

July, 2006

# Cost Pass-Through in Differentiated Product Markets: The Case of U.S. Processed Cheese

Donghun Kim\*

Ronald W. Cotterill

---

International University of Japan and University of Connecticut, respectively. Corresponding coauthor, Donghun Kim, [dhkim@iuj.ac.jp](mailto:dhkim@iuj.ac.jp), International Development Program, International University of Japan, Kokusai-cho, Minami Uonuma-shi, Niigata 949-7277, Japan. Fax:81-25-779-1187, Tel:81-25-779-1413. We would like to thank Robert T. Masson, Oleg Melnikov, Ted O'Donoghue, and George Jakubson for valuable suggestions. We are also grateful to anonymous referees and Editor Ken Hendricks for helpful comments.

# Cost Pass-Through in Differentiated Product Markets: The Case of U.S. Processed Cheese

## ABSTRACT

In this paper, we estimate a mixed logit model for demand in the U.S. processed cheese market. The estimates are used to determine pass-through rates of cost changes under different behavioral regimes. We find that, under collusion, the pass-through rates for all brands fall between 21% and 31% while, under Bertrand-Nash price competition, the range of pass-through rates are between 73% and 103%. The mixed logit model provides a more flexible framework for studying pass-through rates than the logit model since the curvature of the demand functions depends upon the empirical distribution of consumer types.

JEL: D40, D60, L13, L66, H20

Keyword: Market Structure, Cost Pass-Through, Consumer Welfare, Mixed Logit

## I. Introduction

In this paper we estimate cost pass-through rates in the market for processed cheese under Bertrand-Nash pricing and collusive pricing. Cost pass-through rates measure the proportion of a change in input costs that is passed through to price. A cost change may arise from various sources, including input price changes or changes in state or federal taxes. In processed cheese, the main input is raw milk. A frequently asked question in this market is: what is the impact of an increase in raw milk prices on cheese prices, consumer surplus, and profits? Our estimates of the cost-pass through rate provide an answer to these questions.

Early studies of cost pass-through have focused on two polar cases, perfect competition and monopoly. Under perfect competition, pass-through is determined by the relative demand and supply elasticities. The pass-through rate is greater when demand is more inelastic and supply more elastic; it is 100% when input supply is infinitely elastic. By contrast, the monopolist passes through only 50% of an input cost change when input supply is infinitely elastic and demand is linear (Bulow et al. 1983). Several studies have analyzed the effects of cost shocks under imperfect competition (Stern 1987, Katz & Rosen 1985, and Delipalla & Keen 1992). Most of the theoretical work have focused on homogeneous products with quantity competition. The empirical work consists mainly of reduced-form analysis using industry-level data (see, e.g., Sumner 1981; Sullivan 1985; Karp & Perloff 1989; and Besely & Rosen 1996). Few studies have studied the effect of cost changes on prices in differentiated product markets. The exceptions include theoretical studies by Anderson et al. 2001 and Froeb et al. 2005. The former analyzes the incidence of ad valorem and excise taxes in an oligopolistic industry with differentiated products and price-setting firms; the latter investigates the relationship under Bertrand oligopoly between the price effects of

mergers absent synergies and the rates at which merger synergies are passed through to consumers in the form of lower prices.

The main goal of this paper is to estimate cost pass-through rates for a differentiated product market using a structural model. We first estimate the demand system for the U.S processed cheese market using a mixed logit model.<sup>1</sup> We use the estimated demands in the firms' pricing equations to back out estimates of their marginal costs. We then change marginal costs and solve the model to obtain the new equilibrium prices.

We use the mixed logit model to estimate demand. This model provides greater flexibility in substitution patterns than the logit model. In the logit model, the curvature of demand system, i.e., the second derivatives, is determined by functional form assumptions; in the mixed logit model, it depends to a significant extent on the empirical distribution of consumers. This property is important for obtaining accurate estimates of cost pass-through rates.

We estimate cost pass-through under Bertrand-Nash pricing and fully collusive pricing in order to evaluate how pass-through depends upon behavior. We find that cost pass-through rates for the different brands under collusion lie between 21% and 31%. The corresponding pass-through rates under Bertrand-Nash pricing are much higher, between 73% and 103%. We also estimated the pass-through rates generated by the logit model to determine the importance of a more flexible specification. We find that logit pass-through rates are on average 12% lower than those of the mixed logit model.

---

<sup>1</sup> Refer to BLP 1995 and Nevo 2001. Nevo 2000 applied the model for merger analysis and Petrin 2001 used the model to estimate the consumer benefits of new products in the automobile industry.

We compared our pass-through estimates with those obtained from reduced-form models. Roughly speaking, the pass-through elasticities of the reduced-form model fall between those of Bertrand-Nash and collusive pricing. The reduced-form model does not impose a specific price-setting mechanism. Consequently, if the reduced form estimates are to be believed, then markups for processed cheese are lower than the monopoly markups but higher than Bertrand-Nash markups. Reduced form results are often used to infer competitiveness, but notice that it would be difficult to draw such inferences without knowing the estimates produced by the benchmark cases of Bertrand-Nash and full collusion. This is another reason for adopting a structural approach.

We proceed as follows. In Section II, we discuss the U.S. processed cheese market and the data. The empirical model is presented in Section III. In Section IV, we describe the estimation strategy. The empirical results are presented in Section V. In Section VI, we compare the structural approach to estimating cost-pass through rates to the reduced form approach. Section VII concludes.

## **II. Market and Data**

Processed cheese is used mostly in sandwiches and cheeseburgers and is typically sold pre-sliced. According to Mueller et al (1996), the four-firm concentration ratio at the 5-digit SIC level was around 70% during the sample period of 1988-1992. Franklin and Cotterill (1994) report some additional statistics on the processed cheese market for 1992. Table 1 shows the volume shares and average prices per pound of the leading processed cheese brands. Philip Morris, whose brands include Kraft and Velveeta, is the dominant firm with a volume share of around 50% in 1992. Borden

Inc., whose main brands are Borden and Lite Line, is a distant second to Philip Morris with a combined share of around 8%. The other national manufacturers, Land O'Lakes and H. J. Heinz Co., have very small volume shares. The value of shipments was US\$5.6 billion.

The data for this study was obtained from Information Resources Inc., which collects quantity and price data from supermarkets in the most populous metropolitan areas in the U.S. The price and quantity data are quarterly, and cover the first quarter of 1988 to the fourth quarter of 1992. The number of cities ranges from 28 in the first quarter of 1988 to 43 in the fourth quarter of 1992. Each city and quarter combination is defined as a market so there are 680 markets represented in the data. We focused on ten major brands. The number of brands varies from 7 to 10, depending on markets, because of the unbalanced nature of the dataset.

The product characteristics of each brand consist of calories, fat, cholesterol and sodium. Their values were obtained from nutrient fact books that were published during the sample period.

Demographic information for each city in our sample was obtained from the Current Population Survey (CPS). The information includes income, age, number of children, and race. The selection of demographic variables is based on previous studies of the cheese industry, which includes Gould et al. 1994, Hein et al. 1990, and Gould 1992.

Table 2 gives the market shares, prices and values of the product characteristics for the ten brands. The market share for each brand is calculated under the assumption that market size is equal to one serving (28g) per person times the number of persons in the market. The low numbers reflect the fact that most people do not buy processed cheese. The price is measured as cents per serving. It is net of any

merchandising activity. Thus, a price reduction for a promotion is reflected in the price. Price is deflated using the regional city CPI and converted to real price per serving.

Table 3 provides summary statistics on the demographic variables. Income is household income divided by the number of household members. The variable Child is a binary variable that is equal to 1 if age is less than 17 years old and 0 otherwise. The binary variable Nonwhite is equal to 1 if an individual is nonwhite and 0 otherwise.

### III. Model

In this section we first specify the model of demand, then derive the pricing equations under different behavioral assumptions, and finally derive the pass-through equations.

#### The Demand Equations

Demand for processed cheese is estimated using a discrete choice model similar to those of BLP 1995 and Nevo 2001.<sup>2</sup> Consumers choose one unit of only one brand in each shopping trip and they choose the brand that offers them the highest utility. The indirect utility of consumer  $i$  from brand  $j$  in market  $m$  is given by  $U_{ijm}(x_{jm}, \xi_{jm}, p_{jm}, D_i, v_i : \theta)$ , where  $x_{jm}$  are observed cheese characteristics,  $p_{jm}$  is price,  $D_i$  are observed consumer characteristics,  $v_i$  and  $\xi_{jm}$  are unobserved individual characteristics and unobserved cheese characteristics, respectively. Here  $\theta$  is an unknown parameter vector to be estimated. Following Berry 1994, we specify the indirect utility function as:

$$(1) \quad u_{ijm} = x_{jm}\beta_i - \alpha_i p_{jm} + \xi_{jm} + \varepsilon_{ijm},$$

---

<sup>2</sup> An alternative approach to solving the dimensionality problem in differentiated product markets is to use a multi-level demand system for differentiated products (Hausman, Leonard, & Zona 1994), which is an application of multi-stage budgeting.

where  $\alpha_i$  is consumer  $i$ 's marginal income utility,  $\beta_i$  represents individual specific parameters, and  $\varepsilon_{ijm}$  is a mean zero stochastic term. Thus, the parameters of the utility function are different for each consumer. By contrast, in the logit model, the parameters are the same for all consumers and consumer heterogeneity is modeled in the error term only.

The indirect utility can be divided into two parts. The first part is the mean utility level of brand  $j$  in market  $m$ ,  $\delta_{jm}$ , and the second part is the deviation from the mean level utility, which captures the effects of the random coefficients,  $\mu_{ijm}$ .

$$(2) \quad u_{ijm} = \delta_{jm}(x_j, p_{jm}, \xi_{jm}; \theta_1) + \mu_{ijm}(x_j, p_{jm}, v_i, D_i; \theta_2) + \varepsilon_{ijm}$$

$$(3) \quad \delta_{jm} = x_{jm}\beta - \alpha p_{jm} + \xi_{jm}$$

$$(4) \quad \mu_{ijm} = \sum_{l=1}^L \eta_l D_{il} p_{jm} + \sigma_{K+1} v_{i(K+1)} p_{jm} + \sum_{l=1}^L \sum_{k=1}^K \phi_{lk} D_{il} x_{jkm} + \sum_{k=1}^K \sigma_k v_{ik} x_{jkm}$$

$$(5) \quad u_{i0m} = \xi_{0m} + \phi_0 D_i + \sigma_0 v_{i0m} + \varepsilon_{i0m}$$

Hence the coefficients on the mean utility function are the same for all individuals and the deviation from the mean utility,  $\mu_{ijm}$ , depends on the consumer's observed characteristics,  $D_i$ , and unobserved characteristics,  $v_i$ . The unobserved individual characteristics are random draws from the multivariate normal distribution,  $N(0, I_{K+1})$ , where  $K+1$  draws for each individual correspond to the price and product characteristics, of which the dimension is  $K \times 1$ .

Equation (5) represents the utility of an outside good, which is normalized to  $u_{i0m} = \varepsilon_{i0m}$ . Without an outside good, a simultaneous increase in the prices of inside goods results in no change in aggregate consumption. The share of outside goods is defined as the total size of the market minus the shares of inside goods. We follow Nevo 2001 and assume that the size of the market is one serving of processed cheese per capita per day. BLP 1995 used the number of households as market size.



Let  $A_{jm}$  represent the set of values of  $D$ ,  $v$ , and  $\varepsilon$  that induces the choice of brand  $j$  in market  $m$ .

$$(6) \quad A_{jm} = \{D, v, \varepsilon \mid u_{ijm} > u_{ihm} \quad \forall h = 0, 1, \dots, J\}$$

We assume that  $D$ ,  $v$ , and  $\varepsilon$  are independently distributed. Here  $D$  is drawn from the empirical distribution,  $F$ , obtained from the Current Population Survey;  $v$  are drawn from a multivariate normal distribution,  $N$ ; and  $\varepsilon$  is drawn from an extreme value distribution. Integrating out the idiosyncratic preference shock, the market share of brand  $j$  in market  $m$  can be expressed as follows:

$$(7) \quad s_{jm}(x, p, \delta; \theta_2) = \int_{D, v} s_{ijm} dF(D) dN(v)$$

Where  $s_{ijm} = \exp(\delta_{jm} + \mu_{ijm}) / (1 + \sum_{s=1}^J \exp(\delta_{sm} + \mu_{ism}))$ , is the probability of individual  $i$  purchasing the product  $j$ .

## The Pricing Equations

Each firm  $f$ ,  $f = 1, \dots, F$ , produces goods  $j = 1, \dots, J_f$ . Marginal costs are constant for each product but vary across markets. Thus, firm  $f$ 's profit in market  $m$ <sup>3</sup> is given by

$$(8) \quad \Pi_f^m = \sum_{j=1}^{J_f} (p_{jm} - mc_{jm}) Ms_{jm}(p)$$

where  $mc_{jm}$  is marginal cost of product  $j$  in market  $m$ ,  $M$  is market size, and  $s_{jm}(p)$  is the market share of  $j$  in market  $m$ .

---

<sup>3</sup> In this paper we assume that firms solve a profit maximization problem in each market separately rather than coordinating pricing across markets.

Suppose first that firms in the processed cheese market choose their prices simultaneously and independently. Given the prices of other brands, firm  $f$ 's prices satisfy the first-order conditions

$$(9) \quad \frac{\partial \Pi_f^m}{\partial p_{jm}} = s_{jm} + \sum_{k=1}^{J_f} (p_{km} - mc_{km}) \frac{\partial s_{km}}{\partial p_{jm}} = 0, \quad j = 1, \dots, J_f$$

Note that the second term takes into account the impact of  $p_{jm}$  on the revenues of the firm's other brands as well as on brand  $j$ . In other words, each firm behaves like a monopolist with respect to its brands.

Suppose next that the firms collude and choose their prices to maximize their joint profits. The first-order condition for joint profit  $\Pi_F$  maximization is:

$$(10) \quad \frac{\partial \Pi_F^m}{\partial p_{jm}} = s_{jm} + \sum_{k=1}^{J_f} (p_{km} - mc_{km}) \frac{\partial s_{km}}{\partial p_{jm}} + \sum_{\substack{f'=1 \\ f' \neq f}}^F \sum_{s=1}^{J_{f'}} (p_{sm} - mc_{sm}) \frac{\partial s_{sm}}{\partial p_{jm}} = 0$$

$$\text{where } s = 1, \dots, J_{f'}, \quad j = 1, \dots, J_f$$

In this case, each firm takes into account the effect of a change in the prices of its brands on revenues of own and other firms' brands.

The first-order conditions, (9) and (10), can be summarized in vector notation as (11):

$$(11) \quad (p - mc)\Delta(p) + s(p) = 0$$

where  $p$  is the vector of all brand prices,  $mc$  is the vector of marginal costs of all brands, and  $s(p)$  is the vector of market shares. Here  $\Delta = J * J$  is a matrix with elements;

$$\left\{ \begin{array}{l} \frac{\partial s_k(p)}{\partial p_j}, \text{ if brands } k \text{ and } j \text{ are produced by the same firm in the Nash model} \\ \text{or by a colluder in the collusion model} \\ 0, \text{ Otherwise} \end{array} \right.$$

From (11), we can solve for marginal cost for each brand for each market as follows:

$$(12) \quad \hat{mc} = p + \Delta(p)^{-1} s(p)$$

Thus, the estimated marginal cost depends on the equilibrium price, the parameters of the demand system, and whether the firms behave non-cooperatively or collude.

### The Pass-Through Equations

From (11) we can also estimate the cost pass-through rate analytically. Rewrite (11) as  $Q = (p - mc)\Delta(p) + s(p) = 0$ . Then, using the implicit function theorem, the pass-through rate matrix can be derived as follows:

$$(13) \quad \frac{\partial p}{\partial mc} = -\left(\frac{\partial Q}{\partial p}\right)^{-1} \left(\frac{\partial Q}{\partial mc}\right)$$

The pass-through rate depends on the first and second derivatives of the market share function. In the mixed logit model, these derivatives depend on the empirical distribution of observable consumer characteristics and have to be estimated. By contrast, in the logit model, the derivatives follow directly from functional form assumptions (Froeb et al. 2005).

Let's assume that there is a discrete industry-wide common shock for each brand in each market so marginal cost changes from  $\hat{mc}$  to  $\bar{mc}$ . Following the cost shock, market prices will converge to a new equilibrium. The new equilibrium price vector is:

$$(14) \quad p_{New} = \bar{mc} - \Delta(p_{New})^{-1} s(p_{New})$$

The price pass-through rate is defined as the ratio of the price change to the change in marginal cost:

$$(15) \quad \text{Pass Through Rate} = \frac{\Delta p}{\Delta mc} \times 100,$$

where  $\Delta p$  is the difference between the new equilibrium price that solves System (14) and the old price and  $\Delta mc = \bar{mc} - \hat{mc}$ . We perturb System (14) with marginal cost shocks of varying sizes.

As prices change with marginal cost shocks, consumer welfare will change accordingly. The change in consumer welfare is estimated using the compensating variation criterion. It measures the amount of income that is needed to keep the consumer at the same utility level after a price change occurs (e.g., McFadden 1981, Small & Rosen, 1983, Nevo 2000a). We estimate the consumer welfare changes for each regime of competition. For price pass-through simulations and consumer welfare calculations analysis, we assume that neither the marginal utility of consumer income following cost shocks nor the utility from outside goods changes.

#### IV. Estimation

To estimate the demand function, we must control for any correlation between prices and the error term in the mean utility function. The error term represents product characteristics that are observed by consumers but not by the econometrician. This correlation is likely to be positive because higher quality could lead suppliers to set higher prices. For example, Trajtenberg (1989, 1990) found that demand for CT scanners was estimated to be positively sloped with price because of the omission of unobserved quality, which was positively correlated with price.

To control for the endogeneity of price, we need to find variables that are correlated with price but are independent of unobserved product characteristics.

Estimation requires an instrument vector with a rank at least equal to the dimensionality of the parameter vectors. One of the instruments typically used is a variable that represents closeness in product space in the particular markets (BLP 1995, Bresnahan, Stern, & Trajnsenber 1997). Such instruments are, however, most appropriate for dynamically changing markets in which product characteristics evolve continuously. If a market is mature and product characteristics do not change much, then this instrumental variable will not change across markets and it will as a consequence have little identifying power. Another approach is to exploit the panel structure of the data. Examples of this approach are found in Hausman 1994 and Nevo 2001. The identifying assumption is that, controlling for brand-specific means and demographics, city-specific demand shocks are independent across cities. Given this assumption, a demand shock for a particular brand will be independent of prices of the same brand in other cities. Due to the common marginal cost, prices of a given brand in different cities within a region will be correlated, and therefore can be used as valid instrumental variables.<sup>4</sup> If, however, there is a national or regional demand shock, this event will increase the unobserved valuation of all brands in all cities and the independence assumption will be violated. Also, if advertising campaigns and promotions are coordinated across cities, these activities will increase demand in the cities that are included in the activities, so the independence assumption will be violated for those cities.<sup>5</sup> We therefore use an additional set of instrumental variables, proxies for production costs, to check the sensitivity of the results obtained to different sets of instrumental variables. We create the production cost proxies by multiplying

---

<sup>4</sup> Refer to Bresnahan's comment on Hausman 1996.

<sup>5</sup> A referee suggested that we include brand-level advertising spending as an independent variable to control for aggregate demand shocks. Nevo 2001 is such an example. Unfortunately, our advertising data was not complete and we could not include such a variable in the model.

input prices such as the raw milk price, the diesel price, wages, and electricity by brand dummies to give cross-brand variations.

Let  $Z$  be an  $N$ -by- $L$  matrix with row  $z_k$  and  $\xi(\theta)$  be an  $N$ -by-1 error term in mean utility with row  $\xi_k$ . We introduce brand dummies as well as time dummies in the model. Hence, a brand-specific component and a time-specific component are removed from the error term in the mean utility. The assumption that the instrumental variables are orthogonal to the structural error implies  $E[z_k \xi_k(\theta)] = 0$ . The corresponding sample moment is  $\bar{m}(\theta) = \frac{1}{n} \sum_{k=1}^n z_k \xi_k(\theta) = \frac{1}{n} Z' \xi(\theta)$ . Now we search for  $\theta$ , which minimizes the GMM objective function. The GMM estimate is

$$(17) \quad \hat{\theta} = \arg \min_{\theta} q = [\bar{m}' W \bar{m}],$$

where  $W$  is a consistent estimate of the inverse of the asymptotic variance of  $\sqrt{n} \bar{m}(\theta)$ .

## V. Results

Table 4 reports parameter estimates for the logit model with and without instrumental variables. Using prices in other cities as the instrumental variable, price sensitivity increases from 2.786 to 5.397. Under an alternative specification using cost data as instrumental variables, the price sensitivity was 4.221. The results suggest that disregarding the correlation between price and unobserved demand shock can cause downward bias in price sensitivity.

Table 5 reports parameter estimates for the mixed logit model. Here we use regional prices in other cities and cost variables as instrumental variables for Model I and Model II, respectively. Overall, the two models yield similar results even though

the size of the respective parameter estimates is a bit different. The parameters for the product characteristics are recovered from those of brand-related fixed effects using the minimum distance method. The coefficient on PRICE is negative and significant. The coefficient on FAT is positive and significant, which suggests that the average consumer prefers the richer taste of higher butterfat despite the higher health risks. Sensitivity to fat increases, however, as income rises. This phenomenon is captured in the negative and significant interaction term between fat and income, FAT\*INCOME. SODIUM has a negative and significant effect on the mean utility.

Table 6 reports own- and cross-price elasticities based on the estimates of the mixed logit model. Each cell  $(i,j)$  gives the percent change in market share of brand  $i$  corresponding to a 1 percent change in the price of brand  $j$ . Own-price elasticities are negative but the cross-price elasticities are positive.

Table 7 reports cost estimates under Bertrand-Nash and collusive pricing respectively. For any vector of prices, marginal costs are lower and markups are higher under collusive pricing than competitive pricing. Recall that equation (12) implies that the estimated marginal costs are higher for products with higher market prices and higher values for  $\Delta(p)^{-1} s(p)$ . For some brands with small market shares, the elements of the latter term are small negative numbers. Therefore, the estimated marginal costs are determined mostly by market prices. Accordingly, some low-fat segment brands, such as Kraft Free, Weight Watchers, and Lite Line, have high marginal costs. This is particularly true for Lite Line, which has the highest market price and a very low market share.

Table 8 shows the results of the estimated price pass-through rates. The pass-through rates are defined as percentage changes in price from a one cent per serving increase in marginal cost. Under collusion, the pass-through rates for all brands fall in a narrow range, between 21% and 31%. Under Bertrand-Nash competition, the level

of brand pass-through rates increase as does the variation across brands, with rates ranging between 73% and 103%. To examine the robustness of results, we simulated the cost pass-through for cost shocks that vary in size from 0.1 cent per serving to 1.2 cents per serving. The results were similar to those reported in Table 8.

Not surprisingly, the simulation results indicate that average pass-through rates are lower than the rates predicted by a linear demand with a homogenous product. With constant marginal cost, cost pass-through is 100% in the competitive case and 50% in the monopoly case (Bulow et al. 1983). Note that, in a differentiated product market, the mixed logit specification allows for price pass-through rates above and below 100%. Differences in the shape of a brand's market share function across markets means that the same brand can have different cost pass-through rates in different markets.

The curvature of the demand function in the mixed logit model, i.e., the second derivative of the demand function, is determined by the product characteristics and the distribution of consumer characteristics. To check on the importance of this flexibility, we compared the results of the mixed logit model with those of the logit model. Under Bertrand-Nash pricing, we find that the average pass-through rate in the logit model for a one-cent per serving change in costs is 71%. This is 12 percent lower than the average pass-through rate for mixed logit models.

Table 9 shows the change in consumer welfare as measured by the compensating variation. CV1 and CV2 represent the compensating variations under Bertrand-Nash and collusive pricing, respectively. In the former case, the CV is 0.63 cents per person for a 1 cent marginal cost decrease and in the latter case, it is 0.23 cents. The ratio of CV2 to CV1 is 37%. Thus, the increase in consumer welfare following a one cent decrease in cost is substantially lower in the collusive regime than in the Bertrand-Nash equilibrium.



## VI. Structural versus Reduced-form Estimates

Reduced-form models have been used extensively in the cost pass-through literature partly because the analysis is easily implemented. To compare the results of the structural model with those of a reduced-form model, we use the following reduced-form model:

$$(16) \quad \ln(\text{price}_{it}) = \gamma_{0i} + \gamma_1 * \ln(\text{input Cost}_t) + \omega_{it}$$

Here  $\ln(\text{price}_{it})$  is a log of processed cheese prices for brand  $i$  and time  $t$ ,

$\ln(\text{inputCost}_t)$  is a log of input price at time  $t$ , and  $\omega_{it}$  represents an error term.

Following Gron and Swenson (2000), we estimate a log-linear regression to obtain a unit-free measure of the pass-through rate. In our model,  $\gamma_{0i}$  is a brand fixed effect and  $\gamma_1$  represents the pass-through elasticity. The brand fixed effects capture time-invariant markups.

We use raw milk prices, wages, and diesel prices as proxies for input costs. The milk price is the raw milk price from USDA federal milk order statistics. Wage and diesel prices are obtained from Bureau of Labor Statistics indices. Table 12 reports summary statistics on the input prices.

Table 10 reports the estimates of the reduced form model. The estimated pass-through elasticities for milk and diesel prices and wage are 0.034, 0.237, and 0.375, respectively. In order to compare these estimates to the pass-through rates obtained from the structural model, we converted them into pass-through elasticities. The pass-through elasticity is 0.07 for collusive pricing and 0.5 for Nash-Bertrand pricing. These are the averages for different size cost shocks. The reduced-form results fall between those of full collusion and Nash price competition. If the reduced-form results capture the market structure of the processed cheese market correctly, it suggests that

the market is less competitive than Bertrand-Nash price competition but more competitive than collusive pricing. If, however, we do not know the results of benchmark cases of pass-through elasticities, i. e., those of Bertrand-Nash pricing and collusion, it may be difficult to infer behavior from the results of a reduced-form analysis. Meanwhile, if we assume along with many previous studies (e.g., BLP,1995) that firms behave as posited by Nash-Bertrand model, the reduced form results yield biased estimates of cost pass-through.

## VII. Conclusion

In this paper we estimate a demand system and pricing relationship for a differentiated product market and implement pass-through simulations and related welfare analysis. There is a gap in the literature, as analysts have paid little attention to cost pass-through in differentiated product markets. This study attempts to fill this gap. In the mixed logit model that we use for demand specification, the curvature of demand depends on the empirical distribution of consumer characteristics. This property provides flexible cost pass-through rates that are not driven solely by the functional form assumption. This paper is the first attempt to examine this issue.

Empirical results indicate that the pass-through rates for the U.S processed cheese market are greater under Bertrand-Nash pricing than under collusive pricing. This implies that changes in consumer welfare following cost shocks are greater under Bertrand-Nash competition. We also compare the results of the structural model with those of the reduced-form models. We find that the pass-through elasticities of the reduced-form models fall between those of Bertrand-Nash competition and collusion. The results suggest that, without knowing the benchmark pass-through elasticities, it

may be difficult to infer the degree of market competitiveness from a reduced-form analysis. They also suggest that the reduced form results are biased.

We have focused here on the Bertrand-Nash equilibrium and collusion. Similar studies pertaining to other equilibrium concepts, such as semi-collusion and a firm's deviation to or from collusion using a cost shock as a focal point, would be possible. A related avenue would be to analyze a dynamic model that could account for changes in firm strategies over time. Still another direction for future research would be to analyze the pass-through rate from manufacturer to retailers and from retailers to consumers. In this paper we implicitly assume that manufacturers and retailers are vertically integrated.

## REFERENCES

- Anderson, Simon P., Andre de Palma and Brent Kreider, 2001, "Tax Incidence in Differentiated Product Oligopoly," *Journal of Public Economics* 81, 173-192.
- Besley J. Timothy and Havey S. Rosen, 1998, "Sales Taxes and Prices: An Empirical Analysis," *NBER Working Paper 6667*, July.
- Besley, Timothy, 1989, "Commodity Taxation and Imperfect Competition: A Note on The Effects of Entry," *Journal of Public Economics* 40, 359-367.
- Berry, S., 1994, "Estimating Discrete-Choice Models of Product Differentiation," *Rand Journal of Economics* 25, 242-262.
- Berry, S., Levinsohn, J., and A. Pakes, 1995, "Automobile Prices in Market Equilibrium," *Econometrica* 63, 841-889.
- Bresnahan, F. Timothy , Scott Stern, Manuel Trajtenberg, 1997, "Market Segmentation and the Sources of Rents from Innovation: Personal Computers in the Late 1980s," *Rand Journal of Economics* 28, No.0, s17-s44.
- Bulow I, Jeremy and Paul Pfleiderer, 1983, "A Note on the Effects of Cost Changes on Prices," *Journal of Political Economy* 91, Issue 1, February, 181-185.
- Delipalla, Sofia and Michael Keen, 1992, "The Comparison Between Ad Valorem and Specific Taxation Under Imperfect Competition," *Journal of Public Economics* 49, 351-367.
- Fershtman, C, Neil Gandal and Sarit Markovich, 1999, "Estimating the Effect of Tax Reform in Differentiated Product Oligopolistic Markets," *Journal of Public Economics* 74, 151-170.
- Franklin, Andrew W. and Ronald W.Cotterill, 1994, *Pricing and Market Strategies in the National Branded Cheese Industry*, Food Marketing Policy Center, University of Connecticut.
- Froeb, Luke and Steven Tschantz and Gregory J. Werden, 2005, "Pass-Through Rates and the Price Effects of Mergers," *International Journal of Industrial Organization* 23, 703-715.
- Gould B.W., 1992, "At-Home consumption of cheese: A purchase-Infrequency Model," *American Journal of Agricultural Economics* 74, May, 453-459.
- Gould B.W. and Huei Chin Lin, 1994, "The Demand for Cheese in the United States:

- The Role of Household Consumption,” *Agribusiness* 10-1, January, 43-59.
- Gron, Anne and Deborah L. Swenson, 2000, “Cost Pass-Through in the U.S. Automobile Market,” *Review of Economics and Statistics*, May, 82(2): 316-324.
- Hausman, J., 1996, “Valuation of New Goods Under Perfect and Imperfect Competition,” in T Bresnahan and R.Gordon, eds., *The Economics of New Goods: Studies in Income and Wealth* Vol. 58, Chicago: National Bureau of Economic Research.
- Hausman, J., G. Leonard, and J.D.Zona, 1994, “Competitive Analysis with Differentiated Products,” *Annales D’Economie et de Statistique* 34, 159-80.
- Hein Dale M., Cathy R. Wessels, 1990, “Demand Systems Estimation with Microdata: a Censored Regression Approach,” *Journal of Business & Economic Statistics* 8-3, 365-371.
- Karp, Larry and Jeffrey Perloff, 1989, “Estimating Market Structure and Tax Incidence: Japanese Television Market,” *Journal of Industrial Economics* 38(3), March, 225-239.
- Katz, Michael and Harvey Rosen, 1985, “Tax Analysis in An Oligopoly Model,” *Public Finance Quarterly* 13 (January), 3-19.
- McFadden, D., 1981, “Econometric Models of Probabilistic Choice,” in C. Manski and D. McFadden, eds., *Structural Analysis of Discrete Data*, 198-272, Cambridge: MIT Press.
- Mueller, Willard, Bruce W.Marion, Maubool H.Sial, F.E.Geithman,1996, *Cheese Pricing: A Study of the National Cheese Exchange*, March, Department of Agricultural Economics, University of Wisconsin-Madison.
- Nevo, Aviv , 2001, “Measuring Market Power in the Ready-To-Eat Cereal Industry,” *Econometrica* 69, 307-342.
- Nevo, Aviv, 2000a, “Mergers with Differentiated Products: The Case of the Ready-To-Eat Cereal Industry,” *Rand Journal of Economics* 31, No.3, 395-421.
- Nevo, Aviv, 2000b, “ A Practioner’s Guide to Estimation of Random-Coefficients Logit Models of Demand,” *Journal of Economics & Management Strategy*, Vol 9, Number 4, Winter 2000, 513-548.
- Petrin, A. 2003, ‘ Quantifying the Benefits of New Products: The Case of the Minivan,’ *Journal of Political Economy*, 110, 705-729.

- Small, K.A. and Rosen, H.S, 1981, "Applied Welfare Economics with Discrete Choice Models," *Econometrica*, Vol. 49, 105-130.
- Stern, Nicholas H, 1987, "The Effects of Taxation, Price Control and Government Contracts in Oligopoly," *Journal of Public Economics* 32, 133-158.
- Sullivan, Daniel, 1985, "Testing Hypothesis About Firm Behavior in the Cigarette Industry," *Journal of Political Economy* 93,586-598.
- Sumner, Daniel A., 1981, "Measuring of Monopoly Behavior: An Application to the Cigarette Industry," *Journal of Political Economy* 89 (October), 1010-1019.

Table 1. Leading Processed Cheese Brands, U.S total, 1992

Manufacturer/Brand	Volume Share	Average Price/lb
Philip Morris		
Kraft	25.51	3.24
Velveeta	15.56	2.82
Light N Lively	0.59	4.20
Kraft Free	3.65	3.76
Kraft Light	3.19	2.52
Velveeta Light	1.70	3.38
Borden Inc		
Borden	7.91	2.80
Lite Line	0.53	4.62
Land O'lakes		
Land O'Lakes	1.28	2.42
HJ Heinz Co		
Weight Watchers	0.41	3.20

Source: Franklin and Cotterill (1994)

Table 2. Market share, Prices, and Product Characteristics

	Market Share	Price	Calories	Fat (g)	Cholesterol (mg)	Sodium (mg)
Kraft	3.172	14.197	90	7	25	380
Velveeta	2.065	12.230	90	6	25	400
Light N Lively	0.098	17.334	70	4	15	406
Kraft Free	0.320	16.541	42	0.3	5	273
Kraft Light	0.173	15.348	70	4	20	160
Velveeta Light	0.233	12.186	60	3	15	430
Borden	0.774	12.931	80	6	20	360
Lite Line	0.0071	19.456	50	2	15	171
Land O'lakes	0.0069	11.990	110	9	26	430
Weight Watchers	0.065	15.376	50	2	7.5	400

Note: Market share (%) and price are the medians for all city-quarter markets. The unit of price is cents per serving (28g).

Table 3. Demographic Variables

	Median	Mean	Std	Min	Max
Log (Income)	7.923	7.935	0.912	0.396	10.876
Log (Age)	3.478	3.312	0.951	0	4.512
Child	0	0.268	0.436	0	1
Nonwhite	0	0.168	0.362	0	1



Table 4. Demand Parameter Estimates: Logit OLS and Logit with IVs

	Logit OLS	Logit with IVs	
Price	-2.786 (0.197)	-5.397 (0.445)	-4.221 (0.397)
Time Dummies	O	O	O
Brand Dummies	O	O	O
Instruments	X	Prices	Cost
R <sup>2</sup>	0.676		
First Stage R <sup>2</sup>		0.914	0.855
N	5734	5734	5734

Note: Dependent Variable is  $\ln(s_{jm}) - \ln(s_{0m})$ . Standard errors are in parentheses.

Table 5. Demand Parameter Estimates: Mixed Logit

Variables	Model(I)	Model(II)
Constant	32.089 (0.487)**	18.445 (1.569)**
Price	-6.848 (0.501)**	-5.632 (1.337)**
Fat	1.285 (0.487)**	4.808 (1.569)**
Sodium	-3.714 (0.166)**	-2.489 (0.247)**
Income	18.756 (7.737)**	20.687 (5.879)**
Nonwhite	-4.611 (0.395)**	-5.953 (0.478)**
Price* Income	-12.061 (3.746)**	-17.063 (9.233)*
Price * [Income] <sup>2</sup>	8.141 (2.937)**	9.148 (3.292)**
Price * Age	-2.159 (1.256)*	-2.751 (2.185)
Price * Child	2.537 (1.438)*	2.521 (2.516)
Fat * Income	-0.540 (0.043)**	-1.490 (0.647)**
Constant* $v_1$	0.929 (1.052)	1.121 (1.782)
Price* $v_2$	2.232 (0.462)**	1.915 (0.544)**
Fat* $v_3$	2.437 (1.716)*	2.668 (0.826)**
Sodium* $v_5$	3.245 (1.583)*	3.021 (1.709)*
Instruments	Prices	Cost
N	5,732	5,732

Note: \* t-value > 1, \*\*: t-value >2. The parameters in the mean utility are recovered from the coefficients of the brand-fixed effects using the minimum distance technique. The numbers in parentheses are standard errors.

Table 6. Own- and Cross-Elasticities

	Borden	Light Line	Weight Watchers	Land O'Lakes	Kraft	Line N lively	Velveeta	Kraft Free	Kraft Light	Velveeta Light
Borden	-6.56	0.03	0.10	0.22	1.21	0.05	0.87	0.23	0.22	0.36
Light Line	0.12	-4.62	0.02	0.03	0.15	0.04	0.27	0.08	0.04	0.06
Weight Watchers	0.78	0.05	-6.59	0.09	0.25	0.07	0.45	0.49	0.28	0.48
Land O'Lakes	1.09	0.02	0.12	-7.35	0.98	0.08	0.95	0.19	0.60	0.43
Kraft	0.75	0.01	0.04	0.24	-5.07	0.04	1.23	0.16	0.21	0.27
Lite N Lively	0.21	0.06	0.05	0.04	0.67	-3.67	0.54	0.12	0.08	0.10
Velveeta	0.92	0.02	0.07	0.21	1.18	0.05	-6.29	0.21	0.20	0.46
Kraft Free	0.39	0.02	0.12	0.03	0.11	0.04	0.62	-4.39	0.36	0.41
Kraft Light	0.72	0.03	0.08	0.20	0.61	0.03	0.56	0.35	-5.88	0.25
Velveeta Light	0.96	0.04	0.16	0.13	0.83	0.05	0.83	0.43	0.26	-7.21
Outside Good	0.63	0.02	0.09	0.14	0.23	0.02	0.34	0.14	0.15	0.17

Note: Elasticities are median values for 210 sample markets from the fourth quarter of 1991 to the fourth quarter of 1992.

Row is  $i$  and column is  $j$ . Each cell  $(i,j)$  gives the percent change in market share of brand  $i$  corresponding to a 1 percent change in the price of brand  $j$ .

Table 7. Marginal cost, Markup, and Margin

Brand	Nash-Bertrand			Full Collusion		
	MC	P-MC	(P-MC)/P*100	MC	P-MC	(P-MC)/P*100
Kraft	7.84	6.08	42.65	4.75	9.62	67.75
Velveeta	6.69	5.53	45.03	4.13	8.44	67.97
Light N Lively	10.35	6.12	36.83	7.24	9.97	58.13
Kraft Free	10.59	5.45	34.91	7.75	8.14	51.78
Kraft Light	9.36	5.30	36.34	6.19	8.53	59.16
Velveeta Light	7.81	4.69	37.80	4.98	7.39	61.26
Borden	11.27	1.62	12.72	4.26	8.94	67.45
Lite Line	18.13	1.89	10.58	10.37	9.43	49.11
Land O'Lakes	10.56	1.37	11.70	3.62	8.37	70.74
Weight Watchers	12.88	1.95	12.58	5.65	9.43	62.51

Note: Median values for all markets. Marginal costs and markups are cents per serving.

Table 8. Pass-Through Rate(%)

	Nash Bertrand	Collusion
Kraft	93.61	30.42
Velveeta	91.56	28.74
Light N Lively	88.72	26.45
Kraft Free	90.12	26.98
Kraft Light	99.93	30.34
Velveeta Light	93.29	30.83
Borden	102.89	30.12
Lite Line	73.33	23.70
Land O'Lakes	88.36	21.25
Weight Watchers	76.86	25.45
Overall	82.67	27.04
MC shock	1.0	1.0

Note: Median values for all markets. Marginal cost shocks are cents per serving.

Table 9. Compensating Variation

Bertrand-Nash (A)	0.63
Collusion (B)	0.23
B/A(%)	37%
MC Shock(Cents)	1.0

Note: Cents/per serving/per person, median values for all markets.

Table 10. Results of Reduced-Form Models

Independent variables	Dependent Variable: $\ln(\text{price})$		
	$\ln(\text{Milkprice})$	0.034 (0.019)	-
$\ln(\text{Diesel})$	-	0.237 (0.010)	-
$\ln(\text{Wage})$	-	-	0.375 (0.029)
$R^2$	0.672	0.702	0.702

Note: Each regression includes brand-fixed effects. The numbers in parentheses are standard errors.

Table 11. Pass-Through Elasticities: Structural model

Nash-Bertrand Competition	Collusion
0.47	0.066

Table 12. Input Prices

	Mean	Std Dev	Min	Max
Milk(US \$/ 100 pounds)	11.69	1.03	10.07	14.50
Wage (PPI)	106.78	5.73	95.70	114.50
Diesel (PPI)	63.16	9.55	44.00	91.93