Retail Sales.

A Study of Pricing Behavior in Supermarkets.

by

Martin Pesendorfer*
Department of Economics
Yale University
PO Box 208 264
New Haven, CT 06520-8264

February 2000

Abstract: This paper examines temporary price reductions, or sales, for ketchup products in supermarkets in Springfield, Missouri, between 1986 and 1988. Ketchup is storable for extended periods of time. The descriptive data analysis indicates that intertemporal demand effects are present. A model of intertemporal pricing is considered in which demand accumulates in the number of time periods since the last sale. We confront implications of the model with the data. The estimates indicate that demand increases in the time elapsed since the last sale. The timing of Ketchup sales is well explained by the number of time periods since the last sale. In addition, competition between retailers for accumulated shoppers influences the sale decision.

JEL Classification Numbers: D4, D12.

* email: martinp@econ.yale.edu. I wish to thank Dirk Bergemann, Ariel Pakes, Peter Rossi and seminar audiences at a number of institutions for helpful comments. I am also grateful to the Institut D'Analisi Economica, Universitat Autonoma de Barcelona for their hospitality during a visit, and the School of Management at Yale University for kindly providing me with the data.

1. INTRODUCTION

Periodic price reductions, or sales, constitute a widely observed phenomenon in retailing. Sales occur on a regular basis which suggests that they are not entirely due to random variations such as shocks to inventory holdings or demand. In recent years the frequency of periodic price reductions has increased, indicating that the sales phenomenon has become more important for retailers and consumers.

This paper examines a particular market in which price reductions occur; namely the market for ketchup products in supermarkets in Springfield, Missouri, between 1986 and 1988. The data consist of daily shelf prices and quantities purchased for four product categories in 80 percent of all supermarkets in the region. The behavior of consumers and retailers involved in this market is described.

The data analysis reveals the following about Ketchup sales: Ketchup prices stay at high levels for a number of time periods followed by a short time period of low prices. Demand during periods of low prices is on average about 7 times higher than during periods of high prices. Intertemporal effects in demand appear strong. Demand is significantly higher if previous prices were high than if they were low. We consider a model of intertemporal pricing. The model assumes that demand at low prices accumulates in the time elapsed since the last sale. The optimal decision to conduct a sale involves randomization. The predicted probability of a sale increases in the time elapsed since last sale. The data support the model. Demand during a sale period increases in the duration since last sale in the store. The decision to conduct a sale is well explained by the time elapsed since last sale in the own and other stores. In addition, the sale decision is affected by competition between retailers for accumulated consumers that are shoppers.

In the literature different explanations for retail sales and price dispersion have been offered. Varian (1980) formulates a model in which there are consumers informed about prices and uninformed consumers. Retailers randomly choose prices every period and informed consumers purchase from the retailer offering the lowest price. An implication of this model is that prices are not predictable and, thus, not correlated over time. Conlisk, Gerstner and Sobel (1984) and Sobel (1991) study intertemporal pricing decisions by a durable goods monopolist with a constant inflow of consumers. They consider strategic behavior by consumers who may purchase later if they expect the price to fall. The policy of the monopolist is to start at a high price, only selling to high valuation consumers, then gradually lower the price over time until low valuation consumers are willing to purchase. After a sale has occurred the cycle starts over. These gradual declines in prices differ from the observed price paths in our data in which prices remain at high levels for extended periods of time, followed by a sudden price cut. Sobel (1984) considers competition between retailers for lows. He assumes that only low valuation consumers behave strategically. High valuation consumers do not discount the future. The resulting equilibrium price paths consists of sudden price cuts similar to the observed price path in the data.

There is little empirical literature on retail sales. Warren and Barsky (1995) document that sales for consumer appliances occur in periods of high demand, on weekends and holidays. Slade (1996a), Slade (1996b) and Aguirregabiria (1999) present evidence showing that retail price reductions depend on intertemporal considerations. In Slade demand for crackers depends on a stock of goodwill that accumulates (erodes) when a firm charges low (high) prices. The stock of goodwill combined with menu costs explains the existence of price rigidities and temporary price reductions. In Aguirregabiria the effects of inventory decisions on price are studied. Price reductions arise more frequently immediately following a new inventory order.

In contrast to the empirical literature this paper emphasizes the role of intertemporal demand effects in explaining the occurrence of sales. Ketchup is storable for extended periods of time which suggests that consumers may be willing to wait for the occurrence of a price reduction. We examine the demand accumulation effect in which demand at low prices accumulates in the duration since the last sale and consider its influence on pricing decisions.

Section 3 describes the empirical evidence on sales. We document that sales do not arise at the same time across stores. This suggests, that wholesale price variation do not cause the adoption of sales entirely. Intertemporal effects in demand appear important. Demand during periods of low prices depends positively on previous prices. If last weeks prices were high then demand is significantly higher than if last weeks prices were low. During periods of high prices demand is also affected by previous prices, but to a lesser extent. In addition, consumers that purchase at low prices visit competing retail stores frequently which suggests that sales may be affected by competition between retail stores.

Section 4 describes a simple model of demand accumulation in which a fixed number of consumers enter every period. In contrast to the durable goods literature, we do not consider strategic behavior by consumers. We assume that low valuation consumers purchase the product as soon as it becomes affordable to them. We distinguish between two stocks of low valuation consumers: Store loyal consumers and shoppers. Loyal consumers shop at one store only. Shoppers purchase at different stores. Retailers face different wholesale prices over time and decide when to hold a sale.[1] Equilibria of the model are described for two special cases. First, when there are no shoppers and the retailer is a monopolist. Second, when there are no store loyal lows and retailers compete for lows that are shoppers. The model predicts that the equilibrium decision to hold a sale is a function of the duration since last sale in the own store and the duration since last sale in other stores. The implied price path consists of an extended period of high prices followed by a short period of low prices. The predicted price path is in accordance with the data.

In section 5 the implications of the theoretical model are confronted with the data. The decision to conduct a sale is estimated as a function of the duration since the last sale in the own-store, and the duration in other stores. The model fits the data well. The effects of the duration variables are significant and have the predicted sign. The evidence suggests that demand accumulation is important for the decision to conduct a sale. In addition, competition between retailers for the stock of shoppers is a relevant factor for the timing of sales. The determinants of demand during a sale period are examined. We find that demand increases in the duration since last sale which is in accordance with the model.

The organization of the paper is as follows. In section 2 the market and the data are described. Demand and supply decisions are characterized in section 3 and it is documented that there are intertemporal linkages in both supply and demand. Section 4 presents a model of intertemporal pricing decisions. The optimal sale decision is studied when demand accumulates in the duration since the last sale. Predictions of the model are discussed. In section 5 we examine the retailer's decision to hold a sale and estimate demand during a sale period. In section 6 conclusions are given.

---

[1] Models of this form are called tree-cutting problems and have been studied in the economics literature in a number of contexts. See Stokey and Lucas (1989, p. 107 and p. 129) for a discussion.

2. MARKET

This paper examines the pricing decisions of supermarkets in Springfield Missouri between 1986 and 1988. The data was collected by the Nielson marketing research company, and consist of daily shelf prices of selected products for 80 percent of the grocery and drug retail stores in this region.[2] The list of products includes ketchup, detergent, yogurt and soup products. In addition, the purchase behavior of a sample of 1,500 households is recorded. For each day the price and quantity purchased of the selected products is listed.[3]

The market consists of consumers, retailers, wholesalers and manufacturers. Manufacturers sell their products to retailers through wholesalers. The data do not contain information on the wholesale market. In particular wholesale prices are not observed. After talking to several wholesale distributors and retailers in this area, the interaction among market participants can be described as follows. There are a number of wholesalers supplying a variety of products to supermarkets. Retailers purchase directly from wholesalers at a pre-specified price and distribute products to their retail outlets. There are no quantity restrictions in the wholesale market. Periodically, manufacturers offer their product at lower prices. Price reductions for ketchup, so called "trade promotions," are "off invoice," meaning that the retailer can buy an unrestricted quantity at the lower price. According to conversations with wholesalers the price in the wholesale market changes infrequently. After a price change occurs, or trade promotion, the wholesale price remains at this level for about 3 months.[4]

---

[2] Scanner data have previously been used in empirical studies in the marketing literature. In the economics literature recent studies include the effects of advertising on purchase behavior, Ackerberg (1996), optimal pricing with adjustment costs, Slade (1996), and the stickiness of retail prices, Slade (1996).

[3] The data were kindly provided to me by the School of Management at Yale. The daily price data are constructed from data on the purchase behavior of households. On some days no purchase for a product is recorded and the price observation is missing. In the price data, missing observations have been filled using adjacent purchase observations and by comparing price data across supermarkets within the same chain. Although a comparison between the actual and constructed daily price series revealed no apparent problem, this paper uses mainly weekly price data.

[4] A number of contributions to the marketing literature, including Lal (1990), Blattberg, Briesch and Fox (1995) and Blattberg and Neslin (1990), point out that trade promotions provide weak incentives for retailers. Retailers need not pass the trade promotions on to the consumers. If a retailer decides to adopt a promotion he may amplify or mitigate the effect of the wholesale price reduction. Marketing studies find that, on average, a smaller amount than the original discount is passed through to the consumer. An additional effect

This study focuses on ketchup products.[5] Ketchup is storable for fairly long periods of time. A particular ketchup product contained in the data set is homogenous across time. And ketchup is offered in identical packages across stores. The data contain a total of 18 different ketchup products. Two products, Heinz and Hunts bottles weighing 32 ounces, are selected. There are several reasons for making this selection. First, the prices of these two products vary substantially over time. Second, these products have the highest market share in dollar revenues among ketchup products. Finally, the overall price distribution of the two products is very similar.

Ketchup price reductions by supermarkets are typically advertised on fliers enclosed in weekend newspaper editions. These advertisements are aimed at informing consumers about price reductions.[6]

Supermarkets offer a wide variety of products. The pricing decisions of one product may affect the pricing and purchase decisions for other products. Coordination of decisions across different product groups is not addressed in this paper. We assume that decisions are separable.

Table 1 provides summary statistics of selected variables. The market consists of a total of 4 Supermarket Chains, three national and one regional, with a total of 21 supermarket stores. The number of stores per chain differs, with an average number of 5, and ranges from 3 to 9. The market shares of the two products vary across chains. In three chains Heinz is the leading product, while in one chain Hunts has the highest sales volume. P-HEINZ denotes the price of Heinz, P-HUNTS is the price of Hunts, P-MIN-HEINZ, is the lowest price for Heinz across all stores in a given time period, and P-MIN-HUNTS, is

of trade promotions is that they induce retailers to purchase in excess of what they sell to consumers. Retailers may store the product. Neslin, Powell and Stone (1995) study optimal inventory policies and the adoption of the trade promotions by retailers.

[5] The data contain a number of other products. However, the other products exhibit characteristics that make them less attractive for this study. Prices of soup products exhibit little variation over time. Yogurt is perishable and the decision to hold a sale may be strongly motivated by supply conditions. Detergent products exhibit dispersion in prices over time, but there is a large number of different detergent products, each with a small share of the market. On a given day, typically more than one product is on sale. In addition, the packages of the same detergent product may differ over time. This makes a comparison of behavior by consumers and retailers across different time periods more difficult.

[6] National advertising is of less importance for Ketchup sales. According to Advertising Age March 3, 1997, the trade and consumer promotions have in the past decade played a much bigger role than advertising for the manufacturer of Heinz ketchup.

the lowest price for Hunts across all stores in a given time period. Both products exhibit substantial price dispersion on a given day, ranging from $0.79 to $1.79, with a sample mean of $1.35. For comparison on any given day, the lowest price in any of the 21 supermarkets is about 30 percent lower than the average price in a given store, with a sample mean of $1.05.

(Figure 1)

Figure 1 illustrates the price over time of the two products in a typical supermarket. All prices in this study are nominal prices. The prices remain constant for long periods of time and occasionally drop for short periods. Other ketchup products in the sample typically exhibit less dispersion in prices over time. For example, Figure 1 also illustrates the price over time of the third leading product, which is a store product. Observe that the price of this third product is substantially lower on a given day.

In Table 2 the distribution of daily prices for selected price levels in supermarkets is documented. The first row gives the price level and the second row gives the corresponding frequency in the distribution of prices. The eleven categories for Hunts and the 9 categories for Heinz span 90 percent of all prices charged in the 21 Supermarkets over the sample period. For Heinz, more than 60 percent of all daily prices fall in the range 1.39 to 1.49, and 23 percent of prices fall in the categories 0.99 or 1.19. We call the last two categories sale categories. Similarly for Hunts, 20 percent of prices fall into the sales categories of 0.99 and 1.19, and 54 percent of prices fall in the range 1.31 to 1.49.

The third row in Table 2 gives the percent of all purchases undertaken at any given price level. About 45 percent of purchases of Heinz ketchup take place at prices below $1.00, and about 65 percent of all Heinz purchases take place at prices below $1.20. Similarly, approximately 36 percent of all Hunts purchases take place at prices below $1.00, and about 60 percent of all Hunts purchases take place at prices below $1.20. Adjusting for the relative frequencies of prices, it is apparent that there are substantial differences in the number of units sold between high and low price levels. At a price of $0.99, about 7 times as many Heinz ketchup units are sold than at a price of $1.39. Similarly, about 8 times as many Hunts ketchup units are sold at a price of $0.99 compared with a price of $1.43.

The fourth row in Table 2 reports the average number of days at which the price stays at this level. For low price levels the average number of days appears smaller than for high price levels. Moving from low to high prices, the average number of days increases for both Heinz and Hunts prices. To illustrate this relationship we regress the number of days at which the price stays at this level on a constant and the price level. The relationship is significant and explains roughly 10 percent of the variation for Heinz, and about 15 percent in the variation for Hunts. The coefficient on the price level is significant and positive for both Heinz and Hunts. Increasing the price of Heinz by 10 cents, increases the number-of-days variable by about 6 days. Increasing the price of Hunts by 10 cents increases the number-of-days variable by about 9 days. Thus, non-sale periods are significantly longer than sale periods.

3. DESCRIPTION OF PRICE REDUCTIONS

This section reports descriptive analysis of the data. We find that prices (and sales) exhibit little correlation across stores. This suggests that variations in wholesale prices do not explain sales entirely. Second, we document that the distribution of prices depends on previous prices of the same and competing brands which indicates intertemporal effects in supply. Third, we examine the dependence of demand on past prices. We find that demand depends on past prices. This rejects random events which are unpredictable by previous prices as an explanations for retail sales.[7] Demand at low prices is significantly higher if previous prices were high than if they were low. Fourth, we examine how frequently consumers visit different stores. We find that consumers that purchase Ketchup at low prices are more likely to visit different stores.

Table 3 gives correlation coefficients for prices of Heinz and Hunts over time. The correlation coefficients are given for prices within a chain and across chains. The pricing behavior in supermarkets within a chain for the same product is very similar - for Heinz and for Hunts the correlation coefficient is about 0.5. For supermarkets in different chains the correlation in prices of the same product is positive, but with a smaller amount of correlation than within chains. The correlation between prices of different ketchup products is positive

[7] For example, shocks to inventory holdings, demand shocks or randomness due to mixing over different prices in a mixed strategy equilibrium. Models in which sales are exclusively explained as an outcome of a mixed strategy equilibrium have received considerable attention in the literature. These models assume that current demand is independent of past prices. They imply that current price choices should be unaffected by past price choices.

and, again, stronger within a chain than across chains. Since prices for supermarkets within a chain are highly correlated it appears reasonable to assume that supermarkets coordinate their pricing behavior within a chain.

The correlation of Heinz prices across chains is low (correlation coefficient of 0.04). This indicates that variations in wholesale prices, do not explain price reductions entirely.[8] Static models of monopoly and Bertrand competition predict that retail prices follow a pattern similar to wholesale prices. According to these models, a strong variation in the wholesale price should yield a positive association between retail prices across chains. The small magnitude of the price correlation may suggest that the predictions of static models are not relevant, and/or that changes in common cost factors are not the only factor determining price changes.

Price changes mostly occur on particular week days. Sixty-eight percent of the price changes for Heinz, and 77 percent of the price changes for Hunts, occur on a Wednesday. Twenty percent of the price changes for Heinz and 15 percent for Hunts occur on a Thursday. The remaining price changes are evenly distributed across the remaining days of the week. An inspection of the number of price changes in a supermarket reveals that changes occur infrequently. The number of price changes, in the average supermarket, equals 24 during the sample period for Heinz, and 18 for Hunts in the average supermarket. This variable differs across supermarkets and ranges from 11 to 34. The absolute value of a price change is, on average, 30 cents for Heinz and 18 cents for Hunts.

Figure 1 and Table 2 suggest the possibility of serial correlation in prices as prices remain constant for extended periods of time. To determine how current prices depend on past prices, weekly price changes can be studied. Although, we do not report the test results in detail, we briefly summarize the findings: We examined whether the distribution of prices conditional on a price change depends on past prices. The null is that conditional

[8] Although the data do not provide wholesale prices paid by individual supermarkets, conversations with wholesalers indicate that supermarkets purchase Ketchup products at the same wholesale price. Furthermore, unequal wholesale prices are not in accordance with the law. The Robinson-Patman Act, which amended Section 2 of the Clayton Act in 1936, prohibits a manufacturer (or wholesaler) from price discriminating if it harms competition among the retail firms. The Robinson-Patman Act was passed in response to political pressure from small retail stores who complained that larger chains were able to purchase supplies on more favorable terms and thereby charge lower prices (Ross, 1984).

distributions are identical for different last weeks' prices. For example, under the null, the distribution of prices over the categories of \$1.19, 1.39 and 1.46 is the same whether last weeks price was \$0.99 or \$1.49. Pairwise comparisons of conditional distributions for the largest 5 price categories for each product were considered. The null of identical price distributions can be rejected in 19 of 20 cases. We also considered tests of independence of previous prices of competing brands. The null of independence was again rejected. Chosen price levels depend also on last week's prices of the competing brand.

We next examine the dependence of demand on lagged prices. Consider the following equation,

$$D^i_{k,t} = \sum_l [p_{t-7} B_l + X^i_{k,t} \beta_l] 1_{\{p_t \in I_l\}} + \varepsilon^i_{k,t} \qquad (1)$$

where $D^i_{k,t}$ denotes the number of units purchased in supermarket k of product i, p_{t-7} denotes a vector of lagged prices, X denotes additional explanatory variables and $\mathbf{1}_{\{A\}}$ denotes an indicator function that equals one if condition A is true and zero otherwise. We permit the coefficients in the demand equation to vary with current period prices. Due to the discreteness of prices, we partition the set of current prices in a number of disjoint intervals, I_l. We let the coefficients, B_l and β_l, to differ across intervals. Thus, the coefficients in equation (1) capture variations in the number of units purchased at a given price level. The data are obtained from a sample of households and contain a number of observations with zero units purchased. We account explicitly for the truncation of the dependent variable and estimate a Tobit model.

Table 4 and 5 report parameter estimates of Tobit regressions for Heinz and for Hunts. The dependent variable is the logarithm of the number of units purchased.[9] Explanatory variables include lagged supermarket specific prices, lagged minimum prices across all stores, a set of advertising dummies that indicate whether a supermarket advertisement for a ketchup product appeared in the weekly newspaper, a 4$^{\text{th}}$ of July dummy variable that equals one between the 15$^{\text{th}}$ of June and the 15$^{\text{th}}$ of July of every year. In addition, a set of weekday dummies and a set of supermarket specific dummy variables are included, but

---

[9] One unit is added to every observation of the dependent variable to obtain a truncation point of zero after taking the logarithm.

not reported.

At the bottom of Tables 4 and 5 test results for the significance of lagged prices are reported. Under the null of no significant effects a F-test can be constructed to determine whether lagged price variables are jointly significant. The null hypothesis can be rejected if the F-statistic exceeds the critical value. Both for Heinz and Hunts, lagged super-market-specific prices are significant at the lowest two price categories and at the highest price category. For Hunts, the null is also rejected at the fourth category. At other price categories the null cannot be rejected.

For Heinz, lagged minimum prices charged in other stores are significant at the two percent level at the lowest three price categories. They are also significant at the highest price category at the 6 percent level. At other category they are not significant. For Hunts, lagged minimum prices charged in other stores are significant at the lowest category and in the fifth category. Lagged minimum prices are not significant at other price categories.

The important effects in Table 4 are the following. At the lowest price of Heinz, the demand of Heinz is significantly higher if last week's prices in the same supermarket are high. When the price of Hunts is below 1.20, holding other variables constant, a one percent increase in $\mathrm{P-HEINZ}_{t-7}$, increases Heinz demand by 2.1 percent. Moreover, an increase of $\mathrm{P-HUNTS}_{t-7}$ by one percent increases Heinz demand by 1.0 percent. When the price of Hunts exceeds 1.20, then the effects become even stronger: A one percent increase in $\mathrm{P-HEINZ}_{t-7}$ increases demand by 2.3 percent. A one percent increase in $\mathrm{P-HUNTS}_{t-7}$, increases Heinz demand by 7 percent. As we move to the right in the table, the magnitude of the effect of past prices declines. The effect is stronger when $\mathrm{P-HUNTS}_{t}$ exceeds 1.2 than when it is below 1.2. Prices charged in other supermarkets have a significant effect on demand at the lowest price level. Demand is higher, if past prices in other supermarkets are high. The effect of the minimum price of Heinz equals 1.2 and 1.9 percent at the lowest two categories.

The findings in Table 5 for the lagged product specific price are similar to Table 4. With the exception of the first price category, lagged prices of Hunts have a positive effect on Hunts demand. A one percent increase in $\mathrm{P-HUNTS}_{t-7}$ increases demand by 1.5 percent in the second category. The effect increases to 2.9 percent and 2.5 percent in the third and fourth category. At the highest two categories, where the current price of Hunts exceeds

1.20, the effect declines in magnitude. It is positive and equals 0.1 percent and 0.7 percent.

For Heinz and also for Hunts (with the exception of the first category), the effect of lagged store prices of the same product are stronger when current prices are low than high. This difference suggests that consumers who buy at low price levels are more sensitive to past prices in the same supermarket than consumers who buy at high price levels.

Weekly advertisements in the newspaper have the expected sign. Advertisements have a positive effect on the demand of the product and a negative effect on the demand of competing brands. The 4th OF JULY variable has a positive and significant effect on Hunts demand and a mostly negative, but not significant, effect on the demand of Heinz.

In Tables 4 and 5, the demand for Heinz and Hunts appears to depend on past prices charged in other supermarkets. This raises the question of how often do consumers shop at different supermarket chains? The data contain information on the purchase behavior of a sample of households. Notice that an observation in these data is a household and not an individual. Table 6 reports the percentage of occasions in which households go shopping to their most preferred chain, second most preferred chain and third most preferred chain. In the table, "1st Chain" denotes the supermarket chain the consumer visits most frequently. "2nd Chain" denotes the supermarket chain the consumer visits the second most frequently, and so on. The shopping frequencies are given for households with at least 70 shopping trips during the sample period. For consumers with at least 4 purchases of Heinz or Hunts ketchup, which we call repeat buyers, the shopping frequencies are reported separately and also grouped by the average price of Hunts or Heinz ketchup paid per household. The percentages in the table sum to less than 100 since a (small) fraction of the store visits are for the fourth choice.

On average (across consumers) two out of three times the first chain is chosen, about one out of four times the second chain is chosen, and about every tenth visit the third chain is chosen. These numbers are roughly the same for repeat buyers as for other households. The standard deviations in Table 6 are high. This suggests that some households shop around very little, while other consumers may shop around a lot. Indeed about twenty percent of all consumers go almost exclusively to one store (19 of 20 times). On the other hand, about 20 percent of all consumers go only around 40 percent of times to their most preferred chain; they go on every third shopping trip to the second most preferred chain, every fifth trip to the third most preferred chain, and once every 15 shopping trips to the least preferred chain.

Table 6 also suggests a dispersion in the average price paid by repeat buyers of Heinz and Hunts ketchup. A total of 429 consumers in the sample, or about one third of all households, qualify as repeat buyers. The first two elements in Table 6 illustrate that about 30 percent of repeat buyers pay an average price of less than $1.09 per ketchup bottle. Calculating the mean average purchase price for this group yields an estimate of $1.02. At the other extreme, about 20 percent of consumers pay an average price of more than $1.29, with a mean average purchase price of $1.35. For comparison, a price insensitive consumer, or random buyer, would pay an average price of $1.35, and a consumer buying only at the store offering the lowest price on a given day would pay, on average, $1.05.[10]

Consumers who buy at low prices appear to shop around more frequently. In Table 6 the fraction of visits to the most preferred chain appears to increase as we move down the table. To determine whether this relationship is significant we regressed the percentage of visits to the first chain on the average price paid and a constant. About 8 percent of the variation in the dependent variable is explained. Moreover, the regression coefficient for the average price is significant and positive.

Ketchup sales may be intended to increase the inflow of consumers that otherwise do not shop in that store. These consumers may purchase other products and enhance the gains from conducting a sale. Lal and Matutes (1994) consider "loss leader pricing" in which one product is offered at marginal cost or below in order to increase store traffic. Using the data we examine whether the demand for other products increases when ketchup is on sale. The evidence indicates only little effects if anything.[11]

[10] Assuming that our measure of the average purchase price for repeat buyers reflects the true average price paid per household implies the following. About 80 percent of consumers buy at prices lower than the average daily shelf price. About 30 percent of consumers buy at prices lower than the lowest price offered across all stores on a given day. Unfortunately, in the data the number of purchases per consumer is relatively small, ranging between 4 and 10 purchases for 85 percent of consumers. This weakens the implication and makes a more careful analysis impossible. However, a narrower definition of repeat purchasers does not change the distribution of average price paid per consumer substantially. A total of 62 households satisfy the stronger requirement of at least 10 purchases of Heinz or Hunts Ketchup. From these, about 21 percent buy at a price below $1.09 and about 21 percent buy at a price above $1.29, which yields a similar distribution as given in Table 6.

[11] If consumers do not substitute between ketchup and other products, and there are

Summarizing, we find that both demand and supply depend on past price choices. The distribution of prices depends on previous price choices of competing ketchup brands within the store. Across supermarket chains there is little correlation in prices. Sales do not arise at the same time across supermarket chains. Demand at low price levels is higher if past prices are high than if past prices are low, holding other variables constant. Demand at high prices is also affected by past prices, but to a lesser extent. Individual households differ substantially in the average price they pay and in their willingness to shop around. Consumers that buy on average at low prices are more likely to visit competing chains. This may indicate that competition between retailers affects sale decisions.

The characterization of the data is used as a basis to formulate a model of intertemporal pricing. In the next section, the model is described and predictions of the model are provided that can be confronted with the data.

4. DEMAND ACCUMULATION

In this section we describe the implications of a model of intertemporal pricing for a single product in which the stock of low valuation consumers accumulates in the duration since the last sale. Retailers face uncertain future wholesale prices and decide when to adopt a sale.

Time is discrete. Agents are fully informed and risk neutral. There are m retailers each of which sells the same product. Retailers choose retail prices to maximize discounted present value, calculated with discount factor δ (with $0 < \delta < 1$), taking the prices of other retailers as given. Retailers cannot store the product. The cost of holding inventories exceeds the gains from storing the product. The product is supplied to the retailer by a manufacturer. The retail market is small compared to the wholesale market and we assume that the wholesale price (paid from the retailer to the manufacturer) in period t

no budget constraints, then demand for other products may increase. We examined this hypothesis with the data on soup, detergent and yogurt products. The logarithm of demand for the leading product in each category, at a given price level of the product, is regressed on explanatory variables (similar to Tables 4 and 5). Price levels which account for at least 10 percent in the price distribution are used. This yields a total of 12 regressions. Explanatory variables include one indicator variables that equals one if Heinz or Hunts ketchup is on sale during that day, a set of supermarket specific dummy variables, and a set of weekday dummy variables. In these 12 regressions 4 sale dummies are significant. Seven of the sale dummies are negative and 5 positive. This evidence does not indicate positive externalities across groups of products.

is exogenous to the retail market. The wholesale price equals c_1 with probability ρ and c_2 with probability $1-\rho$, with $c_1 < c_2$.

One consumer enters the market each period. Each consumer wishes to purchase one unit of a product. Consumers differ in their valuation for the products. A fraction of the consumers have high valuations and buy only from a particular retailer. Specifically, a fraction $\frac{\alpha}{m}$ of consumers value the product at v_1 and buy only from retailer k, with $0 < \alpha < 1$. A fraction $1-\alpha$ of consumers value the product at v_2, with $v_1 > v_2 > c_1 > 0$. Consumers who value a product at v_1 are sometimes referred to as high valuation consumers and consumers who value the product at v_2 are called low valuation consumers.

High valuation consumers stay in the market for one period. Independent of whether they actually purchase the product they leave the market at the end of the period they entered. In contrast low valuation consumers who do not purchase a product stay in the market. Low valuation consumers leave the market only after purchase of a product. They have discount factor zero. This distinction reflects that some consumers must have the product immediately, provided they can afford it. While other consumers have low search cost and stay around until a product becomes affordable to them, at which point they buy the product immediately and leave the market.

We distinguish two types of low valuation consumers: Store loyal consumers and shoppers. This distinction may arise due to differences in traveling costs. A fraction $\frac{\gamma}{m}$ of low valuation consumers have high traveling costs and buy only from retailer k. A fraction $1-\gamma$ of low valuations consumers are shoppers who purchase from the store offering the lowest price (provided the price is below v_2).

To illustrate the assumptions we describe the demand for retailer k. During a period in which the price is above v_2 demand consists of highs and equals $\frac{\alpha}{m}$. Let T_k denote the number of time periods since the last sale in retail store k. During a sale period (when the price does not exceed v_2) demand is given by

$$\frac{\alpha}{m} + (1-\alpha)\frac{\gamma}{m}T_k + (1-\alpha)(1-\gamma)\min(T_1, T_2, \ldots, T_m) \tag{2}$$

It consists of $\frac{\alpha}{m}$ highs, $(1-\alpha)\frac{\gamma}{m}T_k$ store loyal lows and $(1-\alpha)(1-\gamma)\min(T_1, T_2, \ldots, T_m)$ lows that are shoppers. Hence, retailers have monopoly power over high valuation consumers, and store loyal lows. Retailers compete with other retailers for the fraction of consumers who are shoppers.

We assume that retail pricing strategies can only depend on the number of time periods since the last sale in individual stores $(T_1, T_2, \ldots, T_m)$ and the current period cost realizations c with $c \in \{c_1, c_2\}$. This strategy space rules out behavior in which firms condition their behavior on observed histories of prices.

We first examine a situation in which there are no shoppers, $\gamma = 1$ (or $m = 1$). Theorem 1 characterizes the optimal decision to hold a sale for a monopolist in the retail market. Later we examine equilibrium sales behavior under competition among retailers. Before stating the theorem we illustrate the intuition. For any realization of costs sufficiently below v_2, as the number of low valuation consumers accumulates, the revenues of a price cut increase. Eventually the gains from a price cut exceed the expected gains from waiting one more period and the retailer holds a sale.

Theorem 1. *Suppose $\gamma = 1$ (or $m = 1$). Then there exists integers $\overline{T}(c_1)$, $\overline{T}(c_2)$ such that the price in a period with state (T, c) is given by*

$$p(T,c) = \begin{cases} v_2 & \text{if } T \geq \overline{T}(c); \\ v_1 & \text{otherwise.} \end{cases}$$

Moreover, for $c_1 < c_2$, $\overline{T}(c_1) \leq \overline{T}(c_2)$; For $c_2 \geq \frac{(1-\delta)v_2 + \delta\rho c_1}{1-\delta(1-\rho)}$, $\overline{T}(c_2) = \infty$.

All proofs are given in the appendix. The optimal strategy of the retailer for a given cost realization has the following qualitative form. For $\overline{T}$ periods the retailer charges v_1 for the product. After this point, there is a sale in which the retailer charges v_2, and all the low valuation consumers buy the product on sale. The process then repeats. Sales occur earlier for lower cost realizations than for higher cost realizations.

The assumption that wholesale prices are random implies that the probability of a sale equals the probability that the manufacturer offers his product at a wholesale price below a certain threshold. This threshold increases over time and therefore implies that the probability of a sale increases in the number of periods since the last sale. What is observed is a price cut of the product followed by an interval of at least $\overline{T}(c_1)$ of high prices.

The assumption that high valuation consumers leave the market at the end of the period they entered ensures that retailers sell to all high valuation consumers in every period. If high valuation consumers do not leave the market at the end of the period, then a retailer, facing a high wholesale price, may prefer not to sell to high valuation consumers, but to sell later at a lower wholesale price.

Competition between retailers is described next. Consider the situation with no store loyal lows, $\gamma = 0$. Equilibrium prices in a similar model are examined in Sobel (1984). The difference to Sobel is that he assumes low valuation consumers do not necessarily buy in the first period at which the price is below v_2, but they may also wait if they expect the price to fall even further.[12] We do not consider strategic behavior by consumers and assume that lows purchase immediately provided the product is affordable to them. Non-strategic behavior is also emphasized in the marketing literature (Blattberg and Neslin, 1989). The literature on reference prices illustrates that consumers remember a small set of reference prices for super market products. Thus, in the context of super market products it appears reasonable to rule out strategic purchase behavior.

The following Theorem describes equilibrium prices under competition.

Theorem 2. *Suppose $\gamma = 0$ and let c denote the cost realization and $T = \min(T_1, T_2, \ldots, T_m)$. A symmetric equilibrium is given by the following prices: If $T < \frac{\frac{\alpha}{m}(v_1 - v_2)}{(1-\alpha)(v_2 - c)}$, or $c \geq v_2$, then the price in period T equals v_1 in all retail stores. If $T \geq \frac{\frac{\alpha}{m}(v_1 - v_2)}{(1-\alpha)(v_2 - c)}$, and $c < v_2$, then the price in every retail store is drawn from the distribution,*

$$G(p,T,c) = \begin{cases} 0 & \text{if } p < c + \frac{\frac{\alpha}{m}(v_1 - c)}{T(1-\alpha)}; \\ 1 - \left[\frac{\frac{\alpha}{m}(v_1 - c)}{[\frac{\alpha}{m} + T(1-\alpha)](p-c)}\right]^{\frac{1}{m-1}} & \text{if } p \in [c + \frac{\frac{\alpha}{m}(v_1 - c)}{\frac{\alpha}{m} + T(1-\alpha)}, v_2]; \\ 1 - \left[\frac{\frac{\alpha}{m}(v_1 - c)}{[\frac{\alpha}{m} + T(1-\alpha)](v_2 - c)}\right]^{\frac{1}{m-1}} & \text{if } p \in [v_2, v_1); \\ 1 & \text{if } p = v_1. \end{cases}$$

.

The equilibrium has the following qualitative form. For $\frac{\frac{\alpha}{m}(v_1 - v_2)}{(1-\alpha)(v_2 - c_1)}$ periods retail stores charge the high price. After this time, stores hold a sale with positive probability in any period. If a sale occurs then the sale price is drawn randomly from a distribution with support below v_2, and all low valuation consumers purchase from the store offering the

---

[12] As a result, Sobel's equilibrium distribution of prices below v_2 differs from this model. Moreover, as Sobel shows, there are possibly multiple symmetric equilibria. In contrast, in this model there is only one symmetric equilibrium.

lowest price.[13] After this sale period the cycle starts over. The implied price path consists of a price cut in one store followed by an interval of high prices.

Comparative statics for the probability of a sale are easily obtained. An increase in the number of low valuation consumers increases the probability of a sale in any retail store. As the number of retailers gets large the probability that a sale occurs in some retail store approaches one.[14] The reason is that holding the total number of shoppers per period constant, an increase in the number of retailers is equivalent to a decrease in the number of loyal consumers per store.

In the Theorem it is assumed that retailers face the same wholesale price, and retailers have the same share of high valuation consumers. If one store can buy the product at a lower wholesale price, then this store offers the product on sale with a higher probability. Similarly, if one store has a smaller share of high valuation consumers, then this store may hold a sale earlier than other stores. Expectations about future wholesale prices do not affect the equilibrium in Theorem 2. In particular, serial correlation in wholesale prices does not alter the equilibrium outcome.

Theorem 2 characterizes the symmetric equilibrium. If the number of retailers exceeds two, then there also exist asymmetric equilibria. In asymmetric equilibria one or more retailers may completely refrain from holding a sale.[15] An example is given in the appendix.

Theorem 1 and Theorem 2 describe the sales decision for two extreme cases: All lows are store loyal, or all lows are shoppers. In the general case we expect that the sales decision is a function of the stock of lows in all retail stores. This decision rule can be studied with the data.

4.1. PREDICTION

To summarize, the predicted price path consists of a number of periods of high prices followed by a short period of low prices. After the price cut the sale cycle starts over.

---

[13] Observe, that it is a zero probability event that more than one store offers the same sale price. However, in this case, the demand of low valuation consumers is split equally among the stores offering the lowest price.

[14] Examples can be constructed in which the convergence is not be monotone.

[15] Supermarkets label themselves as HiLo price setters and Every Day Low price setters. Asymmetric equilibria may explain this distinction. HiLo supermarkets charge high and low prices according to Theorem 2 while constant prices are obtained by completely refraining from holding a sale.

The equilibrium prices are described by a draw from a distribution function, G, that depends on the current state.

$$p \in G(p|T_1, T_2, \ldots, T_m, c) \tag{3}$$

The equilibrium distribution function in (3) has a mass point at v_1 and if γ does not vanish also at v_2. When there are no shoppers, $\gamma = 1$, then sales are entirely determined by the duration since the last sale in the store. When there are no store loyal lows, $\gamma = 0$, then the minimum time since last sale across stores, $\min(T_1, T_2, \ldots, T_m)$, determines sales. In general the model implies that the decision to conduct a sale is a function of the wholesale price and the duration since the last sale in the own and other stores.

The model is presented with one product per store. The formulation can easily be extended to permit multiple products. Related products can be incorporated by distinguishing between two additional types of lows: Product loyal lows and consumers that perceive products as perfect substitutes. Observe, that competition between products is analogous to competition between stores. Although, we do not model multiple products explicitly, the equilibrium decision to conduct a sale for a particular product is a function of stocks of product loyal lows for all products in all stores. In addition, differences in wholesale prices between products can influence the decision to conduct a sale.

5. THE SALE DECISION AND DEMAND FOR KETCHUP

This section examines the predictions outlined in section 4. First, in subsection 5.1. the determinants of the decision to hold a sale are examined. We find that both the store specific sale duration and the sale duration across stores explain the decision to hold a sale. Second, in subsection 5.2. the determinants of demand conditional on a sale period are studied. We examine whether variables measuring the time elapsed since the last sale have a positive effect on demand.

5.1. THE SALE DECISION

This section examines the decision to conduct a sale. The equation (3) in section 4 implies that the distribution of prices is a function of wholesale prices and the time elapsed since last sale in the own and other stores. In addition, the distribution of prices has a mass point at the non-sale price (or regular price) and mass contained in an interval below the sales price. The price decision problem can be modeled as a discrete choice problem with two prices: Sale and no sale. The probability of holding a sale will be a function of the time elapsed since the last sale for the product in the store, time elapsed since last sale of competing products in the store, duration variables in other stores, the wholesale price, and idiosyncratic randomness. Idiosyncratic effects may include shocks to inventory holdings.

The retailer not only decides on conducting a sale but also which product to offer on sale. It may be expected that the decision to hold a sale is correlated across products. Unfortunately, the data contain only a very few observations in which both products are on sale at the same time. An estimation of the bivariate decision model was not successful. The likelihood of the bivariate model is very flat and significant estimates for the correlation in the decision variables were not obtained. We therefore report only estimates of the univariate case.

The decision to offer the product i on sale in supermarket k, $y^i_{kt} = 1$, can be described by the following rule,

$$y^{i*}_{kt} = \gamma Z_{k,t} + \beta' X_{kt} + \varepsilon_{kt}$$

and

$$y^i_{kt} = \begin{cases} 1 & \text{if } y^{i*}_{kt} > 0; \\ 0 & \text{if } y^{i*}_{kt} \leq 0. \end{cases} \tag{4}$$

where Z are a set of variables that measure the time elapsed since last sale in the store and in competing stores, X_{kt} are additional explanatory variables and ε_{kt} is idiosyncratic randomness. Under the assumption that ε_{kt} is independent of past sale decisions this model can be consistently estimated.

Before proceeding to the estimation results two choices are discussed that are made in estimating relation (4). First, the data do not include wholesale prices. According to distributors in this market, the wholesale price did not change for extended periods of time. After a trade promotion is announced the wholesale price stays at this level for an intervals of about 3 months.[16] Since we estimate the model using weekly prices[17], the persistence of wholesale prices will lead to serially correlated errors and, as a result, the estimators will be inconsistent. To resolve this problem we include a set of time dummy variables that equal one during a period of fixed length. Variations across super markets are used to identify this parameter. Specifically, we select a set of time dummies with interval length of eight weeks.[18]

The second issue concerns the selection of data. The theory in section 4 implies that a sale lasts one time period. From Figure 1 and Table 2 we see that sales may last for more than one week. If consumers only periodically go shopping, this may be intended to reach a large fraction of customers. The theory in section 4 does not provide an explanation for this behavior. To resolve this issue, we omit all sale observations except the first week of the sale. An additional problem is that the initial values for lagged values are missing. In the estimation we omit observations stemming from the first twelve weeks. The first observation for supermarket k begins in week thirteen.

Tables 7 and 8 report probit estimates for the decision to conduct a sale for Heinz and Hunts using weekly data.[19] The dependent variable equals one if the price falls below a certain threshold. As discussed in section 2, we interpret prices below $1.20 as sale prices. Since this definition may seem somewhat arbitrary we report estimates for different threshold levels. Specifically, results are reported for thresholds of 0.99, 1.09 and 1.19. Observe that the definition of explanatory variables changes as the threshold varies.

Explanatory variables include MIN-T-HEINZ, the minimum time elapsed since the last sale for Heinz ketchup across all supermarkets, MIN-T-HUNTS, the minimum time elapsed since the last sale for Hunts ketchup across all supermarkets, T-HEINZ, the time elapsed since the last sale for Heinz ketchup in the supermarket under consideration, T-HUNTS, the

[16] As is discussed in section 2, the predicted equilibrium outcome in Theorem 2 extends to the case of serially correlated wholesale prices.

[17] As described before, price changes occur typically on a Wednesday. Following a price change, the price stays at this level for at least one week. We select Wednesday observations in the estimation and omit observations during other weekdays.

[18] Eight weeks are used to account for possible variations in wholesale prices of the two competing products. We also estimated the model using dummies measuring shorter and longer time periods. The results were qualitatively very similar.

[19] Although daily price data are available we report estimates using weekly prices. The reason is that the decision period is weekly since most of the price changes occur on a Wednesday. An estimation using daily prices yielded qualitatively similar results.

time elapsed since the last sale for Hunts ketchup in the supermarket under consideration, 4^{th}-OF-JULY, a dummy variable that equals one between the 15^{th} of June and the 15^{th} of July, and a set of supermarket specific dummy variables which are not reported. In addition, a set of time specific dummy variables are included, but not reported. All non-qualitative variables are in logarithm. To account for possible non-linearities, squared terms of variables are included in Table 8.[20]

In Table 7, the null hypothesis that the duration variables are jointly not significant can be rejected for the first two thresholds at the one percent level and for the threshold of 1.19 at the two percent level. In Table 7, the null hypothesis of no significant effects can be rejected for all three thresholds at the one percent level.

If sales are not affected by the interaction between retailers, then this should be detected by examining whether the minimum time elapsed since the last sale across stores has a significant effect on the decision to hold a sale in a particular supermarket. Under the null hypothesis, T-H-MIN=0; that is, the parameters measuring the effect of the elapsed time in other chains are zero.[21] The test statistic is distributed as a Chi-squared random variable. The test results are reported in Tables 6 and 7. In Table 7 the null can be rejected at the two percent level. In Table 8 the null can be rejected in two of three cases at the ten percent level. At the threshold level of 1.19 the null cannot be rejected.

The main implications in Table 7 are the following. An inspection of the linear and quadratic coefficients of time variables reveals that, with two exceptions, all linear coefficients are positive and all quadratic coefficients are negative. This implies that, as a particular explanatory variable increases, the probability of a sale increases initially and then decreases. The exceptions occur at the threshold of 1.09 for the variable MIN-T-HUNTS and at the threshold of 1.19 for the variable MIN-T-HEINZ. In the first exception an increase in the variable reduces the probability for a small range and then increases it. In the second case, the variable has a negative effect on the probability of a sale. To evaluate and compare the effects of different variables we calculate their effects at the sample mean of the variable and contrast it to their effect when the variable equals zero, holding other variables constant. This reveals that store specific variables have stronger effects than

[20] We omit squared terms of variables in Table 9 due to the small number of sales observations.

[21] The null corresponds to the restriction $\gamma = 1$ in section 4.

variables measuring duration in competing stores.[22]

Table 8 reports the results for Hunts. There are only a total of 40 sales observations at the threshold of 0.99 and, therefore, only linear coefficients of duration variables are included. An examination of coefficients reveals that with one exception duration variables have positive effects. As the time since the last sale in the own or competing store increases sales are more likely to occur. The exception occurs at the threshold of 0.99 for the variable MIN-T-HEINZ. There the effect is negative.

Warren and Barsky (1995) document that sales for consumer appliances occur on weekends and holidays. Table 5 reveals that, at least for Hunts, the peak period of demand is during the early summer. A 4$^{\text{th}}$ OF JULY dummy variable is included in Tables 7 and 8 to examine this effect. Both, in Table 7 and in Table 8, the dummy variable is positive. It is significant in all but one specification. The probability of a sale is higher during periods of high demand which confirms the finding of Warren and Barsky.

To determine whether the competition for accumulated shoppers is less important than the monopoly sales decision the following test is constructed. We estimate the sales decision of the monopolist using only supermarket specific variables measuring the time since last sale, within the supermarket under consideration, for each product. We include variables for Heinz and Hunts separately to permit product specific effects. The competitive sales decision is estimated using only the minimum time since last sale across all supermarkets. The monopoly sales decision is estimated using only store specific duration variables. The two alternative models correspond to the extreme cases of $\gamma = 0$ and $\gamma = 1$ in section 2. To determine which model fits the data best we use Akaike's information criterion. Since the number of parameters is the same in both specifications this is equivalent to comparing the likelihood of the two specifications. We find that for Heinz the competitive model fits the data better than the monopoly model at the lowest two thresholds. For the highest

[22] The relative effects are the following: We first report effects for the threshold 0.99 and then comment on other thresholds. Supermarket specific variables have strong effects, with an average effect of 0.81 for T-HEINZ and 0.98 for T-HUNTS. The effect of T-HEINZ-MIN equals 0.32. For T-HUNTS-MIN the effect equals 0.10 at the sample mean relative to the effect of zero. As we move to higher thresholds the effects of these variables become the following: T-HEINZ has an effect of 0.62 and 0.06. The effect of T-HUNTS becomes 0.50 and then equals 0.10 at the threshold of 1.19. The effect of T-HEINZ-MIN declines to 0.28 and -0.24. The effect of T-HUNTS-MIN becomes 0.05 at the threshold 1.09, and 0.30 at the threshold 1.19.

thresholds the monopoly model fits the data better than the competitive model. For Hunts, the monopoly model fits the data better at all three thresholds. The test compares two extreme cases and suggests that competition for lows that are shoppers is important at least for the sale decision of Heinz.

As pointed out in section 4 the model permits several equilibria. A symmetric equilibrium in which retailers behave in the same way in every time period, and asymmetric equilibria in which one or more retailers refrain from holding a sale in some time periods. In the symmetric equilibrium the variables measuring time since last sale increase the probability of sale. Under asymmetric equilibria, these variables affect the probability of sale, but not necessarily in a monotone way. Moreover, in the symmetric equilibrium there should be no differences across retailers. In asymmetric equilibria there may be differences across retailers. Of course differences across retailers may also arise if demand differs across stores. The coefficients in Tables 7 and 8 may indicate whether the observed behavior is more likely to have arisen from asymmetric or symmetric behavior. An examination of coefficients did not indicate asymmetric behavior. The estimates support the symmetric equilibrium.[23]

To summarize, the estimates of the decision to hold a sale support the model in section 4. Both store specific and competitive duration variables are significant. Product specific duration variables have stronger effects than duration variables for the competing brand. In the next section the determinants of demand during a sale period are reported.

5.2. DEMAND EFFECTS

We next consider the determinants of demand. According to equation (2) demand during a sale period in supermarket k for product i, $D^i_{k,t}$, equals the stock of low valuation consumers plus high valuation consumers. This can be estimated from the data using the time since last sale as a measure for the stock of low valuation consumers. Specifically,

[23] There are two variables that may be examined. First, the time since the last sale, and second, the supermarket specific dummy. As described above in Table 7, the variables measuring the time since the last sale consistently increase the probability of sale at a decreasing rate. This is in accordance with the predictions of the symmetric equilibrium. In Table 8 the results are similar. The time since the last sale has a positive effect on the probability of a sale. The store specific dummies may indicate differences across super markets. For Heinz we cannot reject the null, that super market specific dummies have no effect. For Hunts, the null is rejected at the one percent level. A closer examination reveals that chain four offers Hunts more frequently on sale than other chains. Between chains one, two and three there are very little differences.

demand conditional on a sale period is described by

$$D^i_{k,t} = \alpha T_{k,t} + \beta X_{k,t} + \nu_{k,t} \tag{5}$$

where D denotes demand during the first week of a sale, $T_{k,t}$ denotes a vector of duration variables, X denotes additional explanatory variables, and $\nu_{k,t}$ is idiosyncratic randomness.

To account for selection of sales periods, we include the mills ratio in the estimation. It is constructed from the first stage probit estimates of equation (4). Tables 9 and 10 report the determinants of weekly demand in supermarkets during the first week of a sale period. Explanatory variables include duration variables that measure the time since the last sale in weeks[24], an advertising indicator that measures whether advertising appeared in the last edition of the newspaper and a variable that measures average sales volume during a sale period in that store. In order to account for possible non-linearities squared terms for duration variables are included in Table 9. In Table 10, due to the smaller number of observations, only linear duration variables are used.

In Table 9 about 60 percent of the variation in demand is explained. In Table 10 more than 49 percent in the variation in demand is explained. To determine whether duration variables are jointly significant we construct an F-test. In Table 9 the null of no significant effects can be rejected at the threshold of 0.99 at the five percent level and at the thresholds of 1.09 at the one percent level. In Table 10, the null cannot be rejected at the lowest threshold, but can be rejected at the threshold of 1.09 at the two percent level.

The effects of duration variables in Table 9 are the following: An examination of coefficients reveals that linear coefficient have a positive sign and quadratic coefficients have a negative sign. The coefficients imply that, as a particular duration variable increases, demand is increased initially and then decreased. To illustrate the effect of variables, we report the marginal effect of duration variables evaluated at two values: Two and four weeks. For comparison the sample mean of the variable T-HEINZ equals 3.8 weeks with a standard deviation of 8.1 weeks. We first report effects at the lowest threshold and then comment on the effects at the threshold of 1.09. Two weeks after the last sale of Heinz, a one percent increase in T-HEINZ increases demand by 0.37 percent. This effect falls to 0.14

---

24 Measuring time since the last sale in weeks appears appropriate from Table 2. However, we also used biweekly measurement and the results were similar.

percent after 4 weeks. The marginal effect of T-HUNTS equals 0.21 percent after two weeks. This effect declines to 0.18 percent after four weeks. Two weeks after the last Heinz sale in any store, a one percent increase in MIN-T-HEINZ increases demand by 0.40 percent. After four weeks this effect declines to 0.35 percent. The marginal effect of MIN-T-HUNTS equals 0.12 percent after two weeks. At the threshold of 1.09 the effects in Table 8 are the following: A one percent increase in T-HEINZ increases demand by 0.86 percent two weeks after the last sale and 0.30 percent after four weeks. The marginal effect of T-HUNTS equals 0.21 percent after two weeks and declines to 0.18 percent after four weeks. MIN-T-HEINZ has an effect of 0.24 percent after two weeks and the marginal effect of MIN-T-HUNTS equals 0.44 after two weeks.

In Table 10, duration variables enter only linearly. The effects of store specific duration variables is the following: The effect of an increase of T-HUNTS by one percent on the demand of Hunts equals 0.08 at both thresholds. The effect of an increase of T-HEINZ by one percent on the demand of Hunts equals 0.14 at the threshold of 0.99 and it equals 0.36 at the threshold of 1.09.

To assess the importance of the demand accumulation effects, we next report the cumulative effect of store specific duration variables. For Heinz, the cumulative effect can be calculated from the linear and quadratic coefficients in Table 9. We first comment on the cumulative effects at the threshold of 0.99: T-HEINZ increases Heinz demand by 30 percent after four weeks. If all other stores do not hold a sale for Heinz during this time period, then Heinz demand increases additionally by 30 percent. T-HUNTS increases Heinz demand by 20 percent after four weeks. The effects are larger in magnitude at the threshold of 1.09: As T-HEINZ increases from zero to four weeks, Heinz demand is increased by a total of 138 percent. T-HUNTS increases Heinz demand by 21 percent after four weeks.[25]

[25] For Hunts the effects are in general smaller in magnitude. At the threshold of 0.99 T-HUNTS increases Hunts demand by 8 percent after four weeks. T-HEINZ increases Hunts demand by 19 percent after four weeks. The effect of T- HUNTS increases to 14 percent at the threshold of 1.09 and the effect of T-HEINZ increases to 200 percent at the threshold of 1.09.

6. CONCLUSION

This paper examines supermarket prices for ketchup products to explain temporary price reductions. We find that demand at low price levels depends on past prices, suggesting intertemporal effects in demand. Based on the descriptive data analysis, a model of intertemporal pricing is considered in which a fixed number of consumers arrive every period. Low valuation consumers may wait for the occurrence of a sale and, thus, the stock of low valuation consumers accumulates in the duration since the last sale. We distinguish two stocks: a stock of store loyal consumers and a stock of shoppers.

We find that the timing of ketchup sales is well explained by the model. Store loyal consumers are important for the timing of sales. The probability of a sale is increasing in the stocks at a decreasing rate. In addition, competition between retailers for accumulated shoppers, similar to Sobel (1984), influences the sale decision.

The demand accumulation effect implies that the number of units purchased at low prices increase in the duration since last sale. At a sale price of 0.99 cents, an increase in the time since last sale of Heinz at the same store from 0 to 4 weeks increases Heinz demand by 31 percent. If all other stores do not hold a sale for Heinz during this time period, then Heinz demand increases additionally by 30 percent. The demand accumulation effect is asymmetric. It affects demand during low prices, but not during high prices. Thus, estimates of the demand-elasticity of Ketchup based on a static model may be substantially overestimated.

7. APPENDIX

Proof of Theorem 1: We consider the case in which $m = 1$. To obtain the case $\gamma = 1$ demand in all time periods is rescaled by a factor of m. The analysis does not change.

First observe that the retailer prefers to sell to high valuation consumers than not selling any goods at all. The optimal price in non-sale periods equals v_1. During a sale period, the optimal price equals v_2, since this is the highest price at which low valuation consumers are willing to purchase. The policy of the retailer can thus take only two values, sale or no sale. Let $V(T, c)$ denote the expected discounted future payoff to a retailer under the optimal pricing policy, with state of demand characterized by T and current cost realization c. We can write the functional equation of the problem in the following way

$$V(T,c) = \max\{[\alpha + T(1-\alpha)](v_2 - c) + \delta E_{c'}V(1,c'), \alpha(v_1 - c) + \delta E_{c'}V(T+1,c')\} \quad \text{(A1)}$$

where $E_{c'}$ denotes the expectation operator. The first term in the max is the gain from holding a sale and the second term is the gain from not holding a sale. The retailer holds a sale if the first term in the max exceeds the second term. Clearly a retailer will not hold a sale if $c > v_2$, since this results in a loss. If the cost is low, $c < v_2$, the retailer is willing to hold a sale if the gains from holding a sale exceed the expected future gains from not holding a sale in that period,

$$[\alpha + T(1-\alpha)](v_2 - c) + \delta E_{c'}V(1,c') \geq \alpha(v_1 - c) + \delta E_{c'}V(T+1,c')$$

Equivalently, this can be rewritten as

$$T(1-\alpha)(v_2 - c) - \alpha(v_1 - v_2) \geq \delta E_{c'}[V(T+1,c') - V(1,c')] \quad \text{(A2)}$$

Let $\overline{T}_i$ denote the smallest T such that equation (A2) is satisfied at cost realization c_i. Observe that $\overline{T}_1 < \overline{T}_2$, since the right hand side in (A2) is independent of the current period cost realization and the left hand side is decreasing in the cost.

We next show that for $T > \overline{T}_i$ the retailer holds a sale if the cost realization is c_i. We prove this first for cost realization c_1, and then for cost realization c_2. Consider the following inequalities for cost realization c_1:

$$\begin{aligned}(\overline{T}_1 + j)(1-\alpha)&(v_2 - c_1) - \alpha(v_1 - v_2) \\ &\geq j(1-\alpha)(v_2 - c_1) + \delta E_{c'}[V(\overline{T}_1 + 1, c') - V(1,c')] \\ &> \delta E_{c'}[V(\overline{T}_1 + 1, c') + j(1-\alpha)(v_2 - c_1) - V(1,c')] \\ &\geq \delta E_{c'}[V(\overline{T}_1 + j + 1, c') - V(1,c')]\end{aligned}$$

The first inequality is obtained by adding $j(1-\alpha)(v_2 - c_1)$ on both sides of inequality (A2). The second inequality is strict since $\delta < 1$. To see the third inequality observe that $V(T+1,c') - V(T,c') \leq (v_2 - c_1)(1-\alpha)$. The policy in state (T,c') that mimics the behavior of the policy at $(T+1,c')$ achieves this bound. Repeated application of this bound establishes the inequality. This completes the proof for cost realization c_1.

To complete the proof we consider next the cost realization c_2. We distinguish two cases, $v_2 - c_2 \geq \delta E_c[v_2 - c]$ and $v_2 - c_2 < \delta E_c[v_2 - c]$.

First case: $v_2 - c_2 \geq \delta E_c[v_2 - c]$. Consider the following inequalities.

$$\begin{aligned}(\overline{T}_2 + j)(1-\alpha)(v_2 - c_2) - \alpha(v_1 - v_2) \\ &\geq j(1-\alpha)\delta E_c[v_2 - c] + \delta E_{c'}[V(\overline{T}_2 + 1, c') - V(1, c')] \\ &= \delta E_{c'}[V(\overline{T}_2 + 1, c') + j(1-\alpha)(v_2 - c') - V(1, c')] \\ &\geq \delta E_{c'}[V(\overline{T}_2 + j + 1, c') - V(1, c')]\end{aligned}$$

The first inequality is obtained by adding $j(1-\alpha)(v_2 - c_2)$ on both sides of inequality (A2) evaluated at $\overline{T}_2$ and using $v_2 - c_2 \geq \delta E_c[v_2 - c]$. The second equality is obtained by rearranging terms. The last inequality repeatedly uses $E_{c'}[V(T+1, c') - V(T, c')] \leq (1-\alpha)E_c[v_2 - c]$. To see that this inequality is satisfied, observe that for $T \geq \overline{T}_2$ a sale always occurs if the cost realization equals c_1. The marginal gain in the value function is thus given by

$$\begin{aligned}E_{c'}[V(T+1, c') - V(T, c')] &= (1-\alpha)\rho(v_2 - c_1) \\ &+ (1-\rho)\max\{(v_2 - c_2)(1-\alpha), \delta E_{c'}[V(N+2, c') - V(T+1, c')]\}\end{aligned}$$

This equation is satisfied for any $T > \overline{T}_2$ and we can solve it: If $(v_2 - c_2)(1-\alpha) \geq \delta E_{c'}[V(N+2, c') - V(T+1, c')]$ for all T, then solving yields $E_{c'}[V(T+1, c') - V(T, c')] = (1-\alpha)E_c[v_2 - c]$. Since $v_2 - c_2 \geq \delta E_c[v_2 - c]$, this is indeed a solution. Suppose next $(v_2 - c_2)(1-\alpha) < \delta E_{c'}[V(N+2, c') - V(T+1, c')]$ for some T. If $(v_2 - c_2)(1-\alpha) \geq \delta E_{c'}[V(N+3, c') - V(N+2, c')]$, then $E_{c'}[V(N+2, c') - V(T+1, c')] = (1-\alpha)E_c[v_2 - c]$; a contradiction. Thus it has to be that $(v_2 - c_2)(1-\alpha) < \delta E_{c'}[V(N+2, c') - V(T+1, c')]$ for all T. Solving yields $E_{c'}[V(T+1, c') - V(T, c')] = \frac{\rho(v_2 - c_1)}{1 - \delta(1-\rho)}(1-\alpha)$. Since $v_2 - c_2 \geq \delta E_c[v_2 - c]$ this cannot be a solution and the first guess is the only solution. This concludes the proof for the first case.

Second case: $v_2 - c_2 < \delta E_c[v_2 - c]$. Since for $T \geq \overline{T}_2$ a sale always occurs if the cost realization equals c_1, the marginal gain in the value function is given by $E_{c'}[V(T+1, c') - V(T, c')] = \rho(v_1 - c_1)(1-\alpha) + (1-\rho)\max\{(v_2 - c_2)(1-\alpha), \delta E_{c'}[V(N+2, c') - V(T+1, c')]\}$. Using the assumption, $v_2 - c_2 < \delta E_c[v_2 - c]$, we can solve this equation in the same way as before and obtain $E_{c'}[V(T+1, c') - V(T, c')] = \frac{\rho(v_2 - c_1)}{1 - \delta(1-\rho)}(1-\alpha)$. Consider now equation (A2). Suppose it holds for the first time at some $\overline{T}_2$. At $\overline{T}_2 - 1$ we have

$$(\overline{T}_2 - 1)(1-\alpha)(v_2 - c) - \alpha(v_1 - v_2) < \delta E_{c'}[V(\overline{T}_2, c') - V(1, c')]$$

Subtracting the right hand side of this inequality from the left hand side in equation (A2), and the left hand side from the right hand side in equation (A2) yields,

$$(1-\alpha)(v_2-c_2) \geq \delta E_{c'}[V(\overline{T}_2+1,c') - V(\overline{T}_2,c')]$$
$$= \frac{\rho(v_1-c_1)}{1-\delta(1-\rho)}(1-\alpha)$$

The equality follows from the previous argument. Canceling and rearranging yields, $(v_2 - c_2) \geq \delta[\rho(v_2-c_1) + (1-\rho)(v_2-c_2)]$. The right hand side equals $\delta E_c[v_2 - c]$, which is a contradiction. Thus, in the second case $\overline{T}_2 = \infty$. This completes the proof.

QED

Before establishing the next theorem we state the following Lemma due to Sobel (1984). It shows that the per period payoff during a sale period equals the payoff during a non-sale period. The proof is similar to a Bertrand argument. The lemma does not require a stationary wholesale price distribution, and holds for any family of distribution functions.

Lemma 3. *For any retail store the profit in period T, with wholesale price c, is given by $\frac{\alpha}{m}(v_1 - c)$.*

Proof of Theorem 2: Consider any state of demand T with cost realization c. Let $G_{-k}(p)$ denote the price distribution of the minimum price charged in retail stores other than retail store k . Let $[\underline{p},\overline{p}]$ be the set of points that contain the support of prices charged below v_2 during a sale period for product i in period T. The profit from charging prices in this region is given by $[\frac{\alpha}{m} + T(1-\alpha)](p-c)[1-G_{-k}(p)]$. From the previous lemma in equilibrium this equals $\frac{\alpha}{m}(v_1 - c)$. Rearranging this equality we obtain.

$$G_{-k}(p) = 1 - \frac{\frac{\alpha}{m}}{(v_1-c)}[\frac{\alpha}{m} + T(1-2\alpha)](p-c)$$

Let $G(p)$ denote the price distribution of retail store k. By symmetry assumption, the distribution of the minimum price charged in retail stores, other than retail store k, is the first order statistic of $m-1$ draws from G, and is given by $G_{-k}(p) = 1-[1-G(p)]^{m-1}$. We can rewrite this expression to obtain the price distribution in retail store k as $G(p) = 1-[1-G_{-k}(p)]^{\frac{1}{m-1}}$. Substituting the above expression for $G_{-k}(p)$ yields the second line of $G(p)$ in the theorem.

To characterize the range $[\underline{p},\overline{p}]$, observe that the lower endpoint of the support is given by the equation $G(p)=0$, or $1 - \frac{\frac{\alpha}{m}}{(v_1-c)}[\frac{\alpha}{m} + T(1-\alpha)](p-c) = 0$. This can be rewritten as $\underline{p} - c = \frac{\frac{\alpha}{m}(v_1-c)}{\frac{\alpha}{m}+T(1-\alpha)}$. To see that the upper end point of the support is given by $\overline{p} = v_2$, suppose not, that is $\overline{p} < v_2$. Then the profit of a seller charging v_2 during a sale period is given by $[\frac{\alpha}{m}+T(1-\alpha)](v_2-c)\frac{\frac{\alpha}{m}(v_1-c)}{[\frac{\alpha}{m}+T(1-\alpha)](\overline{p}-c)} = \frac{v_2-c}{\overline{p}-c}\frac{\alpha}{m}(v_1-c) > \frac{\alpha}{m}(v_1-c)$, a contradiction to the lemma.

QED

Example of an Asymmetric Equilibrium. Suppose all but the first two retailers always charge price v_1, and the first two retailers charge a price according to the following strategy. If $T < \frac{\alpha(v_1-c)}{(1-\alpha)(v_2-c)}$, or if $c > c^j$, then the price equals v_1, otherwise the price is drawn from the distribution function

$$G(p,T,c) = \begin{cases} 0 & \text{if } p < c + \frac{\frac{\alpha}{m}(v_1-c)}{T(1-\alpha)}; \\ 1 - [\frac{\frac{\alpha}{m}(v_1-c)}{\frac{\alpha}{m}+T(1-\alpha)(p-c)}] & \text{if } p \in [c + \frac{\frac{\alpha}{m}(v_1-c)}{\frac{\alpha}{m}+T(1-\alpha)}, v_2]; \\ 1 - [\frac{\frac{\alpha}{m}(v_1-c)}{\frac{\alpha}{m}+T(1-\alpha)(v_2-c)}] & \text{if } p \in [v_2, v_1); \\ 1 & \text{if } p = v_1. \end{cases}$$

To see that this constitutes an equilibrium consider either of the first two retailers. If retailer 1 charges a price of v_1 she makes a profit of $\frac{\alpha}{m}(v_1 - c)$, which is the best she can do by Lemma 3. If she charges a price $p \in [c + \frac{\frac{\alpha}{m}(v_1-c)}{\frac{\alpha}{m}+T(1-\alpha)}, v_2]$ she receives $[\frac{\alpha}{m} + T(1-\alpha)](p - c)\frac{\frac{\alpha}{m}(v_1-c)}{[\frac{\alpha}{m}+T(1-\alpha)](p-c)}$, which equals $\frac{\alpha}{m}(v_1 - c)$. No other price yields higher payoffs; So the strategy is optimal for retailers 1 and 2. Now consider retailer 3. If he charges a price of v_1, he makes a profit of $\frac{\alpha}{m}(v_1 - c)$, which is the best he can do by Lemma 3. If he charges a price $p \in [c + \frac{\frac{\alpha}{m}(v_1-c)}{\frac{\alpha}{m}+T(1-\alpha)}, v_2]$, he receives $[\frac{\alpha}{m} + T(1-\alpha)](p-c)[\frac{\frac{\alpha}{m}(v_1-c)}{[\frac{\alpha}{m}+T(1-\alpha)](p-c)}]^2$, which equals $\frac{\alpha}{m}(v_1 - c)[\frac{\frac{\alpha}{m}(v_1-c)}{[\frac{\alpha}{m}+T(1-\alpha)](p-c)}]$; this is less than $\frac{\alpha}{m}(v_1 - c)$ since the term in square brackets is less than one. All other possible prices do not yield payoffs exceeding $\frac{\alpha}{m}(v_1 - c)$; thus the strategy is optimal for retailers $k = 3, ..., m$. The strategies described above constitute an equilibrium.

8. REFERENCES

Ackerberg, D. (1996), Ph.D. Dissertation, Yale University.

Aguirregabiria, V. (1999), "The Dynamics of Markups and Inventories in Retailing Firms", Review of Economic Studies, 66 (2), 275-308.

Blattberg, R.C., Briesch, R. and Fox, E.J. (1995) "How Promotions Work", Marketing Science, 14, 122-132.

Blattberg, R.C. and Neslin, S.A. (1989) "Sales Promotion: Concepts, Methods and Strategies", Prentice Hall, Englewood Cliffs, NJ.

Conlisk, J. Gerstner, E. and Sobel, J. (1984), "Cyclic Pricing by a Durable Goods Monopolist", Quarterly Journal of Economics, 99, 489-505.

Lal, R. (1990), "Manufacturer Trade Deals and Retail Price Promotions", Journal of Marketing Research, 27, 428-44.

Lal, R. and Matutes, C. (1994), "Retail Pricing and Advertising Strategies", Journal of Business, 67, 345-370.

Neslin, A.S., Powell, S.G. and Schneider-Stone, L. (1995) "The Effects of Retailer and Consumer Response on Optimal Manufacturer Advertising and Trade Promotion Strategies", Management Science, 41, 749-66.

Ross, T.W. (1984) "Winners and Losers Under the Robinson-Patman Act", Journal of Law and Economics, 27, 243-71.

Slade, M.E. (1996) "Optimal Pricing with Costly Adjustment: Evidence from Retail- Grocery Prices", forthcoming Review of Economic Studies.

Slade, M.E. (1996) "Sticky Prices in a Dynamic Oligopoly: An investigation of (s,S) Thresholds", mimeo, Department of Economics, The University of British Columbia.

Sobel, J. (1984), "The Timing of Sales", Review of Economic Studies, 353-368.

Sobel, J. (1991), "Durable Goods Monopoly with Entry of New Consumers", Econometrica, 59, 1455-1485.

Stokey, N. and Lucas R. with E. Prescott (1989), "Recursive Methods in Economic Dynamics," Harvard University Press.

Varian, H.R. (1980) "A Model of Sales", American Economic Review, 70, 651-59.

Warner, E.J. and Barsky, R.B. (1995) "The Timing and Magnitude of Retail Store Markdowns: Evidence from Weekends and Holidays", Quarterly Journal of Economics, 321-352.

Table 1: Summary Statistics for Selected Variables:

Variable:	Mean	STD	Min	Max
Number of Supermarkets per Chain:	5.25	2.63	3	9
Market Share of Heinz 32 per Chain:	25.78	3.10	21.15	27.78
Market Share of Hunts 32 per Chain:	18.04	6.10	12.02	26.46
P-HEINZ$_t$:	1.35	0.18	0.79	1.79
P-HUNTS$_t$:	1.35	0.18	0.79	1.69
MIN-P-HEINZ$_t$:	1.05	0.15	0.79	1.39
MIN-P-HUNTS$_t$:	1.05	0.11	0.79	1.39

Table 2: Distribution of Prices

P-HEINZ:

Level	0.79	0.89	0.99	1.19	1.29	1.39	1.45	1.46	1.49
Percent:	0.8	0.5	13.2	10.2	4.1	21.9	4.1	22.1	13.1
% of Demand:	6.7	5.3	33.5	15.1	3.6	7.9	2.0	12.5	5.4
Avg # of Days:	9.7	6.7	24.6	19.0	19.9	45.2	53.4	50.6	20.3

P-HUNTS:

Level	0.89	0.99	1.09	1.19	1.31	1.39	1.43	1.44	1.49	1.53	1.79
Percent:	0.9	6.4	3.1	15.4	16.1	8.6	13.3	5.1	11.2	4.8	4.8
% of Demand:	4.1	32.1	3.6	18.5	4.4	3.0	8.3	2.1	4.6	3.3	1.0
Avg # of Days:	10.5	22.8	25.6	35.3	48.3	56.7	82.5	59.2	59.3	96.3	85.8

Table 3: Correlation between Heinz and Hunts Prices:

	within Chain		Across Chains	
	P-HEINZ$_t$	P-HUNTS$_t$	P-HEINZ$_t$	P-HUNTS$_t$
P-HEINZ$_t$	0.52	0.14	0.04	0.07
P-HUNTS$_t$	-	0.47	-	0.21

All correlation coefficients are significant at the 1% level.

Table 4: TOBIT Regression: Demand for Heinz:

Dependent Var:	Logarithm of Heinz Equilibrium Demand at Price Levels					
Observations:	16757					
Degrees of Freedom:	16556					
Chi-Squared:	4208.5					
P-HEINZ$_t$	≤ 0.99		[1.00, 1.19]		>1.20	
P-HUNTS$_t$	<1.2	≥1.2	<1.2	≥1.2	<1.2	≥1.2
# of Observations in this Category	838	1773	570	1192	3129	9255
Variable:						
P-HEINZ$_{t-7}$	2.078	2.298	-1.453	0.780	-0.664	0.130
	(3.1)	(5.7)	(1.4)	(1.1)	(1.0)	(0.4)
P-HUNTS$_{t-7}$	1.021	7.024	0.061	1.351	0.084	1.040
	(0.9)	(6.9)	(0.1)	(1.9)	(0.2)	(3.2)
MIN-P-HEINZ$_{t-7}$	1.162	1.915	3.312	-0.544	-0.701	-0.506
	(1.3)	(3.8)	(1.9)	(0.5)	(1.3)	(2.3)
MIN-P-HUNTS$_{t-7}$	0.873	2.587	-3.062	0.176	-0.019	0.416
	(0.8)	(3.0)	(2.6)	(0.2)	(0.0)	(1.4)
HEINZ-ADVERTISING	1.030	1.439	1.586	1.730	2.019	2.151
	(8.1)	(16.8)	(8.0)	(13.6)	(10.5)	(14.6)
HUNTS-ADVERTISING	-	-0.620	-0.804	-	-0.152	-0.651
		(1.2)	(2.0)		(0.9)	(1.3)
OTHER-PRODUCT-ADVERTISING	0.153	0.139	0.283	-0.132	-0.029	-0.190
	(0.5)	(0.8)	(0.9)	(0.5)	(0.2)	(2.3)
4th-OF-JULY	-0.083	-0.208	0.179	-0.074	0.082	0.036
	(0.5)	(1.8)	(0.9)	(0.6)	(0.7)	(0.1)
F-Test:						
H0: P-* = 0	6.93	41.5	0.9	2.0	0.54	5.4
	reject	reject	-	-	-	reject
H0: MIN-P-* = 0	142.7	11.4	3.6	0.2	0.9	2.8
	reject	reject	reject	-	-	reject
			(2 %)			(6 %)

All non-qualitative variables are in logarithm. A set of supermarket dummies and weekday dummies is included, but not reported. Absolute values of t-statistics are displayed in parenthesis. A "-" instead of a coefficient estimate indicates that the variable is collinear with other variables. Unless otherwise indicated, a "reject" denotes a rejection of the null hypothesis at the 1 percent level.

Table 5: TOBIT Regression: Demand for Hunts:

Dependent Var:	Logarithm of Hunts Equilibrium Demand at Price Levels					
Observations:	16757					
Degrees of Freedom:	16563					
Chi-Squared:	2845.9					
P-HUNTS$_t$	≤ 0.99		[1.00, 1.19]		>1.20	
P-HEINZ$_t$	<1.2	≥1.2	<1.2	≥1.2	<1.2	≥1.2
# of Observations in this Category	292	753	1116	2376	2965	9255
Variable:						
P-HUNTS$_{t-7}$	-0.036	1.472	2.881	2.485	0.103	0.746
	(0.0)	(2.6)	(2.0)	(3.4)	(0.2)	(1.8)
P-HEINZ$_{t-7}$	7.427	-3.560	0.055	1.227	-0.519	0.559
	(5.8)	(2.2)	(0.8)	(1.7)	(1.0)	(1.6)
MIN-P-HUNTS$_{t-7}$	-4.771	1.483	0.267	-1.059	-3.040	-0.332
	(2.3)	(1.1)	(0.3)	(1.5)	(2.8)	(0.9)
MIN-P-HEINZ$_{t-7}$	8.379	-0.942	-0.678	-0.269	-1.839	-0.301
	(3.1)	(0.9)	(0.6)	(0.5)	(2.4)	(1.1)
HUNTS-ADVERTISING	1.319	1.186	2.246	1.799	1.850	2.344
	(3.8)	(7.1)	(2.8)	(11.6)	(5.8)	(10.5)
HEINZ-ADVERTISING	-0.001	-0.055	-0.155	0.378	-0.188	-0.148
	(0.0)	(0.1)	(0.9)	(1.3)	(1.4)	(0.5)
OTHER-PRODUCT-ADVERTISING	-0.277	-0.782	-0.548	0.077	0.018	0.047
	(0.5)	(2.6)	(1.4)	(0.5)	(0.1)	(0.5)
4th-OF-JULY	-	9.897	5.524	4.740	10.797	6.109
		(3.0)	(1.7)	(1.5)	(3.5)	(2.1)
F-Test:						
H0: P-* = 0	2.6	5.9	2.2	7.7	0.6	3.3
	reject	reject	-	reject	-	reject
	(8 %)					(4 %)
H0: MIN-P-* = 0	29.1	0.9	0.2	1.3	6.3	1.5
	reject	-	-	-	reject	-

All non-qualitative variables are in logarithm. A set of supermarket dummies and weekday dummies is included, but not reported. Absolute values of t-statistics are displayed in parenthesis. A "-" instead of a coefficient estimate indicates that the variable is collinear with other variables. Unless otherwise indicated in parenthesis, a "reject" denotes a rejection of the null hypothesis at the 1 percent level.

Table 6: Distribution of Preferred Chains by Average Price Paid for Repeat Purchasers:

Avg Price Paid	N	1st Chain	2nd Chain	3rd Chain
0 - 0.99	43	58.20 (14.8)	28.08 (11.4)	11.18 (7.0)
0.99 - 1.09	80	60.13 (17.7)	25.39 (11.4)	9.92 (7.7)
1.09 - 1.19	130	64.23 (17.2)	24.38 (10.8)	8.64 (7.3)
1.19 - 1.29	95	68.68 (18.8)	21.72 (12.6)	7.80 (7.2)
1.29 - 1.79	81	72.51 (18.7)	19.48 (13.7)	6.20 (6.4)
All Repeat Purchasers[1]	429	65.4 (18.3)	23.4 (12.3)	8.5 (7.3)
All Consumers	1453	66.0 (18.2)	23.1 (12.3)	8.4 (7.4)

1: Data consist of 429 consumers with at least 4 purchases of Heinz or Hunts Ketchup. Standard errors are displayed in parenthesis.

Table 7: Probit: Probability of Sale of Heinz:

Dependent Var:	SALE = 1 if P- HEINZ$_t$ ≤ P-CRITICAL, SALE = 0 Otherwise;		
P-CRITICAL	0.99	1.09	1.19
NUMBER OF SALES	100	108	109
Observations:	1388	1521	1484
Degrees of Freed.:	1351	1483	1447
Chi-squared:	136.9	133.8	110.1
Variable			
T-HEINZ$_t$	0.7695	0.6557	0.4455
	(2.2)	(2.1)	(1.3)
T-HEINZ-SQ$_t$	-0.1772	-0.1617	-0.0777
	(2.4)	(2.4)	(0.9)
T-HUNTS$_t$	0.6842	0.4854	0.3574
	(2.6)	(2.9)	(2.5)
T-HUNTS-SQ$_t$	-0.1181	-0.1091	-0.1613
	(2.5)	(3.1)	(3.7)
MIN-T-HEINZ$_t$	1.0939	0.9925	-0.5960
	(1.9)	(1.8)	(2.3)
MIN-T-HEINZ-SQ$_t$	-0.7335	-0.6823	
	(2.0)	(1.9)	
MIN-T-HUNTS$_t$	0.2413	-0.1322	0.8215
	(0.6)	(0.3)	(2.8)
MIN-T-HUNTS-SQ$_t$	0.0818	0.7306	
	(0.2)	(2.5)	
4th-OF-JULY	1.7819	1.6852	1.0558
	(6.3)	(6.1)	(4.3)
Chi-squared Test:			
H0: MIN-T-* =0	14.8	12.9	11.7
	reject	reject	reject
		(2.%)	
H0: T-* = 0	8.03	8.6	6.34
	reject	reject	
	(10%)	(10%)	

All variables are in logarithms. A set of time specific dummy variables is included but not reported. Absolute values of t-statistics are displayed in parenthesis. Chi-square-statistics are reported for two tests. The first test, MIN-T-*=0, reports the joint significance of the parameters MIN-T-HEINZ, MIN-T-HEINZ-SQ, MIN-T-HUNTS and MIN-T-HUNTS-SQ. The second test, T-* = 0, reports the joint significance of T-HEINZ, T-HEINZ-SQ, T-HUNTS and T-HUNTS-SQ. Results of the test are reported at the bottom of the table. A "reject" indicates that the null is rejected at the 1 percent level except otherwise indicated. A "-" indicates that the null cannot be rejected.

Table 8: Probit: Probability of Sale of Hunts:

Dependent Var:	SALE = 1 if P-HUNTS$_t$ ≤ P-CRITICAL, SALE = 0 Otherwise;		
P-CRITICAL	0.99	1.09	1.19
NUMBER OF SALES	40	58	99
Observations:	1181	1337	1471
Degrees of Freed.:	1152	1306	1435
Chi-squared:	106.7	102.3	149.2
Variable			
T-HUNTS$_t$	0.5153	0.5356	0.3549
	(4.3)	(4.8)	(3.9)
T-HEINZ$_t$	0.5190	0.0846	0.1299
	(3.8)	(1.2)	(2.1)
MIN-T-HUNTS$_t$	0.7534	0.5836	0.0204
	(2.2)	(2.2)	(0.1)
MIN-T-HEINZ$_t$	-0.3094	0.5061	1.0485
	(1.1)	(2.0)	(3.0)
4th-OF-JULY	0.8623	1.0392	0.1311
	(2.8)	(3.7)	(0.6)
Chi-squared Test:			
H0: MIN-T-* = 0	4.5 reject (10%)	3.5 -	4.7 reject (10%)
H0: T-* = 0	21.2 reject	15.2 reject	10.6 reject

All variables are in logarithms. A set of time specific dummy variables is included but not reported. Absolute values of t-statistics are displayed in parenthesis. Chi-square-statistics are reported for two tests. The first test, MIN-T-* = 0, reports the joint significance of the parameters T-MIN-HEINZ, T-MIN- HUNTS. The second test, T-* = 0, reports the joint significance of T-HEINZ and T-HUNTS. Results of the test are reported at the bottom of the table. A "reject" indicates that the null is rejected at the 1 percent level except otherwise indicated. A "-" indicates that the null cannot be rejected.

Table 9: OLS: Demand of Heinz During the First Week of a Sale Period:

Dependent Var:	HEINZ DEMAND	
P-CRITICAL	0.99	1.09
Number of Sales	100	108
Degrees of Freedom	88	96
R-Squared	0.60	0.61
Variable		
T-HEINZ$_t$	0.5874	1.4280
	(1.7)	(3.8)
T-HEINZ-SQ$_t$	-0.1589	-0.4076
	(2.0)	(4.9)
T-HUNTS$_t$	0.2349	0.2266
	(0.9)	(1.3)
T-HUNTS-SQ$_t$	-0.0190	-0.0152
	(0.5)	(0.5)
MIN-T-HEINZ$_t$	0.4555	0.9210
	(1.1)	(0.4)
MIN-T-HEINZ-SQ$_t$	-0.0369	-0.4913
	(0.1)	(1.5)
MIN-T-HUNTS$_t$	1.7092	1.1547
	(2.5)	(1.8)
MIN-T-HUNTS-SQ$_t$	-1.1463	-0.5163
	(2.6)	(1.2)
HEINZ-ADVERTISING	0.9400	0.8078
	(7.1)	(6.0)
AVERAGE -STORE-SALES	0.7404	0.8214
	(5.0)	(5.2)
MILLS-RATIO	0.0550	0.2556
	(0.3)	(1.2)

All non-qualitative variables are in logarithms. Absolute values of t-statistics are displayed in parenthesis.

Table 10: OLS: Demand of Hunts During the First Week of a Sale Period:

Dependent Var:	HUNTS DEMAND	
P-CRITICAL	0.99	1.09
Number of Sales	40	58
Degrees of Freedom	32	50
R-Squared:	0.73	0.46
Variable		
$T\text{-}HUNTS_t$	0.0751	0.0840
	(1.0)	(0.7)
$T\text{-}HEINZ_t$	0.1583	0.3782
	(1.9)	(2.9)
$MIN\text{-}T\text{-}HUNTS_t$	0.5875	-0.1962
	(0.9)	(0.2)
$MIN\text{-}T\text{-}HEINZ_t$	-0.6195	-0.0418
	(0.9)	(0.0)
HUNTS-ADVERTISING	0.5130	0.1618
	(2.4)	(0.5)
AVERAGE-STORE-SALES	0.9379	0.8720
	(8.4)	(4.3)
MILLS-RATIO	0.3290	-0.2249
	(1.8)	(0.9)

All non-qualitative variables are in logarithms. Absolute values of t-statistics are displayed in parenthesis.

Figure 1: Prices for Selected Products in Supermarket 1: