agreement of .77, Cohen's Kappa of .42, and Perreault and Leigh's measure of .81. Coders' disagreements, however, did not concern whether a given strategy was "static" or "dynamic," but whether the answer fell into a third category entitled "not stated." If one disregards the answers for which at least one coder indicated "not stated," then the coefficient of agreement is .98, Cohen's Kappa is .66, and Perreault and Leigh's measure is .98. After the two coders were allowed to reach consensus to reconcile cases of disagreement, there were 104 dynamic strategies, 12 static strategies, and 12 cases not stated.

[29] The coefficient of agreement is.83; Cohen's Kappa is .57; and Perreault and Leigh's measure is .81. After the coders reconciled cases of disagreement, this number grew to 100 subjects.

[30] The coefficient of agreement is.87; Cohen's Kappa is .72, and Perreault and Leigh's measure is .86. After the coders reconciled cases of disagreement, this number grew to 52 subjects.

"leaving money on the table" with the loyals. Players try to predict and capitalize on opponent's actions as they balance these competing objectives—much as in such games as "scissors/paper/stone." A strategy that is too predictable is easy prey; and players that use them are punished. Static (pure) strategies are particularly predictable. Dynamic mixed-strategies arise from efforts to balance the competing objectives and to anticipate the competition in an unpredictable fashion.[31]

As background, one relatively common stated pattern was for a player to continually try to just undercut the opponent's price, until it becomes profitable to jump up to the loyals' reservation prices, and start the cycle again. Another

[31] In general, there appear to be at least four interpretations in the literature of mixed strategy equilibria. The classical rationale for a mixed strategy is based on the desirability of concealment. According to this interpretation, players may intentionally randomize, in particular, in the case of strictly competitive games in order to conceal one's choice, if the game is played repeatedly and players' choices are observable. In contrast to the classic rationale, at least three further interpretations have been suggested. The first of these interpretations is Harsanyi's (1973) purification idea that a player's private information can lead to uncertainty about that player's choice from the opponent's perspective. He states that each player is influenced by small, unmodeled perturbations to his/her payoffs that are not observable by his/her opponents. In every repetition of the game, a player chooses the unique, pure best reply in the corresponding game of incomplete information depending on the realization of the perturbation. Considering the long run average of past choices his/her opponents are led to believe that the player actually randomizes between the pure strategies. The second approach interprets mixed-strategy equilibrium as a population steady state in action (Rosenthal 1979). In this approach, each pure strategy in the support of the mixed equilibrium strategy is being played by the appropriate proportion of the population to give the impression that the population as a whole is playing a mixed strategy even though each individual player uses a pure strategy. The third interpretation of mixed strategy is that it is a steady state in beliefs, and not actions (Aumann 1987, Osborne and Rubinstein 1994). These beliefs are required to be common among all players in the game, and also consistent with the assumption that every player maximizes his/her expected utility. Under this interpretation, each player chooses a single action (strategy) rather than a probability distribution over the set of pure strategies. Overall, the content analysis of the debriefing survey provides support for a combination of the classic rational (the need to be unpredictable from a defensive standpoint) and Harsanyi's interpretation (the desire to form the best reply to capitalize on current understanding of the opponents pattern of actions, from an aggressive standpoint).

pattern was to alternate prices in a random fashion (e.g., "Yo-yo pricing at some points as well as stagnation to bait the other person.")

3.4.2. Tests of Relative Depth and Frequency of Price Discounts: Brand 1 vs. Brand 2

In the previous section, I compared actual and theoretical predictions. I now compare Brand 1 versus Brand 2 in terms of price discounting (i.e., pricing below the reservation levels).[32]

Table 3.6. Mean Discount Price and Discount Frequency for Brands 1 and 2

	Mean Discount Price[1]		Discount Frequency[2]	
	Brand 1	Brand 2	Brand 1	Brand 2
Treatment 1	$24.05	$24.13	25.70	25.60
Treatment 2	$23.39	$22.94	27.45	27.95
Treatment 3	$23.97[3]	$22.59[3]	25.29[4]	21.88[4]

[1] Mean price, conditional on price less than the reservation value of $30.

[2] Number of rounds (out of 30 total) wherein price was less than the reservation price.

[3] Brands 1 and 2 are significantly different at .05 level.

[4] Brands 1 and 2 are significantly different at .105 level (but not at the .05 level).

Table 3.6, columns 2 and 3, show mean discount prices for Treatments 1-3. As predicted by H_{2a} and H_{2b}, Treatments 1 (Symmetric Market) and 2 (Asymmetric Loyal Segments) show no significant difference in mean discounted price between Brands 1 and 2. As predicted by H_{2c}, the mean discounted price

[32] Note that mean discount prices differed from predictions in exactly the same pattern as the mean prices (with the same significance levels) shown in Table 3.5, column 4 (Observed Mean Price). In particular, only Treatment 1 mean discount prices for both brands were not significantly different from predictions. I do not repeat those tests here.

under Treatment 3 (Asymmetric Switcher Preferences) is higher for Brand 1 (i.e., the discount for the preferred brand is lower).

Table 3.6, columns 4 and 5, shows discount frequency. As predicted, there is no significant difference in discount frequency between Brands 1 and 2 under Treatment 1 (Symmetric Market). (In particular, Brands 1 and 2 priced less than $30.00 an average of 25.7 and 25.6 rounds, respectively, which is not significantly different.) However, the discount frequency was predicted to be lower for Brand 1 under Treatment 2 (Asymmetric Loyal Segments) and higher for Brand 1 under Treatment 3 (Asymmetric Switcher Preferences), but the observed differences for these treatments (while almost evident in Treatment 3) were not significant.

Overall, Treatment 1 (Symmetric Market) is consistent with the hypothesized symmetric discounting behavior, but Treatments 2 (Asymmetric Loyal Segments) and 3 (Asymmetric Switcher Preferences) are only consistent with the part of our maintained hypotheses concerning mean discount price. Subjects appear to have more difficulty finding the optimal discount frequency.

3.4.3 Tests of Direct Communication Effects

I now turn to the third hypothesis concerning whether direct communication facilitates cooperation between the firms. This hypothesis is tested in a version of the experiment that enables players to communicate using a chat box (shown at the bottom of Figure 3.2). Treatments 4-6 accordingly include a "chat" condition, but are otherwise identical to Treatments 1-3, respectively. I expect the "chat" condition to result in higher distributions of prices (i.e., distributions that are right-shifted).

Figure 3.4. Observed Probability Distributions of Price Outcomes: Chat vs No-Chat conditions

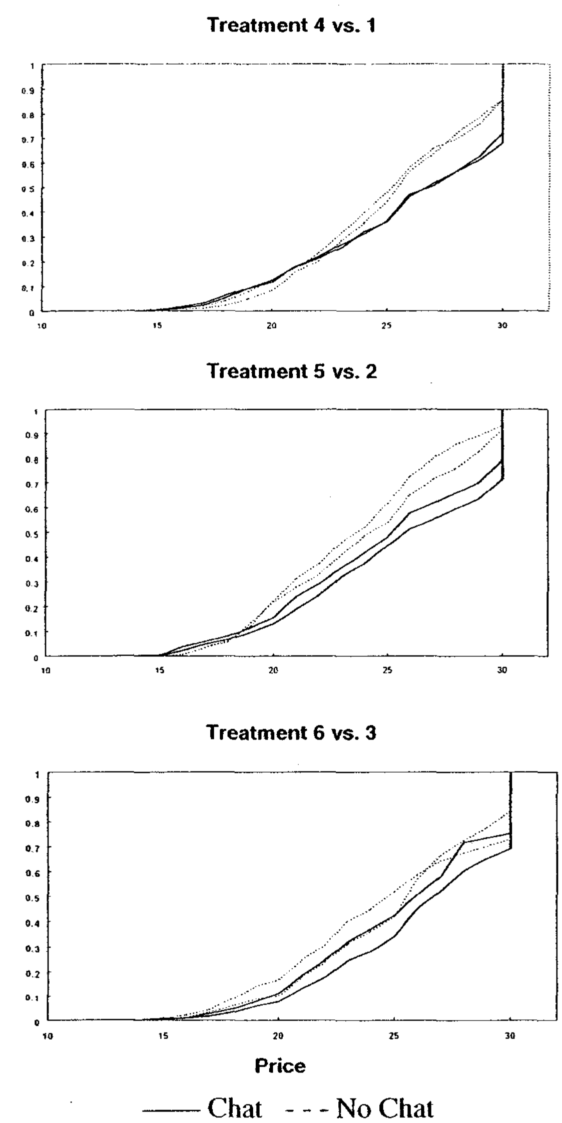


Figure 3.4 shows that, indeed, the observed distributions for both players for the "chat" conditions (Treatments 4, 5, and 6) are right-shifted (higher means) compared with "no-chat" conditions (Treatments 1,

2, and 3). In addition, the maximum price ($30) is chosen more frequently for "chat" conditions than "no-chat" conditions. It appears that players cooperate more when communication is allowed.

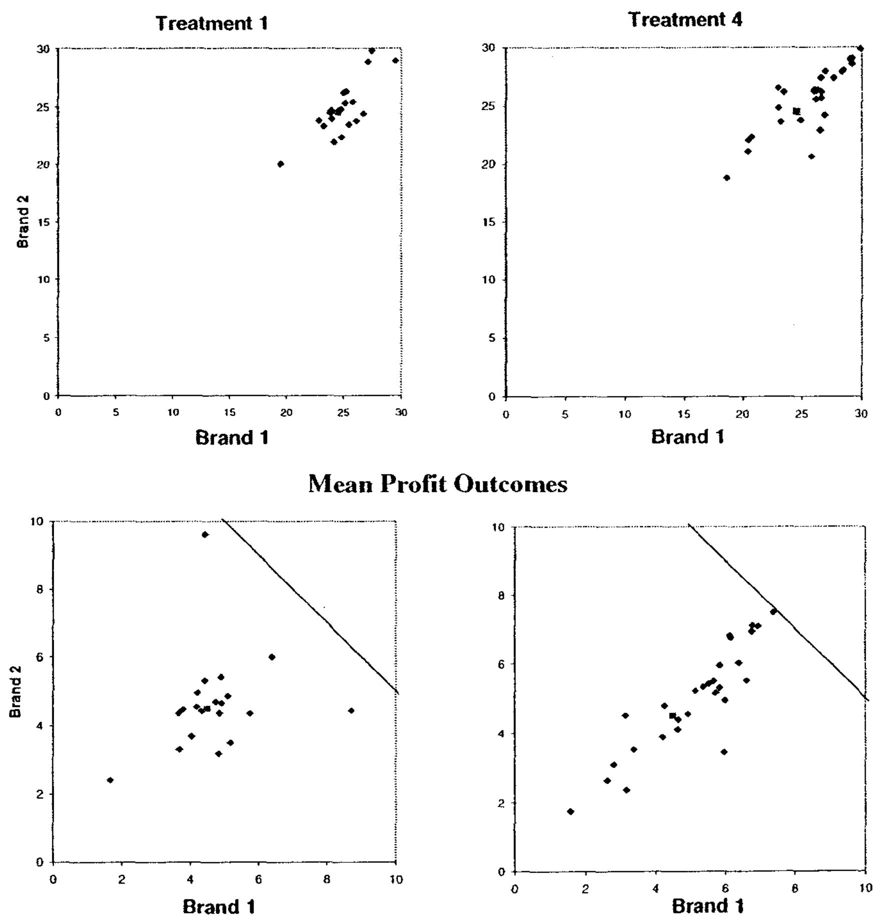
I formally test whether the observed outcomes for "chat" conditions are different from "no-chat" conditions and find that the observed pricing behavior under "chat" conditions is significantly different than "no-chat" conditions (KS for Treatment 4 vs. Treatment 1 = 3.022 for Brand 1 and 3.213 for Brand 2, $p<0.001$; KS for Treatment 5 vs. Treatment 2 = 4.250 for Brand 1 and 3.787 for Brand 2, $p<0.001$; KS for Treatment 6 vs. Treatment 3 = 3.092 for Brand 1 and 2.035 for Brand 2, $p<0.001$, respectively). The data indicate that the "chat" condition facilitates players' cooperation, which supports hypothesis H3.

Figure 3.4 also shows that the observed distributions for "chat" conditions (Treatments 4-6) are flatter (higher variance) than those of the "no-chat" conditions (Treatments 1-3). I show below that such increased aggregate variance is partly attributable to greater heterogeneity between game runs for "chat" conditions.

Figure 3.5 graphs the heterogeneity of price and profit outcomes for Treatments 1 (Symmetric Market) and 4 (Symmetric Market with Chat) in order to compare the "no-chat" and "chat" conditions (Treatments 2 and 5 and Treatments 3 and 6, not shown, show a similar pattern). The profit data are more pronounced and the net impact of the dispersion on player pairs is more evident because the chosen prices tend to be truncated by the unit product cost of $15.00 under these treatments.

Figure 3.5. Variation across Game Runs

Mean Price Outcomes



■Predicted ♦Observed (mean of 30 rounds of one game)

Treatment 1 (Symmetric Market) indicates a fairly circular dispersion pattern for both prices and profits across player pairs. Interestingly, Treatment 4 (Symmetric Market with Chat) indicates somewhat less relative dispersion between the two brands in most games and much more dispersion between games (so that most of the games lie near a 45-degree line in each quadrant). The ability to communicate, thus, appears to lead to more equal profits for the two players, but to greater heterogeneity in profits among game runs (depending on the ability of a player-pair to engage in constructive communication).

To further examine communication in these games, I use content analysis to classify the types of players' messages exchanged during the game and to analyze the impact on profits (Kassarjian 1977, Kolbe and Burnett 1991). Since my major concern is to ascertain how players reach agreement and how they follow or violate the agreement, I identify six categories: No Messages, No Informative Messages, Agreement Nor Reached, Agreement Weakly Followed, Agreement Moderately Followed, and Agreement Strongly Followed. (Note that the unit of analysis is each game's communications as a whole, and not each individual message.) The operationalization of each category is shown in the Appendix 3.3. Two coders were hired to analyze the messages and trained in a pilot study to learn the coding scheme and operational definitions. Then, the two coders classified the communications for each game independently on the basis of the operational definitions. I calculated three common interjudge reliability[33] measures used in the content analysis, including the coefficient of agreement, Cohen's (1960) kappa, and Perreault and Leigh's (1989) measure. The estimated reliability indexes are .932, .913, and .958, respectively, which exceed the critical values suggested in the literature (Kvalseth 1989, Perreault and Leigh 1989).

[33] "[T]he degree of consistency between coders applying the same set of categories to the same content"(Kassarjian 1977).

Lastly, the relatively few instances of differences in interpretation between the coders were resolved by having them review the messages together until a consensus was reached. This procedure was followed to attain as much objectivity as possible and still avoid throwing away data (Kolbe and Burnett 1991).

The following dialogues show typical examples of successful and unsuccessful cooperation.

Example of Agreement Strongly Followed	Example of Agreement Not Reached
[Treatment = 4, the symmetric condition.] Brand B: Lets see how much I make if I both do 30. Brand A: OK. Brand A: whoa! Not bad! Brand B: Are I trying to maximize profit or to compete against each other to try and get more money than the other person? Brand A: Depends, I can try to maximize profit. Brand A: But if I work together I can make a lot of money. Brand A: If one person screws the next, then they make money, but then you have to guess what the other person is going to do. Brand B: Should I keep doing 30 each? Brand A: Sure! [This aggreeement is followed by 5 messages from each sharing information]	[Treatment = 6, where switchers are shared equally if Brand A prices $3 higher than Brand B.] Brand B: Afternoon! Brand A: Yo yo! Brand B: Want to be a monopoly situation? Brand A: Cool! Brand A: What price? Brand B: You be 30..I'll be 27. Brand A: you be 28 I'll be 30. Brand B: No! Brand B: Not good for me Brand B: 27 and 30 is 50% share each. Brand A: At 3 or more its not I thought. Brand B: Make it 27 and 30 and well be 50% each. Brand B: Yes or no? Brand A: No!

In the left dialogue, the subjects agree to set the maximum price ($30.00) and share maximum total profits equally. This is the typical example of Agreement (Strongly Followed), wherein a proposal is made, accepted, and carried out for the remaining periods. In the right dialogue, player B proposes to share total market equally (in a way that maximizes group profits) by setting prices of $30.00 and $27.00, respectively, for Brands A and B, but player A rejects the proposal. This is a typical example of No Agreement.[34]

Overall, I find that 26.1% of the groups (*n*=23) do not exchange any messages and 14.8% of the groups (*n*=13) exchange only non-informative messages. In addition, 28.4% (*n*=25) of the groups do not reach an agreement even though at least one player makes a proposal. For the purposes of the analysis, I treat these three categories as No Agreement Cases. I also find that 30.7% of the groups (*n*=27) reach and follow an agreement (Specifically, 2.3% (*n*=2) of the cases are classified as Agreement Weakly Followed, 6.8% (*n*=6) as Agreement Moderately Followed, and 21.6% (*n*=19) as Agreement Strongly Followed). I treat these as "Agreement Cases."

To examine whether the Agreement Cases have higher profits than the No Agreement Cases, for each brand I conducted an analysis of variance (two types of communication × three treatment conditions). I find a highly significant positive main effect for type of communication for both brands ($F_{(1,82)}$=40.01, p<0.001; $F_{(1,82)}$=49.95, p<0.001 for Brands 1 and 2 , respectively). In addition, the main effect for treatment condition is significant for both brands ($F_{(1,82)}$=4.15, p=0.019; $F_{(1,82)}$=9.36, p<0.001 for Brands 1 and 2 , respectively). (The two-way interaction effect is not significant.)

[34] This latter example happens to be from Treatment 6, where the switchers view Brand A as the premium brand. We conducted a chi-squared test to examine the somewhat greater frequency of non-agreement under Treatments 5 and 6 than under Treatment 4, but the difference was not significant.

I am also interested in comparing the No Agreement and Agreement cases in terms of the percent of games that are consistent with the predicted mixed strategy equilibrium (using Kolmogorov Tests). For Treatments 4-6, of the 28 games that are consistent with the predicted mixed-strategy equilibrium (for at least one of the two subjects), 24 games (83%) fall under No Agreement Cases and 4 games (17%) fall under Agreement Cases. Viewed another way, about 39% of all No Agreement Cases support the predicted mixed strategy equilibrium (24 of the 61 No Agreement Cases for Treatments 4-6) and only 15% of Agreement Cases support the predicted mixed strategy equilibrium (4 of the 27 Agreement Cases for Treatments 4-6). Thus, there is a significant positive relationship between non-agreement and mixed-strategy equilibrium behavior (χ^2=5.19, p=0.023), which is really not a surprise.

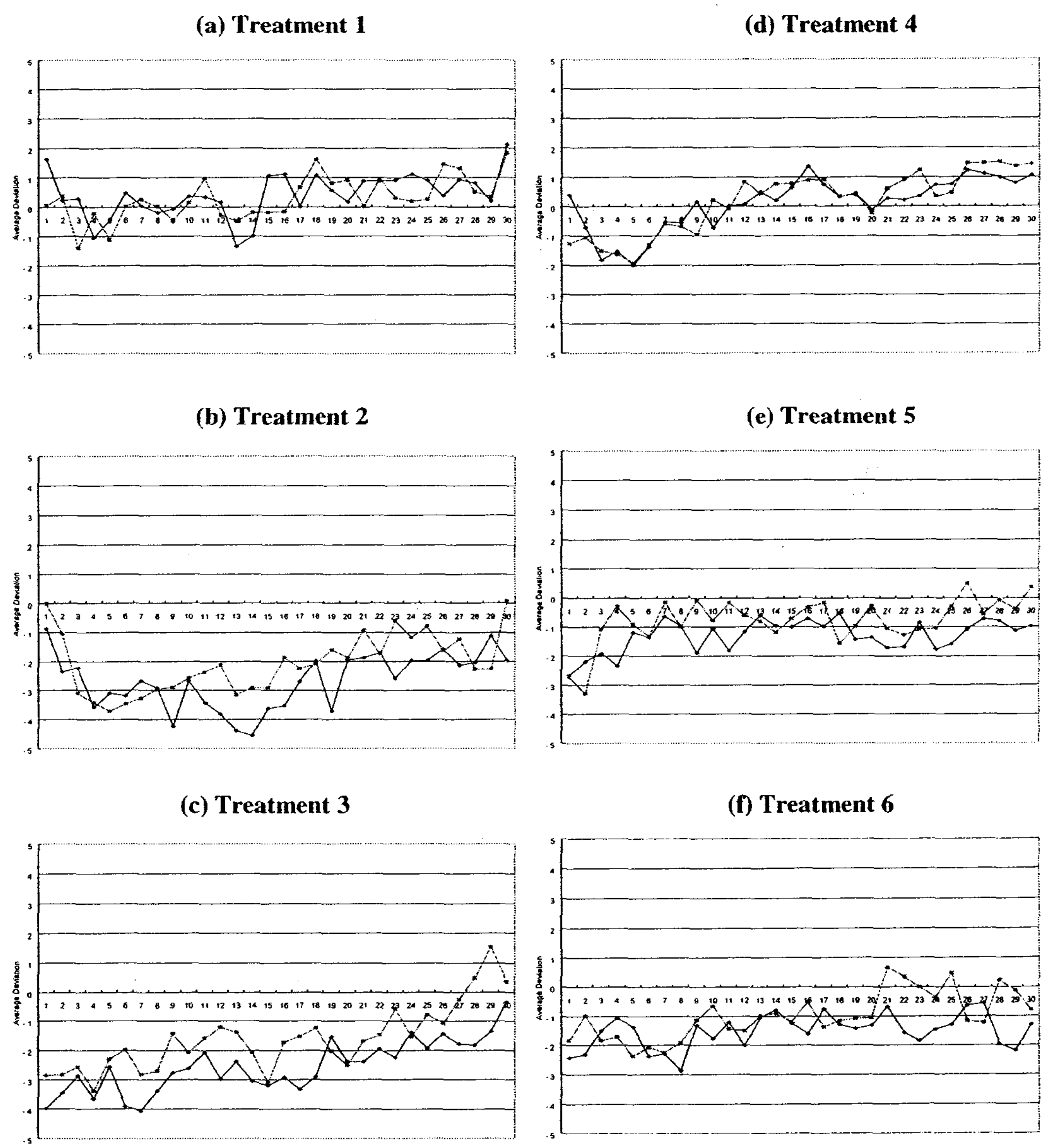
Overall, if players do not reach an agreement, their pricing behavior is more likely to be consistent with the mixed-strategy equilibrium. If players do reach an agreement, pricing is more coordinated than predicted by the mixed-strategy equilibrium and profits are significantly higher. I, thus, confirm that "chat" facilitates cooperation between players.

3.4.4 Tests of Dynamic Behavior

I found that mean pricing behavior of subjects is consistent with predictions under the symmetric market condition, but not under the asymmetric market conditions. One may wonder how subjects adjust to reach equilibrium (or fail to do so) over the course of the game. To consider this question, I first investigate subjects' choices over multiple rounds of play, and I then examine the adaptive response of play.

Figure 3.6 displays the deviation of average observed prices from the mean equilibrium price over all games within each treatment condition. Thus, positive (negative) values represent average prices above (below) the mean predictions. In the symmetric condition (Treatment 1), subjects play stably and close to predictions. In the symmetric chat condition (Treatment 4), subjects increase price over time and prices exceed the equilibrium levels for most of the game. In the asymmetric conditions without communication (Treatments 2 and 3), subjects play below mean predictions for most of the game, but converge gradually upward to a level just below the mean predicted equilibrium. The asymmetric conditions with communication (Treatments 5 and 6) exhibit similar behavior, but prices converge more rapidly and are generally at slightly higher levels at any point in time than the associated conditions without communication (Treatments 2 and 3). All these graphs indicate that subjects learn and adapt to about each other's behavior over the course of the experiment, albeit at different rates for different treatments. The adjustments appear to be slowest for the asymmetric conditions without communication. The fastest upward adjustments (leading to pricing and profits above mean predictions) occur in the symmetric condition with communication, as specific agreements are reached and trust is developed.

Figure 3.6. Average Deviation from Prediction by Treatment



What Figure 3.6 does not show, however, is whether within-game price variation changes over time. It is conceivable that within-game price variation settles down as players learn the game. This would cast a very different light on the presence of randomizing behavior—attributing it to learning at the beginning of the game (i.e., trial and error) rather than stationary mixed-strategy play. To distinguish between these possibilities, Table 3.7 separates the first and second halves of the game and reports the ratio of (Within-Game Sum of Squares) / (Total Sum of Squares) for the two-time periods. I see that, for Treatment 1 (Symmetric Market), the percent of within-game variation does not change perceptibly in the second half as compared to the first half of the game. For Treatment 2 (Asymmetric Loyal Segments), the percentage of within-game variation does fall, but for Treatment 3 (Asymmetric Switcher Segments) it rises for player 2. In all cases, there is substantial within-game (as well as between-game) price variation in both halves of the game, which is consistent with inherent mixed-strategy play.

Table 3.7. Comparisons of Within-Game Sum of Squares between the First and Second Halves of the Game

Treatment	Price	Source	Sum of Squares		% of Total	
			Round 1 to 15	Round 16 to 30	Round 1 to 15	Round 16 to 30
1. Symmetric Market	Price 1	Between Game	1639.349	1680.858	0.391	0.408
		Within Game	2548.412	2437.584	**0.609**	**0.592**
		Total	4187.762	4118.442		
	Price 2	Between Game	2299.157	2100.995	0.463	0.484
		Within Game	2671.504	2239.358	**0.537**	**0.516**
		Total	4970.661	4340.353		
2. Asymmetric Loyal Segments	Price 1	Between Game	2463.08	3785.697	0.509	0.726
		Within Game	2378.485	1426.082	**0.491**	**0.274**
		Total	4841.566	5211.78		
	Price 2	Between Game	1868.737	2857.742	0.455	0.626
		Within Game	2242.802	1704.041	**0.545**	**0.374**
		Total	4111.539	4561.784		
3. Asymmetric Switcher Preferences	Price 1	Between Game	2858.585	2663.33	0.493	0.509
		Within Game	2938.218	2571.002	**0.507**	**0.491**
		Total	5796.803	5234.332		
	Price 2	Between Game	3891.693	3172.673	0.522	0.417
		Within Game	3570.414	4432.608	**0.478**	**0.583**
		Total	7462.107	7605.281		

Next, and last, I further investigate learning effects. In general, there are two learning models to explain how equilibrium emerges in a game: reinforced-based and belief-based models. In a reinforced-based learning model, strategies are assumed to be reinforced by their previous payoffs, and players are assumed to choose those strategies that have done well in the past with higher probability in the future. Thus, players do not have beliefs about what other players do. By contrast, in a belief-based learning model, players form some belief about what others will do in the future based on past observation. Then players tend to choose a strategy (best response) that maximizes expected payoffs given the beliefs formed by observing the history of what others did. In experimental games with unique, mixed strategy equilibria, Erev and Roth (1998) find that a reinforced-based learning model robustly outperforms the equilibrium predictions, and Mookherjee and Sopher (1997) find that reinforced-based learning models are more consistent with experimental evidence than belief-based models. In addition, Binmore *et al.* (1996) find that people do not start their play by randomizing over their pure strategies in finitely iterated, two-person, zero-sum games with no pure-strategy equilibria. Rather, they gradually reach equilibrium play through some process of adaptation.

In the spirit of this literature, I examine the applicability of a particular case of reinforment-based learning model, called adaptive response behavior—defined as players being more likely to use the current decision in the next period, if it was successful, and less likely to use it, if it was unsuccessful (Zwick and

Chen 1999, Zwick and Rapoport 2002). Table 3.8 accordingly presents the frequency of price decisions as a function of the success or failure of the decision on the previous period at the individual level and shows several things.[35] The table shows several things.

First, when "price-up" was a successful decision, there is a weak tendency to choose "price-up" again in the next round rather than switch to "price-down" (21.9% vs. 20.8%, 21.8% vs. 19.3%, 22.9% vs. 22.0%, 20.1% vs. 16.0%, 20.0% vs. 21.1%, 22.0% vs. 21.4% in Treatments 1-6, respectively). This is consistent (in a weak fashion) with adaptive responses. However, when "price-down" was a successful decision, subjects are less likely to continue with "price down" and more likely to switch to "price-up" in the next period (11.4% vs. 24.1%, 12.8% vs. 22.2%, 6.8% vs. 16.2%, 9.5% vs. 22.4%, 9.2% vs. 19.1%, 8.6% vs. 18.4% in Treatments 1-6, respectively). This part is not consistent with adaptive responses.

Second, when "price-up" was unsuccessful, subjects strongly tend to switch from "price up" to "price-down" in the next period (5.5% vs. 23.8%, 4.7% vs. 22.7%, 6.1% vs. 16.5%, 5.3% vs. 23.5%, 4.8% vs. 21.0%, 6.4% vs. 18.8% in Treatments 1-6, respectively). Similarly, when "price-down" was unsuccessful, subjects tend to switch from "price-down" to "price-up" in the next period (24.5% vs. 26.5%, 27.8% vs. 24.2%, 18.0% vs. 34.7%, 16.0% vs. 23.7%, 20.1% vs.

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[35] I define the success as an increase in profits ($\Delta\pi_{t-1}>0$) and the failure as a decrease in profits ($\Delta\pi_{t-1}<0$). In addition, I consider an unchanged profit case ($\Delta\pi_{t-1}=0$). In each case, I consider both changing ($\Delta p_{t-1}>0$ and $\Delta p_{t-1}<0$) and unchanging behavior ($\Delta p_{t-1}=0$).

31.7%, 13.9% vs. 30.8% in Treatments 1-6, respectively). These latter two tendencies are consistent with adaptive responses.

Overall, the experimental outcomes partially support reinforcement-based learning—which is defined as past success with a strategy move increasing the likelihood of the same move being repeated. In particular, the adaptive response after failure is more salient than after success. These results suggest that subjects respond more sensitively to their losses than to their gains.[36]

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[36] There is also a relatively high proportion of unchanging behavior, which is common in this type of research (Zwick and Chen 1999, Weg et al. 1996, Zwick et al. 1992, Ochs and Roth 1989).

Table 3.8. Frequency of Price Decision in Round t as a Function of the Profits of the Decision in Round t-1*

		$\Delta\pi_{t-1}>0$				$\Delta\pi_{t-1}<0$				$\Delta\pi_{t-1}=0$			
		t-1				t-1				t-1			
Treatment	t	$\Delta p_{t-1}>0$	$\Delta p_{t-1}<0$	$\Delta p_{t-1}=0$	Overall	$\Delta p_{t-1}>0$	$\Delta p_{t-1}<0$	$\Delta p_{t-1}=0$	Overall	$\Delta p_{t-1}>0$	$\Delta p_{t-1}<0$	$\Delta p_{t-1}=0$	Overall
	Δpt>0	100 (21.9)	110 (24.1)	6 (1.3)	216 (47.3)	25 (5.5)	120 (26.5)	15 (3.3)	160 (35.3)	0 (0)	2 (1.0)	27 (12.9)	29 (13.8)
	Δpt<0	95 (20.8)	52 (11.4)	3 (0.7)	150 (32.8)	108 (23.8)	111 (24.5)	22 (4.9)	241 (53.2)	1(0.5)	0 (0)	48 (22.9)	49 (23.3)
1	Δpt=0	54 (11.8)	29 (6.3)	8 (1.8)	91 (19.9)	14 (3.1)	28 (6.2)	10 (2.2)	52 (11.5)	0 (0)	1 (.0.5)	131 (62.4)	132 (62.9)
	Overall	249 (54.5)	191 (41.8)	17 (3.7)	457 (100)	147 (32.5)	259 (57.2)	47 (10.4)	453 (100)	1 (0.5)	3 (1.4)	206 (98.1)	210 (100)
	χ^2 test	21.485 (p<0.001)				44.446 (p<0.001)				10.563 (p=0.032)			
	$\Delta p_t>0$	107 (21.8)	109 (22.2)	4 (0.8)	220 (44.8)	22 (4.7)	114 (24.2)	13 (2.8)	149 (31.6)	0 (0)	4 (2.5)	42 (26.8)	46 (29.3)
	$\Delta p_t<0$	95 (19.3)	63 (12.8)	5 (1.0)	163 (33.2)	107 (22.7)	131 (27.8)	29 (6.1)	267 (56.6)	4 (2.5)	0 (0)	49 (31.2)	53 (33.8)
2	$\Delta p_t=0$	58 (11.8)	44 (9.0)	6 (1.2)	108 (22.0)	17 (3.6)	26 (5.5)	13 (2.8)	56 (11.9)	1 (0.6)	1 (0.6)	56 (35.7)	58 (36.9)
	Overall	260 (53.0)	216 (44.0)	15 (3.1)	491 (100)	146 (30.9)	271 (57.4)	55 (11.7)	472 (100)	5 (3.2)	5 (3.2)	147 (93.6)	157 (100)
	χ^2 test		7.8312 (p=0.098)				41.358 (p<0.001)			11.571 (p=0.021)			
	$\Delta p_t>0$	127 (22.9)	90 (16.2)	9 (1.6)	226 (40.7)	29 (6.1)	164 (34.7)	16 (3.4)	209 (44.2)	0 (0)	0 (0)	44 (13.9)	44 (13.9)
	$\Delta p_t<0$	122 (22.0)	38 (6.8)	4 (0.7)	164 (29.5)	78 (16.5)	85 (18.0)	39 (8.2)	202 (42.7)	2 (0.6)	1 (0.3)	82 (25.9)	85 (26.9)
3	$\Delta p_t=0$	105 (18.9)	53 (9.5)	7 (1.3)	165 (29.7)	22 (4.7)	26 (5.5)	14 (3.0)	62 (13.1)	0 (0)	0 (0)	187 (59.2)	187 (59.2)
	Overall	354 (63.8)	181 (32.6)	20 (3.6)	555 (100)	129 (27.3)	275 (58.1)	69 (14.6)	473 (100)	2 (0.6)	1 (0.3)	313 (99.1)	316 (100)
	χ^2 test		13.926 (p=0.008)				64.116 (p<0.001)			8.231 (p=0.083)			
	$\Delta p_t>0$	112 (20.6)	124 (22.8)	16 (2.9)	252 (46.2)	25 (5.4)	110 (24.0)	16 (3.5)	151 (32.9)	0 (0)	0 (0)	58 (11.4)	58 (11.4)
	$\Delta p_t<0$	86 (15.8)	52 (9.5)	4 (0.7)	142 (26.1)	112 (24.4)	73 (15.9)	30 (6.5)	215 (46.8)	3 (0.6)	1 (0.2)	72 (14.2)	76 (15.0)
4	$\Delta p_t=0$	84 (14.9)	50 (9.2)	20 (3.7)	151 (27.7)	43 (9.4)	26 (5.7)	24 (5.2)	93 (20.3)	0 (0)	0 (0)	374 (73.6)	374 (73.6)
	Overall	279 (51.2)	226 (41.5)	40 (7.3)	545 (100)	180 (39.2)	209 (45.5)	70 (15.3)	459 (100)	3 (0.6)	1 (0.2)	504 (99.2)	508 (100)
	χ^2 test		23.310 (p<0.001)				76.591 (p<0.001)			22.921 (p<0.001)			
	$\Delta p_t>0$	128 (20.0)	122 (19.1)	17 (2.7)	267 (41.7)	28 (4.8)	186 (31.7)	14 (2.4)	228 (38.8)	1 (0.3)	11 (2.8)	56 (14.0)	68 (17.0)
	$\Delta p_t<0$	135 (21.1)	59 (9.2)	7 (1.1)	201 (31.4)	123 (21.0)	118 (20.1)	38 (6.5)	279 (47.5)	5 (1.3)	5 (1.3)	97 (24.3)	107 (26.8)
5	$\Delta p_t=0$	103 (16.1)	56 (8.8)	13 (2.0)	172 (26.9)	35 (6.0)	36 (6.1)	9 (1.5)	80 (13.6)	3 (0.8)	2 (0.5)	219 (54.9)	224 (56.1)
	Overall	366 (57.2)	237 (37.0)	37 (5.8)	640 (100)	186 (31.7)	340 (57.9)	61 (10.4)	587 (100)	9 (2.3)	18 (4.5)	372 (93.2)	399 (100)
	χ^2 test		20.183 (p<0.001)				87.230 (p<0.001)			22.917 (p<0.001)			
	$\Delta p_t>0$	149 (22.0)	125 (18.4)	10 (1.5)	284 (41.9)	37 (6.4)	179 (30.8)	19 (3.3)	235 (40.4)	1 (0.2)	6 (1.1)	50 (9.4)	57 (10.7)
	$\Delta p_t<0$	145 (21.4)	58 (8.6)	4 (0.6)	207 (30.5)	109 (18.8)	81 (13.9)	64 (11.0)	254 (43.7)	2 (0.4)	4 (0.8)	93 (17.4)	99 (18.6)
6	$\Delta p_t=0$	101 (14.9)	69 (10.2)	17 (2.5)	187 (27.6)	31 (5.3)	39 (6.7)	22 (3.8)	92 (15.8)	3 (0.6)	0 (0)	374 (70.2)	377 (70.7)
	Overall	395 (58.3)	252 (37.2)	31 (4.6)	678 (100)	177 (30.5)	299 (51.5)	105 (18.1)	581 (100)	6 (1.1)	10 (1.9)	517 (97.0)	533 (100)
	χ^2 test	27.593 (p<0.001)				100.046 (p<0.001)				34.336 (p<0.001)			

3.5 Discussion and Conclusions

This essay examines whether subjects actually randomize as hypothesized by the loyal/switcher model of competitive price promotions (Narasimhan 1988) and, more generally, whether mixed strategies are too complex for humans or inherently unintuitive.

I find that subjects, indeed, use mixed-strategy pricing under certain conditions. In particular, under a symmetric structure, aggregate behavior comes surprisingly close to mixed-strategy predictions. Playing mixed-strategies turns out to be natural and common—even for non-expert subjects—and mean prices match the normative model. (There is, however, evidence of individual differences from game to game and limitations in players' abilities to find the exact theoretical variance of prices.)

The intuitive rationale for why humans play mixed-strategies in this setting is that, if any player is too predictable and the other player figures this out, the former is punished and the latter rewarded. To avoid being vulnerable, each must strike a balance between (1) undercutting the opponents' price to attract the switchers and (2) raising prices to maximize profit from loyals. The need for unpredictability, as in such games as scissors/paper/stone, ultimately leads to randomization, and hence I observe mixed strategies.

By contrast, under asymmetric structures, average prices are lower than predicted, and the observed aggregate price distribution is significantly different from theoretical predictions. This suggests that structural asymmetries engender more outbreaks of price competition and limit the applicability of the Narasimhan's predictions. I conjecture that complexity and lack of fairness in the asymmetric conditions may interfere with fully strategic behavior. I leave the issue of how complexity and lack of fairness may interfere with optimal behavior to future research.

When a "chat" function is introduced that allows explicit verbal communication between players, observed prices and profits are significantly higher than under similar conditions without "chat." Unlimited two-way communication in the experiments, thus, has an effect greater than mere "cheap talk" and appears to provide a mechanism for coordination and cooperation.

With respect to pricing dynamics, under symmetric conditions without verbal communication, subjects play stably and close to predictions. When players can communicate verbally, as specific agreements are reached and trust is developed, prices and profits increase to exceed equilibrium levels for most of the game. In the asymmetric conditions without communication, subjects play below mean predictions for most of the game, but converge gradually upward. When players can communicate using the "chat" function under these asymmetric conditions, prices move upward more rapidly and are generally slightly higher at any point in time than the associated conditions without communication. Overall, price adjustments appear to be slowest for the asymmetric conditions without communication.

With respect to adaptive learning, the experimental outcomes partially support reinforcement-based learning. In particular, the tendency to switch a decision after a previously unsuccessful decision is higher than the tendency to repeat a decision after a previously successful decision, which suggests that subjects are particularly sensitive to losses.

There are several interesting managerial implications of these results for practitioners. First, since human subjects, indeed, appear to carry out mixed strategies, managers should recognize that dynamic price variability is normal. Accordingly, managers should develop accounting and marketing system to facilitate price variations over time for recording purposes, for in-store display of prices, for catalogues, and for e-commerce.

Second, since asymmetric situations may incite destructive competition, managers should be trained to resist the impulse toward destructive competition and to objectively watch competitors' price patterns to recognize an opportunity to help gain profitability and to fully exploit competitive advantages by playing the normative model correctly.

Third, since the results indicate that communication facilitates price coordination, managers should look for legal mechanisms of communication about prices, such as public price announcements, use of mystery shoppers to monitor competitors' prices, and cooperation with Internet shopping agents for the purpose of providing the public with price comparisons. From a different perspective, regulators need to be aware of the extent to which communication about pricing facilitates coordination.

Appendix 3.1: The General Solution and Three Sub-cases

For the model described in Section 3.2.1, Narasimhan (1988) shows that there exists no equilibrium in pure strategies. This motivates the need for a mixed-strategy equilibrium. In general, α_1 and α_2 may be different, c_1 and c_2 may be different, and d may be nonzero.

Domain of Prices for Brands 1 and 2. Each firm i can guarantee itself a profit of at least $\alpha_i(r-c_i)$ by charging the maximum price r and selling only to its loyal segment. Such a firm would have no incentive to cut price so low that, in spite of winning the switcher segment, profit would be lower than this amount. Thus, the minimum price that firm i would rationally charge is given by $\hat{p}_i$ such that $(\hat{p}_i - c_i)(\alpha_i + \beta) = \alpha_i(r-c_i)$. Now, suppose (without loss of generality) that the brand preferred by the switcher segment (as described by parameter d) is Brand 1. If $\hat{p}_1 \leq \hat{p}_2 + d$, the set of non-dominated prices for Brand 1 lies of the closed interval $[\hat{p}_2 + d, r]$ because Brand 2 will not price below $\hat{p}_2$. In addition, Brand 2 will not set the price over the range $(r-d, r)$, since it would lose the switcher segment over this range; instead, Brand 2 may have a mass point at r. The set of non-dominated strategies for Brand 2 is, accordingly, $[\hat{p}_2, r-d] \cup r$. Alternately, if $\hat{p}_1 > \hat{p}_2 + d$, the sets of non-dominated prices for Brands 1 and 2, respectively, are $[\hat{p}_1, r]$ and $[\hat{p}_1 - d, r-d] \cup r$. Thus, setting $\hat{p} \equiv \max(\hat{p}_1, \hat{p}_2 + d)$, we expect Brand 1 to randomize over the interval $[\hat{p}, r]$ and Brand 2 to randomize over $[\hat{p} - d, r-d] \cup r$.

Equilibrium Conditions. The distribution of prices for firm i, F_i, should leave the other firm indifferent between all prices in his support. This implies conditions on F_1 and F_2, below:

$$\alpha_1(p-c_1)+[1-F_2(p-d)]\beta(p-c_1)=(\alpha_1+\beta)(\hat{p}-c_1), \qquad \hat{p}\le p\le r,$$

$$\alpha_2(p-c_2)+[1-F_1(p+d)]\beta(p-c_2)=(\alpha_2+\beta)(\hat{p}-d-c_2), \qquad \hat{p}-d\le p\le r-d.$$

Solving for F_1 and F_2, I obtain

$$F_1(p)=\begin{cases}0 & \text{for } p\le\hat{p},\\ 1+\dfrac{\alpha_2}{\beta}-\dfrac{(\alpha_2+\beta)(\hat{p}-d-c_2)}{\beta(p-d-c_2)} & \text{for } \hat{p}\le p\le r,\\ 1 & \text{for } r<p,\end{cases}$$

$$F_2(p)=\begin{cases}0 & \text{for } p\le\hat{p}-d,\\ 1+\dfrac{\alpha_1}{\beta}-\dfrac{(\alpha_1+\beta)(\hat{p}-c_1)}{\beta(p+d-c_1)} & \text{for } \hat{p}-d\le p\le r-d,\\ 1+\dfrac{\alpha_1}{\beta}-\dfrac{(\alpha_1+\beta)(\hat{p}-c_1)}{\beta(r-c_1)} & \text{for } r-d\le p<r,\\ 1 & \text{for } r\le p.\end{cases}$$

Case 1: Symmetric Market. Setting $\alpha=\alpha_1=\alpha_2$, d=0, $c=c_1=c_2$, I obtain:

$$F_1(p)=F_2(p)=\begin{cases}0 & \text{for } p\le\hat{p},\\ 1+\dfrac{\alpha}{\beta}-\dfrac{(\alpha+\beta)(\hat{p}-c)}{\beta(p-c)} & \text{for } \hat{p}\le p\le r,\\ 1 & \text{for } r\le p.\end{cases}$$

In this case, both firms have no mass points[37] and the same average prices.

Case 2: Asymmetric Loyal Segments. Setting $\alpha_1>\alpha_2$, d=0, $c=c_1=c_2$, I obtain:

[37] The mass points, in these cases, are calculated as $m_i=\lim_{p\to r^-}\left[1-F_i(p)\right]$.

$$F_1(p) = \begin{cases} 0 & \text{for} \quad p \le \hat{p}_1, \\ 1 + \dfrac{\alpha_2}{\beta} - \dfrac{(\alpha_2 + \beta)(\hat{p}_1 - c)}{\beta(p - c)} & \text{for} \quad \hat{p}_1 \le p < r, \\ 1 & \text{for} \quad r \le p, \end{cases}$$

$$F_2(p) = \begin{cases} 0 & \text{for} \quad p \le \hat{p}_1, \\ 1 + \dfrac{\alpha_1}{\beta} - \dfrac{(\alpha_1 + \beta)(\hat{p}_1 - c)}{\beta(p - c)} & \text{for} \quad \hat{p}_1 \le p \le r, \\ 1 & \text{for} \quad r \le p, \end{cases}$$

In this case, only the firm with larger-share brand (Brand 1) has a mass point, and this occurs at $p_1=r$.[38]

Case 3: Asymmetric Switcher Preferences. Setting $\alpha=\alpha_1=\alpha_2$, $d>0$, $c=c_1=c_2$, I obtain:

$$F_1(p) = \begin{cases} 0 & \text{for} \quad p \le \hat{p} + d, \\ 1 + \dfrac{\alpha}{\beta} - \dfrac{(\alpha + \beta)(\hat{p} - c)}{\beta(p - d - c)} & \text{for} \quad \hat{p} + d \le p < r, \\ 1 & \text{for} \quad r \le p, \end{cases}$$

$$F_2(p) = \begin{cases} 0 & \text{for} \quad p \le \hat{p}, \\ 1 + \dfrac{\alpha}{\beta} - \dfrac{(\alpha + \beta)(\hat{p} + d - c)}{\beta(p + d - c)} & \text{for} \quad \hat{p} \le p \le r - d, \\ 1 + \dfrac{\alpha}{\beta} - \dfrac{(\alpha + \beta)(\hat{p} + d - c)}{\beta(r - c)} & \text{for} \quad r - d \le p < r, \\ 1 & \text{for} \quad r \le p. \end{cases}$$

In this case, each firm has a mass point at r, and $m_1 < m_2$.[39]

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[38] $m_1 = \dfrac{(\alpha_1 - \alpha_2)}{(\alpha_1 + \beta)}$.

[39] $m_1 = \dfrac{\alpha_2 d}{\beta(r - d - c_2)}$ and $m_2 = \dfrac{(\alpha_1 + \beta)(\hat{p}_2 + d - c_1)}{\beta(r - c_1)} - \dfrac{\alpha_1}{\beta}$.

Table 3.9 provides a detailed summary of model predictions. Detailed calculations for the model cases are shown below:

Case 1: Symmetric Market.

$E(p) = E(p_1) = E(p_2)$, where $E(p) = \int_{\underline{p}}^{r} pf(p)dp = \frac{\alpha(r-c)}{\beta}\ln\left[\frac{(\alpha+\beta)}{\alpha}\right] + c$.

$E(\Pi_1) = E(\Pi_2) = \alpha(r-c)$.

Case 2: Asymmetric Loyal Segments.

$E(p_1) > E(p_2)$, where

$$E(p_1) = \frac{(\alpha_2+\beta)(\hat{p}_1 - c_2)}{\beta}\ln\left(\left[\frac{(\alpha_1+\beta)}{\alpha_1}\right] + \frac{c_2}{(\hat{p}_1 - c_2)} - \frac{c_2}{(r-c_2)}\right) + rm_1 \text{ and}$$

$$E(p_2) = \frac{\alpha_1(r-c_1)}{\beta}\ln\left[\frac{(\alpha_1+\beta)}{\alpha_1}\right] + c_1.$$

$E(\Pi_1) = \alpha_1(r-c_1)$, and $E(\Pi_2) = \frac{\alpha_1(\alpha_2+\beta)(r-c_1)}{(\alpha_1+\beta)} > \alpha_2(r-c_2)$.

Case 3: Asymmetric Switcher Preferences.

$E(p_1) > E(p_2)$, where

$$E(p_1) = \frac{\alpha_2(r-c_2)}{\beta}\ln\left(\left[\frac{(r-d-c_2)}{(\hat{p}_2 - c_2)}\right] + \frac{(d+c_2)}{(\hat{p}_2 - c_2)} - \frac{(d+c_2)}{(r-d-c_2)}\right) + rm_1 \text{ and}$$

$$E(p_2) = \frac{(\alpha_1+\beta)(\hat{p}_2 + d - c_1)}{\beta}\ln\left[\frac{(r-c_1)}{(\hat{p}_2 + d - c_1)}\right] - \frac{(\alpha_1+\beta)(d-c_1)(r-\hat{p}_2 - d)}{\beta(r-c_1)} + rm_2.$$

$E(\Pi_1) = (\alpha_1+\beta)(\bar{p} - c_1 + d) > \alpha_1(r-c_1)$ and $E(\Pi_2) = \alpha_2(r-c_2)$.

Table 3.9. Summary of the Model Predictions

Conditions	Assumptions	Predictions	Interpretations
1. Symmetric Market	$0<\alpha_1=\alpha_2<1$ $\alpha_1+\alpha_2+\beta=1$ $r_1=r_2=r$ $c_1=c_2$ $d=0$	Price range: $[\hat{p}, r]$ for both brands	Both brands randomize over the same range.
		Mass point: None for both brands	Neither brand has a mass point.
		Average price: $E(p_1)=E(p_2)$	On the average, the price is the same for both brands.
		Average discount: $E(p_1 \mid p_1<r)=E(p_2 \mid p_2<r)$	The average discount is the same for both brands.
		Probability of lower price: $\Pr(p_1<r)=\Pr(p_2<r)$	The frequency of "price-cut" is the same for both brands.
		Expected profit in equilibrium: Brand 1: $E(\Pi_1)=\alpha_1(r-c_1)$ Brand 2: $E(\Pi_2)=\alpha_2(r-c_2)$	In equilibrium, both brands obtain the same expected profit. This profit is equal to what could be obtained from its own loyal segment at the regular price.
2. Asymmetric Loyal Segments	$0<\alpha_2<\alpha_1<1$ $\alpha_1+\alpha_2+\beta=1$ $r_1=r_2=r$ $c_1=c_2$ $d=0$	Price range: Brand 1: $[\hat{p}_1, r]$ and Brand 2: $[\hat{p}_1, r)$	Both brands randomize over the same range.
		Mass point at $p=r$ with probability: $m_1=\frac{(\alpha_1-\alpha_2)}{(\alpha_1+\beta)}$ (only for Brand 1)	A larger-share brand has the mass point at r.
		Average price: $E(p_1)>E(p_2)$	On the average, the larger-share brand is priced higher.
		Average discount: $E(p_1 \mid p_1<r)=E(p_2 \mid p_2<r)$	The average discount is the same for both brands.
		Probability of lower price: $\Pr(p_1<r)<\Pr(p_2<r)$	The larger-share brand promotes less often.
		Expected profit in equilibrium: Brand 1: $E(\Pi_1)=\alpha_1(r-c_1)$ Brand 2: $E(\Pi_2)>\alpha_2(r-c_2)$	In equilibrium, the smaller-share brand earns higher profits than it would obtain from its own loyal segment at the regular price, whereas the larger-share brand obtains the same profit.

Table 3.9. Continued

Conditions	Assumptions	Predictions	Interpretations
3. Asymmetric Switcher Preferences	$0<\alpha_1=\alpha_2<1$ $\alpha_1+\alpha_2+\beta=1$ $r_1=r_2=r$ $c_1=c_2$ $d>0$	Price range: Brand 1: $[\hat{p}+d, r]$ Brand 2: $[\hat{p}, r\text{-}d]$ and a mass point at r	Each brand randomizes over the different ranges.
		Mass point at $p=r$ with probability: Brand 1: $m_1 = \frac{\alpha_2 d}{\beta(r-c_2-d)}$ Brand 2: $m_2 = \frac{(\alpha_1+\beta)(\hat{p}-c_1+d)}{\beta(r-c_1)} - \frac{\alpha_1}{\beta}$	Each firm has the mass point at r.
		Average price: $E(p_1)>E(p_2)$	On the average, the premium brand is priced higher.
		Average discount: $E(p_1 \mid p_1<r)>E(p_2 \mid p_2<r)$	The premium brand offers smaller average discount.
		Probability of lower price: $\Pr(p_1<r)>\Pr(p_2<r)$	The premium brand promote more often.
		Expected profit in equilibrium: Brand 1: $E(\Pi_1)>\alpha_1(r-c_1)$ Brand 2: $E(\Pi_2)=\alpha_2(r-c_2)$	In equilibrium, the premium brand earns higher profits than it would obtain from its own loyal segment at the regular price, whereas the less preferred brand obtains the same profit.

Appendix 3.2: Instruction and Quiz for the symmetric market with chat condition

This experiment examines the pricing behavior of two competing firms. In each round of the game, two players simultaneously set prices for their products. Each player has a loyal segment that will only buy his / her products. There is also a switching segment that will buy products from the lower priced firm. After the two firms set their prices, the computers determine the market share for each player, and the profits for each player are realized. The basic goal of the research is to determine patterns of economic outcomes that emerge in markets where competing firms are mutually dependent on each other. All the responses will be kept confidential throughout the research and the reporting of research results will be anonymous.

The minimum subject fee for this experiment will be $3 and the majority of subjects should earn between $6 and $12 for participation in an experiment that will last about 1 hour. [The payout range was from $3 to $12.]

I give my consent to participate in this experiment. I realize that at any time during the experiment I may withdraw from the experiment. In the event that I withdraw from this experiment, I will still receive $3 plus compensation for the quiz ($0.10 per answer correct, with a maximum payment of $1.00).

Signed ____

Instructions

Thank you for participating in this experiment.

This is an experiment in competitive promotional pricing strategies. These are the instructions for the experiment.

This experiment will be conducted through the use of computer terminals. No special skills are required and the instructions that follow will provide all the information you need to participate. Be sure to ask any questions that you might have during the presentation of the instructions, and ask for assistance, if needed, once you are seated at the computer terminal.

Here is a list of today's activities:

1. An overview of these written instructions.
2. A quiz based on the instructions.
3. A review of the quiz.
4. Instructions on how to use the computer (including 7 practice rounds).
5. Actual experiment, consisting of 30 rounds.
6. Written questionnaire and debriefing.

All the above activities will take place in the basement computer lab.

Please keep these instructions with you until the experiment is complete. You may need to refer to them.

Important Note: This experiment is being conducted over a period of several days. Please do not discuss the specifics of the experiment with other students. Please return the instructions after the experiment.

All the participants will be divided into two groups: Firm 1 and Firm 2. During the experiment you will engage in business over computer with a participant in the other group.

At the end of the experiment you will be asked to complete a questionnaire concerning your strategies and experiences during the experiment.

Experiment Structure

Theory

There are two firms marketing one branded product each in the same market. There are only these two firms competing in this market. The market size is constant and normalized to one. All consumers buy only one unit of a brand at a time as long as the brand's price is less than or equal to the max level price, r, that they are willing to pay.

The consumers are grouped into three segments. The first one is loyal to firm 1 and buys only from that firm. The second segment is loyal to firm 2 and buys only from firm 2. The remaining consumers are in the third segment called the switchers. They switch between the two brands according to the prices the two firm charge. They will only buy the brand that charges a lower price. If the two brands' prices are the same, the switchers will split, half of them will buy brand 1 and half will buy brand 2.

Profit:

Each player's profit for each round is calculated as:

(his loyal segment + the switcher segment he wins for that round) * (price he charges for the round - his cost)

Each player's total profits are the sum of the profits he made from each round.*

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*The payout was based on this formula divided by a parameter that equalized approximate profit potential across treatment conditions. The divider was 20 for both firms under Treatments 1 and 4; the divider was 24 and 16 for firms 1 and 2, respectively, under Treatments 2, 3, 5, and 6.

Participant roles

You and your opponent are the two firms in this market. When the game starts, you will be given both yours and your opponent's brand loyalty percentages, highest prices r, and costs. [This information is shown on a screen at the start of the game for all players to view.]

Round

There are 7 rounds in the practice and 30 rounds in the actual experiment, each round consists of the following steps:

Step 1: Both players offer a retail price p to the market.

Step 2: Based on the two prices you and your opponent input, your market share and profit will be calculated and displayed on the computer monitor, together with your opponent's price and market share.

Time Constraint

Each player will be given 60 seconds in each round to make a decision. If a player takes longer than 60 seconds, he will lose $0.05 per second as a penalty.

Chat

You can communicate with your opponent by writing in the chat box.

Player's cumulative total profit and penalty are shown by the computer.

Experiment Quiz

Please circle the best answer:

True* False 1. There are three segments in the market: consumers who are loyal to brand 1, consumers who are loyal to brand 2, and the switcher segment.

True False* 2. The switcher segment will buy from the two brands randomly, without following any rules.

True False* 3. The players do not know each other's cost.

True* False 4. All switchers follow the same switching rule.

True* False 5. Each player's profit for each round is calculated as:

(his loyal segment + the switcher segment he wins for that round) * (price he charges for the round - his cost)

True* False 6. The player who charges a lower price than the opponent, will definitely get all the switchers segment.

True* False 7. Each player can use chat function to communicate with the opponent.

True False* 8. Each player's timer begins for the next round, as soon as he/she inputs the price and presses the OK button for the current round.

True False* 9. If you have used more than 60 seconds for one round, you can't play anymore.

True False* 10. You will play 5 rounds for the test game and 20 rounds for the real game.

Number of Correct Answer ____________________

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* Correct answers.

Appendix 3.3: Content Analysis Coding Sheet

All 88 games with a chat condition are in a randomized order.

1. **No Messages**: Players do not exchange any messages.
2. **No Informative Messages**: Players exchange only non-informative messages. Non-informational messages are defined as communications that do not attempt to strike an agreement about pricing with the opponent. Examples of non-informational messages are introductions or social comments.
3. **Agreement Not Reached**: Players do not reach an agreement. An agreement is defined as reached if a request for action from one player to another player is made and the resulting action affects more than two successive rounds before round 20.
4. **Agreement Weakly Followed**: Agreement reached and followed for less than 25% of the remaining periods to round 29, inclusive. An agreement is considered followed in each period that the terms of the initial agreement, or subsequent mutually agreed upon modifications of the initial agreement, are met.
5. **Agreement Moderately Followed**: Agreement reached and followed between 25% and 75% of the remaining periods to round 29, inclusive.
6. **Agreement Strongly Followed**: Agreement reached and followed for more than 75% of the remaining periods to round 29, inclusive.

Code Number: Which of items 1-6 above was checked off. Included as a check on previous coding.

Number of A Messages: Number of messages in the game that player A [Brand 1] sends.

Number of B Messages: Number of messages in the game that player B [Brand 2] sends.

Total Number of Messages: Number of messages in the game that player A or B sends.

Dialog suitable for quote in paper. Check if dialog is interesting enough as an illustration of some form of interaction, either cooperation or non-cooperation.

Agreement Breakdown in Round 30. If there was a coordinated price in round 29, then price for either product dropped in the last round.

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Chapter 4

Essay 3: Estimates of Competitive Pricing Behavior among Channel Members Using Experimental Data

In competitive markets in which a firm's brand competes, the appropriate levels of a firm's marketing actives are determined not only by its own effect, but also by its rivals' reactions. For example, a wholesale price cut critically influences both competing manufacturers' and retailers' reactions to the price change. Therefore, identifying the nature of competitive interactions among firms is an important issue of marketing strategy.

4.1 Review of Extant Literature on Competitive Interactions

In the last two decades, competitive interactions among firms have attracted a lot of intention. A general research stream is the structure-conduct-performance paradigm (SCP) (Farris and Ailawadi 1992, Boulding and Staelin 1990, 1993, Messinger and Narasimhan 1995). These studies state that industry structure drives industry conduct, which in turn drives industry performance. Since most of these studies pool cross-sectional data in estimating reduced-form relationships between the structure of industries and performance, they are unable to capture heterogeneity across industries.

Another stream of research measures the direction and magnitude of a firm's reactions to the marketing actions of its competitors (Leeflang and Wittink 1992, 1996, Keil, Reibstein and Wittink 2001). Leeflang and Wittink (1992) examine competitive response functions using scanner data on price and promotional activities. They find that price and feature have statistically significant causal effects more frequently than other promotional variables. In addition, reactions occur with decreasing likelihood over time, suggesting distinctions between retailer- and manufacturer-dominated reactions. They (1996) also study the relationship between competitive reaction elasticities and cross- and own-market share elasticities using scanner data. They find that overreaction effects occur more frequently than underreaction effects. However, the reaction function approach does not provide insight into the underlying reasons for the observed reactions because the reactions are not based on primitives of demand and cost characteristics facing firms and the nature of the equilibrium between firms. To examine the underlying reasons for the observed reactions, Keil, Reibstein and Wittink (2001) experimentally manipulate the formulation of objectives and the time horizon of evaluations to determine the effects of time horizon and objectives on managers' decision and brand performance. They find that managers who are evaluated on a longer time horizon display less intensive reactions to competitive moves. They also find that profit maximization objectives tend to result in a lessen intensity of competitive reactions.

An alternative structural modeling framework to examine competitive interactions is a "New Empirical Industrial Organization (NEIO)" model. The NEIO methodology use three common approach to model competitive interactions: (1) the menu approach, (2) the conjectural variation approach and (3) the conduct parameter approach (see Kadiyali, Sudhir and Rao, 2001 for differences among them). The menu approach derives the first-order conditions under different equilibrium interactions among firms such as Bertrand, Stackelberg, and Collusive and then performs a goodness of fit test to select the best-fitting one (Roy, Hanssens and Raju 1994; Kadiyali, Vilcassim and Chintagunta 1996). In the Conjectural Variations approach, firms are postulated to have conjectures about how competitors will react to changes in their marketing mix and incorporate these conjectures into their decisions (Putsis and Dhar 1999; Vilcassim, Kadiyali and Chintagunta 1999). The conduct parameter approach measures the "conduct parameters" which are enable us to identify the nature of channel interactions between manufacturers and retailers (Kadiyali, Chintagunta and Vilcassim 2000; Sudhir 2001a). In the approach, we can measure cooperative or aggressive behavior by the degree of deviation from Bertrand-Nash equlibrium. Although NEIO approaches provide the understanding of firms' competitive interactions within a particular industry, there are identification problems in some empirical applications by assuming nonstrategic fixed mark-up on manufacturer wholesale prices (Cotterill et al. 2001). Kadiyali, Vilcassim and Chintagunta (1996, 1999), for example, assume that retailers charge a constant margin. This assumption implies that retailers are non-strategic and charge an exogeneous constant margin. In addition, price-cost margins are also estimated from the data. Besanko, Gupta and Jain (1998) estimate a linear function of production cost factors while Sudhir (2001a) estimates a log-linear function of production cost factors. Both alternatives could result in serious errors in market structure estimation (Bresnahan 1989). In fact, Cotterill et al. (2001) find that models specifying proportional mark-up behavior by retailers do not accurately reflect market reality in data for six individual categories.

4.1.1 Vertical Strategic Interaction (VSI) and Horizontal Strategic Interaction (HSI)

Both the menu and conduct parameter approaches are used to analyze different types of competitive interactions in a channel of distribution. Two important types of competitive interactions are (1) the vertical strategic interaction (VSI) between manufacturers and retailer and (2) the horizontal strategic interaction (HSI) between manufacturers or retailers. There has been substantial empirical research on pricing behavior among manufacturers (HSI) using the NEIO approach (Roy, Hanssens and Raju 1994; Kadiyali 1996; Kadiyali, Vilcassim and Chintagunta 1996 and 1999). Further, some researches test only the strategic interactions between manufacturer and retailer (VSI) (Besanko, Gupta and Jain 1998; Cotterill and Putsis 2000).

For the vertical relationship, past research distinguished among three different forms of strategic interactions: vertical strategic complementarity (VSC), vertical strategic substitutability (VSS), and vertical strategic independence (VSI). Lee and Staelin (1997), for example, demonstrate that three types of vertical strategic interactions represent a key driving force for optimal decisions on channel price leadership. They refer to the situation where one channel member finds it best to move in the same direction as the other channel member (i.e., $\partial m/\partial w$ and $\partial w/\partial m > 0$) for a fixed demand function, as vertical strategic complementarity (VSC). This means that the best reply functions slope up. The case where the optimal response is in the opposite direction (i.e., $\partial m/\partial w$ and $\partial w/\partial m < 0$) they refer to as vertical strategic substitutability (VSS). The best reply functions of vertical strategic substitutability (VSS) slope down. The case where it is optimal not to respond to the other channel member's margin change (i.e., $\partial m/\partial w$ and $\partial w/\partial m = 0$) they refer to as vertical strategic independence (VSI).

In this essay, I examine the three types of strategic interactions among competitors to understand the competitive pricing behavior. In a static game, I assume that both manufacturer-to-manufacturer interactions (i.e., $\partial w_1/\partial w_2$ and $\partial w_2/\partial w_1 = 0$) and retailer's interactions across products (i.e., $\partial m_1/\partial m_2$ and $\partial m_2/\partial m_1 = 0$) are Bertrand-Nash (Kadiyali, Chintagunta and Vilcassim 2000). In a dynamic game, however, I do not assume that both manufacturer-to-manufacturer interactions across periods (i.e., $\partial w_{1,t}/\partial w_{2,t-1}$ and $\partial w_{2,t}/\partial w_{1,t-1} \neq 0$) and retailer's interactions across products and periods (i.e., $\partial m_{1,t}/\partial m_{2,t-1}$ and $\partial m_{2,t}/\partial m_{1,t-1} \neq 0$) are Bertrand-Nash. I refer to those interactions as horizontal strategic interactions. Given a demand function, I can obtain optimal pricing rules for manufacturers and the retailer. In determining their optimal prices, manufacturers and the retailer account for how all the players in the channel choose their optimal prices. That is, I account for dependencies in decision making across channel members. These dependencies are characterized by a set of "conduct parameters" which enable us to identify the nature of channel interactions between manufacturers and the retailer described above (Kadiyali, Chintagunta and Vilcassim 2000). I apply these ideas in experimental settings involving multiple rounds to analyze vertical strategic interactions among channel members in different levels of a distribution channel and horizontal strategic interactions between firms in the same level of a distribution channel.

4.1.2 Retail Pass-Through

Recently, there is an emerging literature on retail "pass-through" to examine an aspect of competitive interactions between manufacturers and retailers (Chevalier and Curhan 1976;Blattberg and Levin 1987; Armstrong 1991; Lal and Villas-Boas 1998; Tyagi 1999; Bensanko, Dranove and Shanley 2001; Besanko, Dube and Gupta 2001; Kumar, Rajiv and Jeuland 2001; Moorthy 2001). The term "pass-through" is defined as the ratio of retail price reduction to the manufacturer price reduction, or the percentage of trade deal that is given to the consumers. This refers to how much of the wholesale price discount is passed on to consumers.

A stream of the pass-through research is based on self-reported retailer behavior (Chevalier and Curhan 1976; Armstrong 1991). While Chevalier and

Curhan (1976) find pass-through rate ranging from 0 to 211%, Armstrong (1991) finds pass-through rates for four categories that range from 143 to 285%.

Much of the literature reports results in terms of pass-through rates ($\frac{\partial Price}{\partial Cost} \times 100\%$) (Tyagi 1999; Kumar, Rajiv and Jeuland 2001; Moorthy 2001), while others result in terms of pass-through elasticities which are defined as the rate of percentage change in a firm's price relative to its competitors with respect to a percentage change in its marginal cost relative to competitors ($\frac{\%\Delta Price^{relative}}{\%\Delta MC^{relative}t} = \frac{\%\Delta P - \%\Delta \bar{P}}{\%\Delta MC^{relative}t}$) (Bensanko, Dranove and Shanley 2001; Besanko, Dube and Gupta 2001). Tyagi (1999) finds that the pass-through in a single manufacturer and a single retailer channel depends on the curvature of consumer demand functions. In particular, whereas the linear and all concave consumer demand functions lead to less than 100% optimal retail pass-through rates, a subset of convex consumer demand functions lead to greater than 100% optimal retail pass-through rates. Kumar, Rajiv and Jeuland (2001) examine the roles of search costs, and trade promotion depth and frequency on pass-through incentives in a stylized channel with a single manufacturer that two customer segments through a single retailer. They find that the extent of retail opportunism depends on product-market characteristics such as the retailer's clientele and the heterogeneity in consumer search costs as well as on the characteristics of manufacturer's trade promotion policy. Moorthy (2001) extends Tyagi's analysis of the pass-through to a multiple-product context focusing on both intrabrand competition (competition among retailers on a given brand) and interbrand competition (competition among manufacturers at a given retailer). He finds that the pass-through rate depends not only on the curvature of the demand function but also on the intensities of intraband and interbrand competition. In particular, he finds that a trade promotion on one product induces a retail price reduction of that brand, but a retail price increase a competing product. Bensanko, Dranove and Shanley (2001) examine an empirical investigation of how market and firm characteristics affect the extent to which a firm's relative price changes when it experiences a change in its cost position relative to competitors. They find that a firm's pass-through elasticity systematically depends on whether the firm operates in a commodity or noncommodity industry, the firm's capacity utilization, and its cost and quality position in its industry. They also find that firms in differentiated product industries have significantly greater pass-through elasticities than firms in commodity industries. In addition, in differentiated product industries, the pass-through elasticity is smaller the greater the firm's capacity utilization. Besanko, Dube and Gupta (2001) investigate the determinants of retail pass-through using a reduced-form econometric model. They find that a positive own pass-through elasticity and higher pass-through rates for larger share brands. They also find that cross pass-through elasticities are significant, and are both positive and negative across product-pairs.

In sum, the present essay examines the direction and magnitude of a firm's reactions to the marketing actions of its competitors in marketing channels using market laboratory experiments: (1) a single manufacturer and a single retailer channel, (2) two manufacturers interacting with a common retailer channel. Toward this, I use the price data from Essay 1 and Messinger and Chen (2000), which consist a single manufacturer and a single retailer. In Messinger and Chen (2000)'s experiment, I investigate the competitive pricing behavior between manufacturer and retailer (VSI) in a single manufacturer and a single retailer channel. In the experiment of Essay 1, I extend Messinger and Chen (2000)'s results to channel structure that consists of two manufacturers and a common retailer. I therefore consider competitive interactions between manufacturer and retailer (VSI) as well as between manufacturers (HSI). In particular, I study the roles of three important variables that I consider in experiments on pass-through incentives to examine the vertical strategic interactions (VSI). In addition, I investigate both own pass-through rates and cross pass-through rates. I also consider the interbrand competition in a channel with a single retailer selling two brands from two different manufacturers.

4.2 The Model

I consider two marketing channels to estimate competitive pricing behavior among channel members: (1) a single-manufacturer / single-retailer bilateral monopoly channel, (2) two-manufacturer / a common retailer channel.

4.2.1 A Single-Manufacturer / Single-Retailer Bilateral Monopoly Channel

Messinger and Chen (2000) have conducted an experiment in the context of a simple channel consisting a single manufacturer and a single retailer. Since I estimate competitive interactions on pricing between a manufacturer and a retailer, I focus only on the vertical strategic interaction.

One way to analyze the competitive pricing behavior is to examine the dependencies in decision-making between manufacturer and retailer, as in the following two questions,

$$\Delta w_t = a_1 + b_1 * \Delta w_{t-1} + c_1 * \Delta m_{t-1} \tag{4.1}$$

$$\Delta m_t = a_2 + b_2 * \Delta w_t + c_2 * \Delta m_{t-1} \tag{4.2}$$,

where w_t is manufacturer's wholesale price and m_t is retailer's margin at time period t, respectively.

Since the manufacturer must declare his/her wholesale price before the retailer does in the experiment, the most recent information that the manufacturer has, in period t, about the retailer's change in margin would be by comparing the value in period t-2 to that in period t-1. In equation (4.1), therefore, lags in two terms, which represent the change of the both wholesale price and retail margin, would appear to be necessary. In equation (4.2), however, there is no lag to capture the change of the wholesale price in each period because the retailer knows the wholesale price before the retailer chooses his/her retail margin of the period. In these equations, b_1, and c_2 represent the dependence of a person's change in a period on his/her change in last period; c_1 indicates manufacturer's reactions to an action of retailer, that is the Upstream Vertical Strategic Interaction (VSI); b_2 represent retailer's reaction to an action of manufacturer, that is Downstream Vertical Strategic Interaction (VSI). It also indicates the own pass-through rate.

4.2.2 Two-Manufacturer / A Common Retailer Channel

In Experiment 1, I extend Messinger and Chen (2000)'s experiment by considering more complex channel that consists of two manufacturers and a common retailer. I estimate competitive interactions on pricing between manufacturer and retailer as well as between two manufacturers under various market conditions. I therefore consider both the vertical strategic interaction (VSI) and horizontal strategic interaction (HSI). In particular, I estimate both the own retail pass-through and the cross retail pass-through.

I analyze the competitive pricing behavior by examining the dependencies in decision making across channel members, in the following four equations,

$$\Delta w_{1,t} = a_1 + b_1 * \Delta w_{1,t-1} + c_1 * \Delta w_{2,t-1} + d_1 * \Delta m_{1,t-1} + e_1 * \Delta m_{2,t-1} \quad (4.3)$$

$$\Delta w_{2,t} = a_2 + b_2 * \Delta w_{1,t-1} + c_2 * \Delta w_{2,t-1} + d_2 * \Delta m_{1,t-1} + e_2 * \Delta m_{2,t-1} \quad (4.4)$$

$$\Delta m_{1,t} = a_3 + b_3 * \Delta w_{1,t} + c_3 * \Delta w_{2,t} + d_3 * \Delta m_{1,t-1} + e_3 * \Delta m_{2,t-1} \quad (4.5)$$

$$\Delta m_{2,t} = a_4 + b_4 * \Delta w_{1,t} + c_4 * \Delta w_{2,t} + d_4 * \Delta m_{1,t-1} + e_4 * \Delta m_{2,t-1} \quad (4.6).$$

Since each manufacturer not only sets his/her wholesale price simultaneously without knowledge of the other's current decision and but also must declare his/her price before the retailer does in the experiment, the most recent information that a manufacturer has, in period t, about the other player's change in wholesale price and margins would be by comparing these values in period t-2 to those in period t-1. In equation (4.3) and (4.4), therefore, lags in all terms would appear to be necessary. In equation (4.5) and (4.6), however, there are no lags in terms of wholesale price change because manufacturers set their wholesale prices before the retailer does. By doing this, this representation is consistent with the idea that reactions occur in the form of changes from previous conditions (Leeflang and Wittink 1996).

In these equations, b_1, c_2, d_3, and e_4 represent the dependence of a person's change in a period on his/her change in last period; b_2 and c_1 represent manufacturers' reactions to the competing manufacturer. Those also indicate the Horizontal Strategic Interaction (HSI); d_1, d_2, e_1, and e_2 represent manufacturers' reactions to an action of retailer for the two product. Those indicate the Upstream Vertical Strategic Interaction (VSI); b_3, b_4, c_3, and c_4 represent retailer's reaction to an action of each manufacturer. Those indicate Downstream Vertical Strategic Interaction (VSI). In equation (4.5) and (4.6), especially, b_3 and c_4 represent the own pass-through rate, while b_4 and c_3 indicate the cross pass-through rate.

4.3 Messinger and Chen (2000)'s Experiment

The overall tasks and procedures were similar to the task in Experiment 1 except for the number of players (See Messinger and Chen (2000) for details of the experiment).

4.3.1 Subjects

Ninety-four undergraduate business and mostly MBA students at two North American universities participated in this experiment. Subjects were recruited through advertisements and class announcements. They were paid a token of $5 for participation as well as a monetary reward contingent on performance.

4.3.2 Experimental Design

They conduct two treatment conditions that depend on whether the players know each other's cost and profit (see Table 4.1).

Table 4.1 Experimental Design

Treatment Condition	Description	Responses
Incomplete Information	No Competitor Cost and Profit Information	25
Full Information	Players Know Competitor's Cost and Profit	22

4.3.2.1 Incomplete Information Treatment

In many competitive situations, there may be incomplete information about demand and cost conditions as well as competitors' profits. Since I was concerned that manufacturers and retailers in actual channels may not know each other's costs and profits, I became interested in knowing the extent to which channel interaction in the presence of incomplete cost and profit information would differ from the full information case. I therefore considered a treatment in which the players do not know the cost and profits of the opponent. In particular, the manufacturer knows his cost c_m as well as his own profit and the retailer knows her cost c_r as well as her own profits. The game starts with no history of previous play. After Round 1, the results of Round 1 only are shown; further results are displayed as the game proceeds, until after Round 5, the screen show the most recent five rounds of play.

4.3.2.2 Full Information Treatment

I call this a full information treatment because each player is told both his/her own cost and profits and the cost and profits of the other player. The manufacturer knows the retailer's handling cost and profits. The retailer knows the manufacturer's production cost and profits. With this information, each player can readily compare his/her unit price with that of the other player.

4.4 Results

4.4.1 A Single-Manufacturer / Single-Retailer Bilateral Monopoly Channel

Table 4.2 shows competitive pricing behaviors between manufacturer and retailer as follow.[40]

First, all coefficients that represent the dependence of a person's change in period t on his/her change in period t-1 across treatment are negative and significant. This indicates that the players negatively respond to changes in own actions last period. In addition, I find that the dependence of a person's change in a period on his/her own change in last period (diagonal coefficients in the last two columns in table 4.2) is higher than that on the partners' changes in last period (off-diagonal coefficients in the last two columns in table 4.2).

Table 4.2. Model Estimates (Strategic Interactions)
(Standard Errors in Parentheses)

		intercept	b_i	c_i
Treatment 1	Δw_t	0.011	**-0.139***	0.026
		(0.069)	(0.039)	(0.023)
(Incomplete	Δm_t	-0.105	**0.256***	**-0.300***
Information)		(0.109)	(0.062)	(0.036)
Treatment 2	Δw_t	0.052	**-0.239***	0.034
		(0.064)	(0.040)	(0.026)
(Full	Δm_t	0.016	**0.280***	**-0.377***
Information)		(0.090)	(0.056)	(0.036)

[40] The percentages of the case of zero change in dependent variables (Δw_t and Δm_t), which indicates no response to the other channel member's margin change, ranged between 15.2% and 18.2%.

Second, the retailer positively reacts to an action of the manufacturer for the product, regardless of market information level (0.256 for the incomplete information condition; 0.280 for the full information condition, respectively). That is, retail pass-through rates of both treatment conditions are significant. This means that a decrease in the wholesale price results in a decrease in the retail margin. It indicates that the retailer pricing exhibits properties of a downstream vertical strategic complementarity (VSC).

So far, I have estimated the competitive pricing behavior for each channel member by regressing the margin changes for the manufacturer (or retailer) in period t on the margin changes for the two channel members one period lagged. This approach is consistent with Leeflang and Wittink (1996)'s idea that competitive reactions occur in the form of changes from previous conditions, and adaptive response behavior that the behavior of subjects is significantly influenced by the results of their decision in the most recent iteration of the game (Zwick and Rapoport 1999). Nevertheless, this approach raises the question of how players respond to price changes in the long run. To help understand this, I examine competitive pricing behavior by considering one more lag as shown below:

$$\Delta w_t = a_1 + b_1 * \Delta w_{t-1} + c_1 * \Delta w_{t-2} + d_1 * \Delta m_{t-1} + e_1 * \Delta m_{t-2} \quad (4.7)$$

$$\Delta m_t = a_2 + b_2 * \Delta w_t + c_2 * \Delta w_{t-1} + d_2 * \Delta m_{t-1} + e_2 * \Delta m_{t-2} \quad (4.8).$$

Table 4.3 represents the model estimates for the Full Information condition (Treatment 2). The results show a very similar competitive pricing pattern with the one period lag case, suggesting that adding more lags does not significantly provide better explanation for competitive pricing behavior. One interesting result is that the changes in retail margins are significantly effected by its own one period and two period lagged margin changes.

Table 4.3. Model Estimates (Two Period Lags)
(Standard Errors in Parentheses)

		intercept	b_i	c_i	d_i	e_i
Full Information	Δw_t	0.068 (0.062)	**-0.229*** (0.041)	-.059 (.040)	0.021 (0.027)	-.022 (.028)
(Treatment 2)	Δm_t	0.055 (0.089)	**0.270*** (0.056)	-.020 (.049)	**-0.445*** (0.040)	**-.239*** (.041)

4.4.2 Two-Manufacturer / A Common Retailer Channel

Table 4.4 (shown on page 140) represents competitive pricing behaviors and pass-through.[41] This table suggests the following conclusions.

First, all coefficients which represent the dependence of a person's change in period t on his/her change in period t-1 across treatment are negative and significant except for b_1 of the equation (4.3) in Treatment 5. This indicates that the players negatively respond to changes in own actions last period.

[41] The percentages of the case of zero change in the dependent variables ranged between 14.0% and 30.9%. Such high percentages are relatively common in this type of research (see footnote 36). This suggests that in future research it would be desirable to compare the regression results with more complex models that treated cases with no change in the dependent variable differently than the cases with changes in the dependent variable.

Table 4.4. Estimates of Strategic Interactions
(Standard Errors in Parentheses)

		Intercept	b_i	c_i	d_i	e_i
Treatment Condition 1	Δw_1	0.09631	**-0.167***	**0.134***	**-0.127***	0.05134
		(0.126)	*(0.039)*	*(0.030)*	*(0.034)*	*(0.032)*
Incomplete	Δw_2	0.04937	-0.00681	**-0.349***	0.08329	-0.07318
Information		*(0.175)*	*(0.054)*	*(0.041)*	*(0.046)*	*(0.045)*
Cm1=Cm2	Δm_1	0.114	**0.290***	0.02972	**-0.240***	0.02436
γ=75		*(0.167)*	*(0.055)*	*(0.039)*	*(0.044)*	*(0.039)*
	Δm_2	0.03895	0.05006	**-0.253***	0.0683	**-0.364***
		(0.159)	*(0.052)*	*(0.037)*	*(0.042)*	*(0.038)*
Treatment Condition 2	Δw_1	0.02801	**-0.177***	**0.08114***	**-0.07513***	0.0455
		(0.123)	*(0.039)*	*(0.038)*	*(0.032)*	*(0.025)*
Complete	Δw_2	-0.0221	**0.09613***	**-0.276***	0.03256	-0.02097
Information		*(0.130)*	*(0.041)*	*(0.041)*	*(0.034)*	*(0.027)*
Cm1=Cm2	Δm_1	0.283	-0.01951	**0.138***	**-0.243***	0.03359
γ=75		*(0.176)*	*(0.061)*	*(0.056)*	*(0.046)*	*(0.034)*
	Δm_2	0.164	0.02016	0.104	-0.09495	**-0.298***
		(0.215)	*(0.075)*	*(0.070)*	*(0.056)*	*(0.042)*
Treatment Condition 3	Δw_1	0.04802	**-0.389***	0.02103	-0.04852	0.013
		(0.136)	*(0.039)*	*(0.039)*	*(0.036)*	*(0.037)*
Complete	Δw_2	0.09301	0.07071	**-0.260***	0.02307	**-0.08738***
Information		*(0.138)*	*(0.040)*	*(0.040)*	*(0.036)*	*(0.038)*
Cm1>Cm2	Δm_1	0.163	**0.105***	0.08099	**-0.360***	0.06049
γ=75		*(0.168)*	*(0.049)*	*(0.05)*	*(0.044)*	*(0.046)*
	Δm_2	0.0856	0.08529	0.07047	0.04843	**-0.425***
		(0.146)	*(0.044)*	*(0.043)*	*(0.039)*	*(0.040)*
Treatment Condition 4	Δw_1	0.01039	**-0.293***	**0.382***	**0.06115***	**-0.0764***
		(0.490)	*(0.040)*	*(0.054)*	*(0.029)*	*(0.025)*
Complete	Δw_2	0.237	-0.03439	**-0.392***	0.01152	**0.06293***
Information		*(0.364)*	*(0.029)*	*(0.040)*	*(0.022)*	*(0.019)*
Cm1=Cm2	Δm_1	1.629	**0.619***	0.113	**-0.292***	**0.177***
γ=200		*(0.727)*	*(0.058)*	*(0.079)*	*(0.038)*	*(0.038)*
	Δm_2	**1.972***	**0.345***	**0.431***	**0.0936***	**-0.378***
		(0.789)	*(0.063)*	*(0.087)*	*(0.042)*	*(0.042)*
Treatment Condition 5	Δw_1	0.188	-0.0379	**0.115***	0.005338	**0.07785***
		(0.423)	*(0.043)*	*(0.047)*	*(0.031)*	*(0.033)*
Complete	Δw_2	0.610	**0.126***	**-0.256***	-0.03355	-0.0557
Information		*(0.412)*	*(0.041)*	*(0.045)*	*(0.030)*	*(0.031)*
Cm1>Cm2	Δm_1	**1.659***	**0.251***	-0.03171	**-0.398***	0.08691
γ=200		*(0.615)*	*(0.062)*	*(0.061)*	*(0.044)*	*(0.048)*
	Δm_2	**1.337***	**0.153***	**0.236***	**0.176***	**-0.358***
		(0.610)	*(0.062)*	*(0.061)*	*(0.044)*	*(0.048)*

In addition, in the most cases, I find that the dependence of a person's change in period t on his/her own change in period t-1 (diagonal coefficients in the last four columns in table 4.3) is higher than that on the partners' change in period t-1 (off-diagonal coefficients in the last four columns in table 6). I also see that manufacturer 1 (2)'s reaction is more sensitive to the retailer's pricing behavior for product 1 (2) than that for product 2 (1), and the retailer's reaction in setting the retail price for product 1 (2) is more sensitive to the manufacturer 1 (2)'s pricing behavior than manufacturer 2 (1)'s behavior. I therefore conclude that each player's reaction is more sensitive to a partner within a channel than across channel. In other words, the vertical competitive reaction effect of intrabrand is higher than that of interbrand.

Furthermore, I see own pass-through rates are higher than cross pass-through rates. It means that a trade promotion on one product induces a higher retail price reduction of that brand than that on competing product. In particular, all own pass-through rates are positive except for product 2 in Treatment 1. It is consistent with profit-maximizing retailer behavior, thus the results have strong face validity (Besanko, Dube and Gupta 2001).

Second, the manufacturer interacts with the competing manufacturer with positive coefficients in setting the wholesale price in most cases. For example, while manufacturer 1 positively interacts with manufacturer 2 in setting the wholesale price in Treatment 1 (0.134) and 4 (0.382), both manufacturers positively interact with the other manufacturer in Treatment 2 and 5 (0.081 and

0.096 for Treatment 2; 0.115 and 0.126 for Treatment 5, respectively). That is, an increase in w_2 results in an increase in w_1, and vise versa in Treatment 2 and 5. This indicates that wholesale prices are horizontal strategic complements (HSC) (Choi 1991).

Third, manufacturers negatively react to an action of the retailer for their own products in the highly differentiated market conditions (-0.127, -0.075, and –0.087 for Treatment 1, 2, and 3, respectively). This means that an increase in the retail margin results in a decrease in the wholesale price. It indicates that manufacturer pricing exhibits properties of an upstream vertical strategic substitutability (VSS) in the highly differentiated market. By contrast, manufacturers behave to retailer in setting the wholesale price as if interaction is an upstream vertical strategic complementarity (VSC) in the less differentiated market conditions (0.061 and 0.063 for Treatment 4; 0.078 for Treatment 5, respectively). In Treatment 4, particularly, manufacturers positively react to an action of the retailer for their own product.

In addition, I see that all vertical cross-competitive reaction effects are insignificant except for c_3 of Treatment 2 in the highly differentiated market conditions, whereas some are significant in the less differentiated market conditions. It indicates that players less sensitive to the price change of the competing brand, as products are less substitutable.

Fourth, under the incomplete information condition (Treatment 1), the retailer reacts to manufacturer 1 in setting the retail price for product 1 in such a way that the interaction is a downstream vertical strategic complementarity (0.290; VSC), whereas the retailer reacts to manufacturer 2 in setting the retail price for product 2 in such a way that the interaction is a downstream vertical strategic substitutability (-0.253; VSS). Since players do not know each other's cost and profit information in this Treatment condition, only the own retail pass-through rate is significant. It is interesting to note the negative pass-through of product 2, suggesting that the retailer's pricing behavior under the incomplete information may be different from his/her behavior under the full information condition.

Fifth, in Treatment 2, retailer reacts to manufacturer 2 in setting the retail price for product 1 as if the interaction is a downstream vertical strategic complementarity (0.138; VSC). It refers to the cross pass-through rate of product 1. In Treatment 3, only the own pass-through for the high production cost product (product 1) is significant. That is, the retailer reacts to manufacturer 1 in setting the retail price for product 1 as if the interaction is a downstream vertical strategic complementarity (0.105; VSC).

Sixth, in the less differentiated market conditions (Treatment 4 and 5), own pass-through rates for the two products are significant. In addition, cross pass-through rates for the product 2 are significant. All significant coefficients are positive, implying that the retailer reacts to manufacturer in setting the retail price for the product as if the interaction is a downstream vertical strategic complementarity (VSC). In addition, I confirm that the retailer's optimal reaction for product 2 is more sensitive to a change in the wholesale price 2 (0.431 for Treatment 4; 0.236 for Treatment 5, respectively) than that in the wholesale price 1 (0.345 for Treatment 4; 0.153 for Treatment 5, respectively).

Seventh, in full information conditions, retailers in less differentiated product conditions (Treatment 4 and 5) have significantly greater own and cross pass-through rates than retailers in highly differentiated product conditions (Treatment 2 and 3). Unlike the intuition, Jeuland and Shugan (1988) and Choi (1991) show that both wholesale and retail prices increase as products are less differentiated under the linear demand function. Choi and Messinger (2002) confirm the result from their experimental data. Since channel profits were significantly higher in the high degree of substitutability condition (Treatment 4 and 5) versus the low degree of substitutability condition (Treatment 2 and 3) in these experiments (See Choi and Messinger (2002) for details), relative marginal costs of less differentiated products to their retail prices are significantly lower than those of highly differentiated products. Consequently, the lower relative marginal costs to their retail prices, the higher will be their pass-through rates. This finding is consistent with the theoretical model of Moorthy (2001) that predicts the own and cross pass through rate decrease as interbrand differentiation increase.

Overall, I conclude that wholesale prices are horizontal strategic complements. I also find that the manufacturer pricing exhibits properties of an upstream vertical strategic substitutability at lower degree of substitutability, whereas the manufacturer pricing exhibits properties of an upstraem vertical strategic complementarity at higher degree of substitutability. I show that a trade promotion on one product induces a higher retail price reduction of that brand than that on competing product. In addition, the retailer pricing exhibits properties of a downstream vertical strategic complementarity in most cases due to the absence of retail competition. I also see that each player reaction is more sensitive to a partner within a channel than across a channel. Finally, retailers in less differentiated product conditions (Treatment 4 and 5) have significantly greater pass-through rates than retailers in highly differentiated product conditions (Treatment 2 and 3).

4.5 Discussion and Conclusions

This essay describes two experiments testing competitive pricing behaviors among channel members in the context of wholesale price/retail margin setting in marketing channels. I find that the players negatively respond to changes in own actions last period. In addition, I find that the dependability of a person's change in a period on his/her own change in last period is higher than that on the partners' changes in last period.

I find that manufacturers positively react to competing manufacturer's actions. That is, an increase in w_2 results in an increase in w_1, and vise versa.

This indicates that wholesale prices are horizontal strategic complements. I also find that the manufacturer pricing exhibits properties of an upstream vertical strategic substitutability in a highly differentiated market, whereas manufacturer pricing exhibits properties of an upstream vertical strategic complementarity in a less differentiated market in the two manufacturers / a common retailer channel model. In addition, the retailer pricing exhibits properties of a downstream vertical strategic complementarity for both channel structures. I also find that the vertical competitive reaction effect of intrabrand is higher than that of interbrand in the second channel model.

I find the impact of the production cost on the competitive pricing behaviors. That is, manufacturer's production cost has an impact on the manufacturer's competitive reaction, whereas it has an impact on the retailer's competitive reaction only when products are more differentiated.

Retailers' pass-through of cost changes induced by trade promotions is a crucial determinant of the profitability of trade deals (Besanko, Dube and Gupta 2001). Previous empirical work in marketing has provided estimates of pass-through rates largely based on self-reports by retailers or econometric approaches in certain product categories. I examine the impact of market characteristics on pass-through. This essay shows that retailers in less differentiated product conditions have significantly greater own and cross pass-through rates than retailers in highly differentiated product. This finding helps explain the expectation in Moorthy (2001), which pass-through rate increases with the intensity of interbrand competition.

There are at least two managerial implications of these results. First, since the estimates are policy invariant, management will benefit from performing a variety of "what if" analyses before new marketing activities are initiated or reactions are undertaken. That is, it is useful to estimate the impact on competitors' businesses and contemplate likely competitive reactions. Second, cross pass-through rates are significantly greater in less differentiated markets than in moderately differentiated markets. This implies that price promotions have the unexpected consequence that not only the target products' but also competing products' retail prices are changed in response to a promotion. This finding has important consequences for manufacturers' price promotion planning.

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Chapter 5

General Discussion and Conclusions

Given the growth of experimental approach to modify and test economic and marketing predictions, it is important to study marketers' strategic activities predicted from theoretical marketing models. This thesis tested theoretical models of price competition among competitors in various market structures, so that the primary contribution of the thesis is to add to the experimental work on price competition. In particular, from a theoretic perspective, most existing game theoretic models of competition are one-shot games, whereas institutional applications are repeated situations. Thus, I examined whether the predicted outcomes hold up in more realistic repeated contexts and whether human cognitive and instinctual reactions match with theoretic predictions.

Every methodology has strengths and weaknesses, and the use of student subjects is a limitation of this research. In fact, one common criticism leveled at laboratory experiments is that the behavior of the typical experimental subject (students) is likely to be quite different from that of mature agents with field experience. Essentially this criticism speaks to the issue of external validity. Although experiments with experienced subjects from the industry are logistically more difficult to carry out, I think it would be desirable for future experimental research to include experienced industry subjects. To assess external validity more directly, I think it would also be desirable to test game-theoretic competitive models at the market level using the New Empirical Industrial Organization (NEIO) approach.

Overall, the work in this thesis makes the following contributions.

The first essay of the thesis gives experimental evidence to an "open question" of which model structure is most applicable. To investigate this issue, I tested the applicability of competing possible channel models in the context of Choi's (1991) model of a channel consisting of two manufacturers and a common retailer: Manufacturer Stackelberg leadership, Retailer Stackelberg leadership, Vertical Nash, or channel coordination. By investigating deviations of individual pricing behavior from optimal reactions, the first essay also provided a plausible explanation to better understand the behavioral reasons for the observed market outcomes. A direction for future research is a test of a more general model that includes other marketing variables such as advertising, promotions, quantity discounts, and store brands.

The second essay explains to what extent the actual behavior of financially motivated subjects conforms to the mixed-strategy predictions. Toward this objective, I experimentally tested a model of Narasimhan (1988) which predicts competitive price promotional strategies between two competing firms. In particular, I compared a symmetric structure with two asymmetric structures to test the boundary conditions of when firms randomize as hypothesized by theory (Varian 1980, Narasimhan 1988). I also compared the case of no communication with the case in which players are allowed to "chat" as they play to examine whether a "chat" condition that allows communication between competitors facilitates cooperation. Although the second essay provides experimental support for a particular loyal/switcher price promotion model, many questions are left open. Natural extensions could involve experimental examination of related models concerning such factors as pricing to different segments with lock-in, competition between store and national brands, trade deals to multi-product retail channels (e.g., Lal and Villas-Boas 1998), co-location at Internet malls, and selling in markets with infomediaries. More generally, in competitive contexts involving marketing variables such as price, advertising, and distribution, it will be important to better understand how managers deal with complexity, lack of fairness, learning effects, and sharing of information.

The final essay contributes on identifying the nature of competitive interactions on pricing among firms. To understand the pricing behavior in competitive markets, I examined the direction and magnitude of a firm's reactions to the marketing actions of its competitors in marketing channels using market laboratory experiments: (1) a single manufacturer and a single retailer channel, (2) two manufacturers interacting with a common retailer channel. There are numerous opportunities to do other experimental manipulations and to examine other marketing variables. Since I stressed that the experiment involves simple channel structures considering only one strategic variable-price, I did not include forwarding buying that the extent of retail pass-through is likely to be vastly overstated. With a more general model that includes other marketing mix variables such as inventory, quantity discount, and advertising, I can provide insight into the impact of forwarding buying and advertising on interrelationships among channel members. I also look forward to extensions of this type of experiment to include such important factors as multiple retailers, store brand products, two-way communication, and bargaining.

In conclusion, I believe that experimental tests of competitive models can serve to help bridge the gap between theoretical research concerning competitive behavior and social psychological research examining human behavior and, thereby, provide a means of assessing game theoretic models in a way that is complementary to approaches that, instead, rely on aggregate or disaggregate market data.

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