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# An Application of Game Theory to Supermarket Pricing

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Game theory is a field of study that focuses on human interactions within specified rules of play and alternative choices. Its language includes concepts such as coalitions, markets, payoffs, and votes—concepts that permeate our everyday lives and help shape our “real world” experiences. Yet the mathematical rigor of game theory, together with its many solution notions, has limited its appeal to mainstream economists and caused some critics to question the ability of game theory to identify a solution notion that “truly” describes human behavior (Aumann 1985; Goeree and Holt 2001). Indeed, one of these solution notions is a Nash equilibrium, a payoff point in which firms reach and maintain their position. This position can be illustrated by deriving a series of mathematical equations and proofs, or it can be demonstrated with a model structure known as the normal or strategic form. This paper will employ the latter approach to derive a game-theoretic framework that captures the basic structure of the U.S. supermarket industry and then illustrate observed behavior for supermarket chains within this industry. First, a discussion of the supermarket industry is provided to help focus this discussion.

## Perspectives on Two Types of Supermarkets

An acceptable classification system for the retail supermarket industry has evolved consisting of two types of firms pursuing different pricing strategies: Everyday Low Pricing (EDLP) and High-Low Pricing (HLP). A fair amount of literature has been developed on these firms and much of it suggests that EDLP supermarkets enjoy lower costs and higher profit rates than do promotional or HLP supermarkets. Lal and Rao (1997) cite an *American Demographics* report showing the top five EDLP supermarket chains realized net-profit rates in 1992 ranging from 2.1% to 2.7%, whereas the top five

HLP chains had profit rates ranging from 0.5% to 2.0%. Much of the literature also suggests that an EDLP format better meets the needs of an ever-growing population of time-constrained consumers (Lal and Rao 1997; Corstjens and Corstjens 1994). As further evidence of the advantages of EDLP, some authors point to the success of chains like Wal-Mart and Home Depot (Kotler and Armstrong 2000; Ortmeyer, Quelch, and Salmon 1991). Given the identified advantages of EDLP, one would expect to see supermarkets switching from an HLP format to an EDLP format. Instead, we more frequently see EDLP chains adopting many of the attributes of HLP chains (Hoch et al. 1994). What accounts for this apparent anomaly? Should we assume that supermarket managers are irrational and unaware of the cost component of profit equations? Or should we assume that revenue gains on the demand side from an HLP format far exceed the cost savings on the supply side from an EDLP format?

It is conceivable that in an all-EDLP world consumers could realize lower food expenditures and supermarket chains could realize higher profit rates. This implicitly assumes here is that advertising and merchandising costs impact food prices and the operating costs of supermarkets (Hoch et al. 1994). However, an EDLP world cannot possibly represent an equilibrium state, since any departure from it would result in one chain gaining an advantage over another one. That is, in the absence of uniform consumer preferences and opportunity costs, a chain could adopt an HLP format and increase its sales and profits (Hoch et al. 1994; Mulhern and Leone 1990).<sup>1</sup> Moreover, such a change would place competitive pressure on all remaining chains and perhaps cause them to consider a similar format. To increase their competitiveness under this scenario, EDLP supermarket chains tend to adopt some

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<sup>1</sup> In a series of field experiments with 86 stores, Hoch et al. concluded that a 10% price increase at HLP stores leads to a 15% increase in profits; by contrast, a 10% decrease in prices at EDLP stores leads to an 18% decrease in profits. This suggests profitable opportunities for a departure from EDLP formats.

of the attributes of an HLP format. Some common features of this format include week-to-week price promotions, media advertising, and in-store advertising and merchandising. In the nomenclature of game theory, this process is best described as a non-cooperative game played among competing chains. Each chain selects its advertising, price promotions, and in-store advertising and merchandising simultaneously and independently. However, the nature of the supermarket industry is such that the chains are involved in a dynamic game of “almost perfect” information.<sup>2</sup> To operationalize this game, this paper follows an approach suggested by Aumann (1985) in which a model is developed to provide an understanding of the strategies supermarket chains engage in to increase their sales and profitability. Specifically, a framework is developed that shows consumers and retailers reaching equilibrium through a market structure of many HLP chains and a limited number of EDLP chains.<sup>3</sup>

### Model Development

Following the lead of Lal and Rao (1997), it seems reasonable to segment food shoppers into two categories: cherry pickers and time-constrained. Time-constrained consumers have been characterized as the largest segment of the American population and, assuming search costs play a major role in determining shoppers’ store selections, this population segment is likely to provide a ready clientele for EDLP supermarkets. Cherry pickers are considered to have lower opportunity costs and a strong preference for low prices. These attributes define a population segment that is likely to search between EDLP and HLP chains for the best purchases. That is, these shoppers are likely to be attracted to the everyday low prices of EDLP chains as well as to the advertised deals of HLP chains.

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<sup>2</sup> According to Tirole (1997), the games are dynamic because each chain chooses an action after observing the actions of its opponents; they are games of “almost perfect” information because each chain knows the actions of other chains for periods 1 through  $t-1$ , but simply makes simultaneous decisions at period  $t$ .

<sup>3</sup> Everyday-low-price chains are constrained by the difficulty of any two chains positioning themselves as the lowest-price alternative for a market basket of goods.

Manufacturers influence the group of products selected for advertising and promotion, but each supermarket chain combines manufacturers’ incentives with its own marketing strategies to project a favorable store image and pricing strategy to consumers (Lal and Rao 1997). Since a typical supermarket carries more than 40,000 products, search costs would prohibit a consumer from gaining complete information on pricing. Yet, with respect to HLP chains, consumers are believed to make their shopping decisions based on advertised prices and some rational expectations about unadvertised prices. Indeed, one of the competitive disadvantages of an EDLP chain is believed to be its inability to offset the highly visible pricing strategies of HLP chains. A typical EDLP store projects itself as having the lowest prices for a market basket of goods, but consumers, given limited ability to process price information across a wide array of products, will sometimes make cost comparisons among stores based on a selected set of advertised prices across a few product categories. As such, EDLP supermarkets feel competitive pressure to develop a communication mechanism for informing consumers of the cost savings on a market basket of goods. These communication costs, since they are not product and price specific, receive limited levels of compensation from food manufacturers. Indeed, this differential in promotion compensation partly explains the motivation for EDLP chains to adopt attributes of HLP chains.

A fundamental assumption of game theory is that all players are rational and intelligent (Moorthy 1985). Furthermore, each player is assumed to pursue a set of actions or strategies that leads in the long run to a point of equilibrium. At this equilibrium, no player desires to deviate from its chosen strategy. Within the supermarket industry, these strategies are played weekly among HLP chains, but less frequently and less directly among HLP and EDLP chains.<sup>4</sup> Specifically, both EDLP and HLP chains attempt to maximize their sales and profits (payoffs), but HLP chains pursue a more transparent and explicit strategy. HLP chains’ weekly strategies consist of a combination of price reductions, in-store advertising and merchandising,

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<sup>4</sup> It should be emphasized that some of the discussion in this paper is based on the author’s experience with the supermarket industry.

and media advertising. EDLP chains, by contrast, make limited use of all three strategies. EDLP chains use price reductions and in-store advertising and merchandising to stimulate sales, but such strategies are generally communicated to consumers on a monthly basis through media advertising (especially circulars or free-standing inserts). For all practical purposes, the game-theoretic framework for supermarket competition is most applicable for HLP chains, with each chain implementing strategies that are cognizant of the positioning image and prices of EDLP chains. As a matter of approach, chains are assumed to focus on sales and margins in the short run, while recognizing the contribution of each to long-run profit objectives. Specifically, chains are hypothesized to develop long-run sales and profit objectives, but then use short-run sales changes to develop their game strategies.

Strategies utilized in a supermarket game are

shown in Table 1; these strategies consist of a combination of price reductions, in-store advertising and merchandising, and media advertising. In the nomenclature of game theory, this table represents the normal or strategic form of a game.<sup>5</sup> Critical elements of this form of the game are the players of the game, the strategies available to each player, the payoff received by each player for each combination of strategies that could be chosen by the players. As illustrated here, strategies  $\alpha_i$ ,  $\delta_i$ , or  $\gamma_i$  are available to Player i and  $\alpha_j$ ,  $\delta_j$ , or  $\gamma_j$  are available to Player j. These promotional strategies can be set

<sup>5</sup> Strictly speaking, a normal form of a game shows the strategies available to each player along the top and left side of the bi-matrix and the payoffs in each cell. This matrix is modified slightly to show varying levels of the strategies in each cell. A precise form of a normal form game is shown within the bi-matrix in Table 2.

**Table 1. A Modified Illustration of a Normal-form Game.\***

		Player j		
		Price Reduction ( $\alpha_j$ )	In-Store Advertising/ Merchandising ( $\delta_j$ )	Media Advertising— FSI, R, T.V. & NP** ( $\gamma_j$ )
Player i	Price Reduction ( $\alpha_i$ )	$(\alpha_i, \alpha_j)$ $(\alpha_i \geq \alpha_j)$ or $(\alpha_i > \alpha_j)$	$(\alpha_i, \delta_j)$ $(\alpha_i \geq \delta_j)$ or $(\alpha_i > \delta_j)$	$(\alpha_i, \gamma_j)$ $(\alpha_i \geq \gamma_j)$ or $(\alpha_i > \gamma_j)$
	In-Store Advertising/ Merchandising ( $\delta_i$ )	$(\delta_i, \alpha_j)$ $(\delta_i \geq \alpha_j)$ or $(\delta_i > \alpha_j)$	$(\delta_i, \delta_j)$ $(\delta_i \geq \delta_j)$ or $(\delta_i > \delta_j)$	$(\delta_i, \gamma_j)$ $(\delta_i \geq \gamma_j)$ or $(\delta_i > \gamma_j)$
	Media Advertising— FSI, R, TV, and NP** ( $\gamma_i$ )	$(\gamma_i, \alpha_j)$ $(\gamma_i \geq \alpha_j)$ or $(\gamma_i > \alpha_j)$	$(\gamma_i, \delta_j)$ $(\gamma_i \geq \delta_j)$ or $(\gamma_i > \delta_j)$	$(\gamma_i, \gamma_j)$ $(\gamma_i \geq \gamma_j)$ or $(\gamma_i > \gamma_j)$

\*Note that the cells do not show payoffs, but alternative levels of strategies for each player.  
\*\*FSI is Free-Standing Inserts, R is radio, TV is television, and NP is newspaper.

**Table 2. Total Promotional Effort (Price Reductions, Media Advertising, and In-Store Advertising/Merchandising).**

		Player j		
		TPE A	TPE M	TPE P
Player i	TPE A	$\pi$ A,A (13, 13)	$\pi$ A,M (16, 12)	$\pi$ A,P (30, 8)
	TPE M	$\pi$ M,A (12, 16)	$\pi$ M,M (14, 14)	$\pi$ M,P (25, 12)
	TPE P	$\pi$ P,A (8, 30)	$\pi$ P,M (12, 25)	$\pi$ P,P (20, 20)

and implemented independently by each player. However, past observations on supermarkets' behavior show that all three of these promotional efforts are used concurrently.

Although the parameters  $\alpha$ ,  $\delta$ , and  $\gamma$  of the bi-matrix in Table 1 can take on many values, it is useful to place some constraints on these parameters.<sup>6</sup> To this end, assume that each player has played the game frequently enough to recognize three separate components of his competitors' strategies. For example, Chain 1 knows that Chain 2 is likely to use one of three levels of price reductions, one of three levels of in-store advertising and merchandising, and one of three levels of media advertising. Similarly, Chain 2 has comparable knowledge about Chain 1. Within this framework are nine strategies for each player, and we assume that each play of the game requires a combination of three strategies. In sum, there are a total of twenty-seven possible payoffs ( $3 \times 3 \times 3$ ) for this game. With such a large number of payoffs, illustrating a Nash equilibrium<sup>7</sup> becomes quite challenging. Yet Nash (1951) has shown that an equilibrium point does exist for every game with a finite number of strategies.<sup>8</sup> To illustrate an equilibrium point for the supermarket chains, this paper will present a payoff matrix that is derived from a subset of the many strategies shown in Table 1.

The model is developed around the basic assumption that chains are far more observant of week-to-week sales and product margins than they are of direct profit rates. Indeed, much of the literature on the supermarket industry shows that profit rates tend to decrease as sales increase. For example, between 1990 and 1998 the Food Marketing Institute reported a decline in the profit rates

of supermarket chains with sales over \$100 million but an increase in the profit rates of chains with sales under \$100 million (Natural Foods Merchandiser 1999). This result seems to support the notion that sales represent a major focus of supermarket chains.

### The Game-Theoretic Framework

For a market consisting of two supermarkets, each carrying two products, Lal and Rao (1997) have shown that a Nash equilibrium exists for this market and profit maximization is derived from a format of one EDLP and one HLP store. Moreover, this equilibrium is reached with each store serving both cherry pickers and time-constrained consumers. Time-constrained consumers are attracted to the HLP store because of greater service and larger product assortment, and cherry pickers are attracted because of product promotions. For the EDLP store, time-constrained consumers are attracted by the lower basket prices and convenient locations. Cherry pickers, with a lower opportunity cost of time, are also attracted by the lower basket prices and the limited need for a high level of service. These conclusions are reached with the aid of several propositions, many mathematical equations, and related proofs. The game developed in this paper is far less abstract and quantitative. A simple model is developed that captures the existing structure of the supermarket industry, and this model describes the interaction among chains that leads to an equilibrium state.

One noticeable observation about supermarket chains in a given market is that there is almost complete uniformity in their promotion periods. For example, promotions in a Florida market might run from Saturday to Friday, while those in a Georgia market might run from Sunday through Saturday. Moreover, freestanding inserts of promotions for any chain will generally appear in the Saturday or Sunday edition of major newspapers. While promotions are run simultaneously and developed independently, each chain gets to assess the positioning and pricing strategies of its competitors on a weekly basis. Moreover, each competitor has information about the deals received by its competitors and this information can then be used to help determine margins and profit rates earned by competitors. Furthermore, each chain receives weekly

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<sup>6</sup> Even though this Table shows a bi-matrix, it is useful to think of this game as Player  $i$  against Player  $j$ , where  $j$  represents all other players. Also, the term "bi" does not define the number of columns and rows, but refers to the fact that there are two payoffs in each cell.

<sup>7</sup> For a dynamic game with "near perfect" information, the equilibrium is technically known as a Bayesian equilibrium. The term Nash equilibrium is more widely recognized and is therefore used in this paper.

<sup>8</sup> To be certain, a pure-strategy equilibrium will not always exist. However, there will always be a mixed-strategy equilibrium. This simply means that each strategy is played with an identifiable level of probability.

reports on its market-share gains and/or losses. This information can then be used to help craft a marketing strategy and game play for the following week. Indeed, the game involves each chain trying to out-perform its competitors by attracting the most shoppers and dollar expenditures through a combination of consumer benefits consisting of manufacturers' deals, retailers' deals, and in-store advertising and merchandising. Even though EDLP and HLP supermarkets compete for shoppers, the number of HLP chains relative to EDLP chains determines the speed of adjustment toward equilibrium. This paper illustrates a Nash equilibrium for a more restricted market of two chains, but additional quantitative analyses can be employed to extend the model to a larger number of chains.

As shown in Table 1, two supermarket chains engage in price reductions, in-store advertising and merchandising, and media advertising to try to maximize their weekly sales and profits. Sales receive the primary focus because many chains adopt the view that increased sales and market shares will lead to increased profits (Hoch et al. 1994). Since supermarket chains engage in weekly competition and receive weekly information on the performance of their competitors, the game illustrated in Table 1 is best characterized as a dynamic game with "almost perfect" information. Since EDLP chains do not engage in week-to-week price promotions, both Players *i* and *j* represent HLP chains (Hoch et al. 1994). Yet the strategies of both players *i* and *j* are influenced by the strategies of EDLP chains because consumers' store selections are influenced by price perceptions that are derived from all promotions. From a practical perspective it seems reasonable to assume that each HLP chain, in an effort to attract both cherry pickers and time-constrained consumers, attempts to project an overall price level of *x* percent of a given EDLP chain. For example, given the higher service demands of time-constrained consumers, an HLP chain may reason that prices within 10% of an EDLP competitor are sufficient to offset the tradeoffs consumers make in their store selections.

As illustrated in Table 1, Player *j* has no way of knowing what level of price reductions, in-store advertising and merchandising, and media advertising player *i* will select in response to any of its actions. Yet because the game is played weekly and intelligent players learn from experience, it seems

reasonable to assume that Player *j* can assign some probabilities to a range of strategies available to Player *i*. Specifically, each player will play mixed strategies. To keep the game tractable, assume that three levels of price reductions, three levels of in-store advertising and merchandising, and three levels of media advertising are available to each player. Each of these levels can be classified respectively as aggressive, moderate, and passive. Since each player (chain) is more likely to maximize sales and profits by utilizing all three, each player selects its game strategy by assigning probabilities to the combination of strategies available to its competitor. Given this scenario, 27 strategies are available to each player, and the game is played with each player assigning a probability between 0 and 1 to each strategy. Influencing each probability assignment, of course, are the strategies of EDLP chains. If EDLP chains are gaining sales and market share at the expense of HLP chains, then each HLP chain is likely to assign a higher probability to an aggressive reaction than to a moderate or passive one. Similarly, if an HLP chain is gaining sales and market share at the expense of another HLP chain, the winning chain is likely to assign a higher probability to an aggressive reaction than to a moderate or passive one. Of course, one of the primary objectives of game theory is to show that this interaction among the players will lead to a Nash equilibrium.

### **Analysis and Discussion**

As described in Table 1, each player seeks to maximize its sales and profit, but focuses week-to-week on sales. As each chain receives a report on its sales for a given week, it assesses its performance relative to that of its HLP competitors and its EDLP competitors. If sales changes for Player *i* are in line with long-run profit objectives and competitors are pursuing passive strategies, then Player *i* has a higher probability of pursuing a passive strategy than a moderate or aggressive one. Likewise, if sales changes for Player *i* are below long-run profit objectives and competitors are pursuing aggressive strategies, then Player *i* has a higher probability of pursuing an aggressive strategy than a moderate or passive one. Within this game structure, costs are likely to be lower and profits higher when all players pursue passive strategies (Lal and Rao 1997).

From a practical viewpoint, it is useful to think of this scenario of passive strategies as representing an all-EDLP world. Yet this world cannot represent a Nash equilibrium because one or more players can be made better off by pursuing alternative strategies. As an illustration of this process, consider the payoff matrix in Table 2 that represents nine of the twenty-seven strategies that are implicit within Table 1.

As shown in Table 2, each cell represents the payoffs to each player (chain) from playing aggressive, moderate, and passive strategies. For example,  $TPE_A$  represents total promotional effort that consists of aggressive price reductions, aggressive in-store advertising and merchandising, and aggressive media advertising.  $TPE_M$  and  $TPE_p$  are defined similarly. Under collusive or cooperative behavior, these two chains would reach equilibrium at  $\pi_{pp(20,20)}$  and maximize profits for each chain. This profit point, however, cannot represent an equilibrium because Player  $i$  can increase his profit by playing strategy  $TPE_m$  if he is convinced that Player  $j$  is going to play strategy  $TPE_p$ . Even at  $\pi_{mp(25,12)}$ , a Nash equilibrium is not established, because Player  $i$  has a desire to play strategy  $TPE_A$  if he is convinced that player  $j$  will play  $TPE_p$ . Indeed, a stable equilibrium is not reached until both players implement aggressive strategies with payoffs  $\pi_{AA(13,13)}$ . At this equilibrium both firms are worse off than at point  $\pi_{pp(20,20)}$ , but neither firm has an incentive to move from  $\pi_{AA(13,13)}$ . This conclusion is reasonable despite the fact that this is a dynamic game with each player assumed to be rational and intelligent. With promotions being driven by deals from manufacturers, each chain recognizes the inevitability of promotions as well as the self-inflicted wounds that result from a non-retaliatory strategy.

It might seem counter-intuitive that a dynamic game with rational and intelligent firms would not lead to the equilibrium  $\pi_{pp(20,20)}$ . Manufacturers could perhaps facilitate this equilibrium point by reducing deals and incentives to chains. However, once a manufacturer offers deals to one chain and this chain engages in promotions at the expense of other chains, all chains have an incentive and a reason to react. In the absence of deals, the rationality and intelligence assumption should lead firms to recognize the interdependency of their actions and allow them to reach equilibrium at  $\pi_{pp(20,20)}$ . However, even this level of profit is not likely to repre-

sent a stable equilibrium because, as described in this paper, it represents a low level of promotion by the HLP chains, and such promotion makes it more difficult for HLP chains to distinguish themselves from EDLP chains. In other words, it is very difficult for any two chains to position themselves as the lowest price alternative for a market basket of goods.

## Conclusions

This paper has illustrated a game-theoretic model that shows supermarket chains reaching an equilibrium that maximizes profits for none of the chains. Intuition and deductive logic are used to derive this equilibrium, and the lower profits associated with it can be attributed to higher inventory and promotion costs. For example, inventory build-ups before a promotion can add to labor and storage costs and decrease the overall profitability of promotions. Additionally, higher labor costs are often associated with planning and executing promotions. Despite these higher costs, HLP promotional strategies are considered imperative because once a competitor decides to engage in promotion it can increase its profits at the expense of other chains. To guard against lost sales and profits, all chains simultaneously engage in promotional activities. Everyday-low-price chains, while not engaged in promotions on a week-to-week basis, do incur some adverse impacts from the week-to-week promotions of HLP chains. To minimize these effects, EDLP chains react by taking on some of the promotional attributes of HLP chains.

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