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ABSTRACT

In this paper, we estimate a mixed logit model for the U.S. processed cheese market and implement cost pass-through simulations and related consumer welfare analysis under different regimes of competition. In the model, the curvature of demand is determined to a significant extent by the empirical distribution of consumers. This property reduces the prediction errors of cost pass-through caused by an erroneous assumption as to the functional form of demand. We find that, under collusion, the pass-through rates for all brands fall between 23% and 37% and under Nash price competition, the range of pass-through is 67% ~ 98%.

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

JEL classification: D40, D60, L13, L66, H20

Market Structure, Cost Pass-Through and Welfare with Differentiated Products

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I. Introduction

In this paper we analyze firms' cost pass-through behaviors in a differentiated product market with price competition. 'Cost pass-through' refers to the phenomenon through which a change in input cost transmits into a change in price. A cost change may stem from various sources, including input price changes or changes in state or federal taxes. For example, when raw milk prices increase, the question typically arises as to how much of this will transmit to higher retail cheese prices. The effects of such a change in milk prices on consumer welfare and firm profits will be determined by the degree of cost pass-through to retail cheese prices.

Early studies on cost pass-through have focused on two extreme cases, perfect competition and monopoly. Under perfect competition, pass-through is determined by the relative demand and supply elasticities. When demand is more inelastic and supply more elastic, pass-through is greater. When input supply is infinitely elastic, pass-through is 100% in the competitive case. In the case of linear demand and infinitely elastic input supply, a monopolist passes through only half of an input cost change (Bulow et al. 1983). Some models have analyzed the effects of cost shocks under imperfect competition, using primarily conjectural variation analysis in quantity competition (Stern 1987, Katz & Rosen 1985, and Delipalla & Keen 1992). So far, most theoretical work has focused on homogeneous products with quantity competition and much of the empirical work is based on reduced-form analysis using industry-level data (e.g., Sumner 1981; Sullivan 1985; Karp & Perloff 1989; and Besely & Rosen 1996).

Very little effort has been devoted to analyzing the effect of cost changes on prices in differentiated product markets. Among the few exceptions are studies by Anderson et al. 2001 and Froeb et al. 2002. The former analyze the incidence of ad valorem and exercise taxes in an oligopolistic industry with differentiated products and price-setting firms. The latter investigate 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 demonstrate a cost pass-through analysis for a differentiated product market using a structural model and compare its results with those of reduced-form models. In the market, firms produce differentiated products with price as the strategic variable. We first estimate the demand system using a mixed logit model.[1] Given the estimated demand surface and estimated marginal costs, we then solve to obtain new equilibrium prices for hypothetical cost shocks. In fact, we estimate cost pass-through for two alternative pricing games, Nash-Bertrand and fully collusive pricing.[2] For empirical estimation of cost pass through, our approach has some advantages. First, the curvature of demand system we use, i.e., the second derivative of demand, is determined to a significant extent by the empirical distribution of consumers. This property reduces the prediction errors of cost pass-through caused by an erroneous assumption as to the functional form of demand. Second, the structural approach allows us to recover marginal costs in the model, which is not possible with reduced-form models.

Our empirical application is the U.S. processed cheese market. For the estimation of processed cheese demand, a discrete choice model is a good option. The use of this cheese adds very little to the total cost of a meal. Accordingly, for many consumers, the choice is less *how much* processed cheese to buy than *which* processed cheese to buy. The market is also potentially a good test ground for the analysis of the effects of cost shocks on prices because cheese prices change with fluctuations in input

[1] 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.

[2] Karp and Perloff 1989 explain that, if a researcher misspecifies strategic conduct in the market, the estimation of price pass-through can be biased.

prices—the price of milk, for example.[3]

The empirical results indicate that the cost pass-through rates for all brands fall between 23% ~ 37% under collusion and its variation among firms is not wide through the entire range of the cost. Meanwhile, the range of pass-through is 67%~98% under Nash-Bertrand equilibrium. We also estimate pass-through elasticities to estimate a unit-free measure of pass-through, comparing the elasticities with the results of reduced-form analysis. We find that the pass-through elasticities are 0.5 for Nash-Bertrand equilibrium and 0.07 for collusive pricing. Meanwhile, the pass-through elasticities for the reduced-form model range from 0.04 to 0.38 depending on input prices. Roughly, the pass-through elasticities of the reduced-form model fall between those of Nash-Bertrand and collusive pricing. If the results of the reduced-form model capture the market structure of the processed cheese correctly, it will be more competitive than full collusion but less competitive than Nash-Bertrand competition. However, without knowing the benchmark cases, i. e., Nash-Bertrand and full collusion, it is difficult to infer market competitiveness using simply the reduced-form results. Rather, a superior strategy would be to specify the market structure first and then estimate the pass-through rate using a structural model.

We proceed as follows. In Section II, we explain the U.S. processed cheese market and describe the data. In Section III, we estimate a mixed logit demand model and implement counterfactual simulations of price pass-though; we then analyze the consumer welfare implications of our alternative solution concepts. In Section IV, we discuss the empirical results. We conclude in Section VI.

II. Market and Data

Processed cheese belongs to industry code SIC 20224, designating processed cheese and related products. The value of shipments for the industry was US 5.6 billion in 1992. The four-firm concentration ratio at the 5-digit level was around 70% during the sample period of 1988-1992. In the market, Kraft, Velveeta, and Borden are the major brands.

[3] For example, it has been alleged that cheese manufacturers have used fluctuations in the prices of manufacturing milk to increase their price-cost margin over time and that they did not pass through the marginal cost reduction to retail cheese prices during the sample period. See Stanley, G 1991.

Philip Morris has a dominant position and its combined volume share was around 50% in 1992. Borden is a distant second to Philip Morris and the other national brands command very small shares.

Data consists of price, market share, product characteristics, and demographic variables for the U.S. processed cheese market. See Table 2 and Table 3 for data summaries. The price and market share are given quarterly from the first quarter of 1988 to the fourth quarter of 1992. The price 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 (28g). The price and quantity data were collected by Information Resources Inc. Each city-quarter combination is defined as a market, and there are 680 total markets in the data. The number of cities ranges from 28 in the first quarter of 1988 to 43 in the fourth quarter of 1992.

For the analysis, 10 brands are selected. The number of brands varies from 7 to 10 depending on markets, adding to the unbalanced nature of the dataset. Among the 10 brands, Kraft, Borden, Velveeta, and Land O'Lakes are the segment's regular processed cheese brands. We also include brands from the low-calorie segment to analyze the competition by segment. These low-fat, low-calorie, high-priced brands capture primarily those consumers who are very sensitive to fat level and are less sensitive to price.

Product characteristics were obtained from nutrient fact books that were published during the sample period. Demographic variables are sampled from the Current Population Survey (CPS). These variables include income, age, child, and race. The selection of demographic variables is based on previous studies of the cheese industry, including Gould et al. 1994, Hein et al.1990, and Gould 1992. We define the child variable as 1 if the age is less than 17 years old and otherwise as 0. For the nonwhite variable, its value is 1 if an individual is nonwhite and 0 if an individual is white. Income is household income divided by the number of household members.

III. Model

III (i). Demand Specification

Demand for processed cheese is estimated with a discrete choice model, which is similar to those of BLP 1995 and Nevo 2001. For the estimation of processed cheese demand, a discrete choice model is a good option. Processed cheese is a special-use product produced for sandwiches and hamburgers. The use of this cheese adds very little to the total cost of a meal. Accordingly, for many consumers, the choice is less *how much* processed cheese than *which* processed cheese to buy. To the extent that this is the case, the discrete choice model is well suited for the demand side of the model.

The demand system we use represents consumer preferences for products as a function of individual consumer characteristics and characteristics of the products.[4] We assume that consumers choose one unit of the processed cheese brand that offers the highest utility and that they choose only one brand during each shopping trip. The indirect utility of consumer i from brand j at market m depends on the characteristics of the product and the consumer: $U_{ijm}(x_{jm}, \xi_{jm}, p_{jm}, D_i, v_i : \theta)$, where x_{jm}, p_{jm} are observed cheese characteristics and prices; and D_i, v_i , ξ_{jm} are observed individual characteristics, unobserved individual characteristics, and unobserved cheese characteristics, respectively. And θ is an unknown parameter vector to be estimated. Following Berry 1994, we specify the indirect utility function as follows.

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

where α_i is consumer i 's marginal income utility, β_i represents individual specific parameters, and ε_{ijm} is a mean zero stochastic term, respectively. Thus, the parameters of the utility function are different for each consumer i. For the logit model, consumers have the same parameters in the utility function and the individual 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, δ_{jm}, and the second part is the deviation from the mean level utility, which captures the effects of the random coefficients. Hence the

[4] A 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.

coefficients on the mean utility function are the same for all individuals and the random component part of utility depends on the consumer's observed characteristics, D_i, and unobserved characteristics, v_i. v_i is the $(K+1)\times 1$ vector. We represent the element of v_i that interacts with price as $v_{i(K+1)}$ and other elements that interact with product characteristics as v_{ik}.

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

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

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

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

μ_{ijm} represents the interaction of price and product characteristics with the observed demographic variables D_i and unobservable individual characteristics v_i. The D_i is an $L\times 1$ vector for each individual. The unobserved individual characteristics, or v_i's, are random draws from the multivariate normal distribution, $N(0, I_{K+1})$, where $K+1$ draws for each individual corresponds to the price and product characteristics of which the dimension is $K\times 1$. We define the parameters in mean utility, β and α, as θ_1 and the parameters for interaction terms, η, σ, φ, as θ_2. Now the contribution of x_{jkm} units of product characteristics to the consumer i 's utility is ($\beta_k + \sum_{l=1}^{L} \phi_{lk} D_{il} + \sigma_k v_{ik}$) x_{jkm}. The consumer's marginal utility of income is $\alpha + \sum_{l=1}^{L} \eta_l D_{il} + \sigma_{K+1} v_{i(K+1)}$. $u_{i0m} = \xi_{0m} + \phi_0 D_i + \sigma_0 v_{i0m} + \varepsilon_{iom}$ is the indirect utility of the outside goods option. In this paper we stipulate that market size is proportional to population size with the proportional factor equal to one serving (28g) per capita per day. The share of outside goods is defined as the total size of the market minus the shares of inside goods. Nevo 2001 assumed the size of the market to be one serving of cereal per capita per day. BLP 1995 used the number of households as market size.

Let F be the joint distribution function of D, v, and ε and then let A_{jm}

represent the set of values for D, v, and ε that induces the choice of brand j in market m.

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

If we assume that D, v, and ε are independent, then the market share of brand j in market m is as follows:

(7) $$s_{jm}(x,\; p, \delta; \theta_2) = \int_{A_{jm}} dF(D, v, \varepsilon) = \int_{A_{jm}} dF(\varepsilon \mid D, v) dF(v \mid D) dF(D)$$
$$= \int_{A_{jm}} dF(\varepsilon) dF(v) dF(D)$$

II (ii). Pricing Relationships: Nash-Bertrand & Collusion

Suppose that each manufacturer f in a total of F firms produces goods j=1,…., J_f and that a firm's marginal cost is constant for each product and varies across markets; thus mc_{jm}, so a firm's profit in market m[5] is

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

where M is market size and s_{jm}(p) is the market share of j in market m. Then we can solve the multi-product firm's profit maximization problem for the different pricing games.

First, let us assume that firms in the processed cheese market behave as posited by Bertrand-Nash competition. For the given prices of other brands, we will obtain the following first-order condition in each market.

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

When a firm produces many brands, it maximizes the sum of brand profits in the firm. Thus, the second term includes the impact of p_{jm} on the other brands' revenues inside the firm as well as the own-price effect on its revenue. In other words, a firm prices its own brands in a fully collusive fashion.

[5] In this paper we assume that firms solve a profit maximization problem in each market separately rather than coordinating pricing across markets.

In the case of a market under the collusive pricing of branded cheeses, each brand has to take into account the effect of its price change on other firms' brands as well as on the brands in the same firm. Hence, the first-order condition for joint profit Π_F maximization is

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

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

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

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

where p, mc, and s(p) are a price vector for all brands, a vector of marginal costs of all brands, and a vector of market shares, respectively. And $\Delta = J * J$ matrix with elements;

$$\begin{cases} \dfrac{\partial \mathrm{s_k}(p)}{\partial \mathrm{p_j}}, \text{if brand k and j are produced by the same firm in the Nash model} \\ \qquad \text{or by a colluder in the collusion model} \\ 0, \text{Otherwise} \end{cases}$$

From (11), we can solve for marginal cost for each brand for each market conditional upon the assumed market structure such that

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

So, the estimated marginal cost depends on the equilibrium price, the parameters of the demand system, and Δ^{-1}, the game being played.

From (11) we can also estimate the cost pass-through rate analytically. Let's denote (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:

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

Therefore, the pass-through rate will depend on the first and second derivatives of the market share function. In the mixed logit model, these derivatives depend on the empirical distribution of consumer characteristics, D and v. This property is expected to reduce the prediction error of pass-through caused by an erroneous assumption on the demand function, as Froeb et al. (2002) pointed out. This paper is the first attempt to test this property in the literature.

III(iii). A Counterfactual Simulation of Cost Pass-Through and Related Welfare Analysis

For pass-through analysis, we assume that marginal cost consists of an industry-specific component and a brand-specific component. Then the marginal cost for each cheese brand j in market m is

(14) $$mc_{jm} = mc_m + mc_j + \varepsilon_{jm},$$

where mc_m is a common component in the market or an industry-wide component, mc_j is a brand-specific component, and ε_{jm} is an iid error term. We assume that market components and brand components are independent of each other and that brand-specific components are also uncorrelated for brands k and j. Here, for notational convenience, we do not project the marginal cost on a firm-specific component. Since we analyze an industry-wide cost shock, this assumption will not affect the results. For price pass-through simulation and consumer welfare analysis, we assume that the marginal utility of consumer income does not change following cost shocks, and that utility from outside goods also does not change.

In this paper, we assume that there is an industry-wide common shock for each brand in each market and 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 is:

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

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

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

where Δp is the difference between the new equilibrium price that solves system (15) and the old price and $\Delta mc = \bar{mc} - \hat{mc}$. We perturb system (15) with marginal cost shocks of varying sizes. The cost shock ranges from 0.1 cents/serving to 1.2 cents per serving of processed cheese. This allows for up to an approximately 10 percent change in marginal cost. See Table 5 for each brand's estimated marginal cost per serving.

As prices change correspondingly with respect to the marginal cost shocks, consumer welfare will also change. Here, we assume that the estimated demand-side parameters do not change while prices will change in a manner that corresponds to the change in marginal cost. Consumer welfare change is estimated by the compensating variation, which measures the net revenue of a planner who must compensate the consumer for the price change after it occurs, bringing the consumer back to the original utility level (e.g., McFadden 1981, Small & Rosen, 1983). We estimate the consumer welfare changes for each regime of competition. Depending on the nature of the competition, the price pass-through rate will vary, as will the size of the compensating variation.

III (iv). Structural model versus reduced-form model

Reduced-form models have been used extensively in the cost pass-through literature partly because with such models the analysis can be easily implemented. To compare the results of the structural model with those of a reduced-form model, we conduct regression analysis using simple reduced-form models. One of difficulties of a reduced-form analysis is that we cannot recover firms' marginal costs in the model as we do in the structural model. Therefore, we approximate them using various input prices. We estimate the following regression:

(17) $$\ln(price_{it}) = \alpha_i + \beta * \ln(input\,Cost_t) + \varepsilon_{it}$$

In the model, $\ln(price_{it})$ is a log of processed cheese prices for brand i and time t, and $\ln(inputCost_t)$ is a log of input price at time t. ε_{it} represents an error term. To approximate industry-wide cost shocks, we use raw milk prices, wages, and diesel prices. The milk price is the raw milk price from the USDA federal milk order statistics. Wage and diesel prices are obtained from Bureau of Labor Statistics indices. One problem here is that the cheese and input prices are measured in different units. We therefore estimate a log-linear regression to obtain a unit-free measure of the pass-through rate. In the model, α_i is a brand-related fixed effect and β represents the pass-through elasticity. The brand-related fixed effects capture time-invariant markups. For comparison, we convert the pass-through rates that are estimated using the structural model to pass though elasticity, $\frac{\partial p}{\partial mc} \cdot \frac{mc}{p}$.

III. Estimation

To estimate the demand function we need to control for any correlation between prices and the error term in the mean utility function. It is difficult to justify a claim that price is independent of unobservable characteristics, which have the interpretation of unobserved product quality. The correlation between price and unobserved characteristics is positive because higher quality could lead suppliers to set higher prices. 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.

In the model, we must find variables that are correlated with price but are independent of unobserved product characteristics. Estimation requires an instrument vector with rank of at least 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, & Trajsenberg 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 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 brand in different cities within a region will be correlated, and therefore can be used as valid instrumental variables.[6] If there is, however, a national or regional demand shock, this shock 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, then these activities will increase the demand in the cities that are included in the activities, so the independence assumption will be violated for those cities.[7] Therefore, we use an additional set of instrumental variables to check the sensitivity of the result obtained by using different instrumental variables. The alternative instrumental variables we use are proxies for production costs. We create the production cost by multiplying input prices such as raw milk price, diesel price, wage, and electricity by brand dummies to give cross-brand variations.

Let Z be an N-by-L matrix with its row z_k and $\xi(\theta)$ is an N-by-1 error tem in mean utility with its row ξ_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. Then the moment condition that the instrumental variables are orthogonal to the structural error is used to form the GMM objective function, $E[z_k \xi_k(\theta)] = 0$. Then the sample moment will be $\bar{m}(\theta) = \frac{1}{n}\sum_{k=1}^{n} z_k \xi_k(\theta) = \frac{1}{n} Z' \xi(\theta)$. Now we search for θ, which minimizes the GMM objective function. The GMM estimate is

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

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[6] Refer to Bresnahan's comment on Hausman 1996.

[7] 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 it in the model.

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

IV. Results

Table 3 represents the results of logit models with and without instrumental variables. Using price 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 4 shows the estimated demand-side parameters. We use regional prices and cost variables as instrumental variables for Model I and Model II, respectively. Overall, the two models present 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. For the parameter estimates of mean utility, the coefficient on PRICE is negative and significant and FAT is positive and significant. This is possibly because the average consumer who purchases processed cheese is not sensitive to the health issues involving FAT but instead wants the richer taste from higher butterfat. 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 4 shows own- and cross-price elasticities. All estimates have the expected signs. An immediate consequence of product differentiation is that cross-price elasticities are generally positive and finite. In contrast, if products were homogeneous, the cross-price elasticities would be infinite at equal prices and zero at all others.

Table 5 shows the cost estimates under the assumption of Bertrand-Nash competition and collusive pricing among branded product firms, respectively. For any given prices, collusive pricing implies lower marginal costs and higher markups than were found under the assumption of Nash-Bertrand competition.

Table 6 and Table 7 show the results of the estimated price pass-through rates, which are defined as percentage change in price corresponding to decreases in cost.

Under collusion, the pass-through rates for all brands fall between 23% and 38% and the variation among firms is not wide through the entire range of the shock. Meanwhile, as the regime of competition among firms changes to a Bertrand-Nash situation, not only do the brand level pass-through rates increase, the variation among firms also widens. On average, the range of pass-through is 67% ~ 98%.

In reference to previous studies on the relationship between the shape of the demand curve and the pass-through rate, we may not be able to compare our results directly with the stylized facts in homogeneous product markets because a brand's price pass-through rate in our model depends on the other brands' demand surfaces as well as on its own demand surface, as in Equation (15). The simulation results, however, indicate that average pass-through rates are close to what a linear demand curve predicts. Our demand specification allows both overshooting and undershooting of price pass-through, i. e., pass-through rates above and below 100%, so these results are not constrained by functional form as is the case with a linear or logarithmic demand specification. Furthermore, because the shape of a brand's market share function differs across markets, the same brand has a different price pass-through rate in different markets. The shapes of the demand curves in our model are determined by the product characteristics and the distribution of consumer characteristics. The demand specification we use here therefore provides a very flexible analysis of price pass-through across markets.

Table 10 shows the consumer welfare change, which is estimated by the compensating variation after a shock that decreases marginal cost. CV1 and CV2 represent the compensating variations under Bertrand-Nash equilibrium and collusive pricing, respectively. The CV is 0.63 cents per person for a 1 cent marginal cost decrease under Nash price competition, while it is 0.23 cents under collusive pricing. The ratio of CV2 to CV1 is 37%. So, under collusive pricing, the increase in consumer welfare following a cost decrease is 37% of that in the Bertrand-Nash equilibrium.

Since our model is symmetric, the price increase corresponding to cost increases is higher under Nash-Bertrand competition than under collusive pricing and a cost increase hurts consumers less when pricing is collusive (Table 13). One policy implication of this result is that we should not always view a high increase in price following an unfavorable shock as evidence of collusive market power. Rather, it may be evidence of Nash-Bertrand competition in a differentiated product market. Finally, we compare the results of the structural model with those of the reduced-form model. The estimated pass-through elasticities for milk price, diesel price, and wage are 0.034, 0.237, and 0.375, respectively. Meanwhile, the pass-though elasticities estimated by the structural model include 0.07 for collusive pricing and 0.5 for Nash-Bertrand competition. These are the averages for different levels of cost shocks under two regimes of competition. Note here that varying input cost is characterized by varying pass-through elasticity. Therefore, approximating marginal cost using a single input cost results in a misreading of the results for a pass-through analysis. Note also that 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 will therefore be less competitive than Nash-price competition but more competitive than collusive pricing. If we do not know the results of benchmark cases of pass-through elasticities, however, i. e., those of Nash-Bertrand pricing and full collusion, it may be difficult to infer the level of market competition from the result of a reduced-form analysis. Rather, a superior strategy would be to specify the market structure first and then estimate the degree of cost pass-through that corresponds to the market structure.

VI. 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. In the literature, very little effort has been devoted to analyzing the cost pass-through in differentiated product markets. This study is an attempt to fill this gap. In the mixed logit model we use for demand specification, the curvature of demand depends on the empirical distribution of consumer characteristics. This property reduces the pass-through prediction error caused by an erroneous assumption pertaining to the demand function. This paper is the first attempt to test the property in the literature.

Empirical results indicate that the pass-through rates for the U.S processed cheese market are greater under Nash-Bertrand competition than under collusive pricing. This implies that increases or decreases in consumer welfare following cost shocks will be greater under Nash-Bertrand 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 Nash-Bertrand competition and full collusion. The results may suggest that, without knowing the benchmark pass-through elasticities, it may be difficult to infer the degree of market competitiveness through a reduced-form analysis.

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

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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	0.59	4.20
Light N Lively	15.56	2.82
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	1.28	2.42
Land O'Lakes		
HJ Heinz Co		
Weight Watchers	0.41	3.20

Table 2. Market share, Prices and Product Characteristics

	Market Share	Price	Calories	Fat (g)	Choles -terol (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)	7.835	7.838	0.905	0.405	10.742
Log (Age)	3.465	3.241	0.940	0	4.564
Child	0	0.255	0.436	0	1
Nonwhite	0	0.155	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^2	0.676		
First Stage R^2		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	18.445
	(0.487)**	(1.569)**
Price	-6.848	-5.632
	(0.501)**	(1.337)**
Fat	1.285	4.808
	(0.487)**	(1.569)**
Sodium	-3.714	-2.489
	(0.166)**	(0.247)**
Income	18.756	20.687
	(7.737)**	(5.879)**
Nonwhite	-4.611	-5.953
	(0.395)**	(0.478)**
Price* Income	-12.061	-17.063
	(3.746)**	(9.233)*
Price * $[\text{Income}]^2$	8.141	9.148
	(2.937)**	(3.292)**
Price * Age	-2.159	-2.751
	(1.256)*	(2.185)
Price * Child	2.537	2.521
	(1.438)*	(2.516)
Fat * Income	-0.540	-1. 490
	(0.043)**	(0.647)**
Constant* v_1	0.929	1.121
	(1.052)	(1.782)
Price* v_2	2.232	1.915
	(0.462)**	(0.544)**
Fat* v_3	2.437	2.668
	(1.716)*	(0.826)**
Sodium* v_5	3.245	3.021
	(1.583)*	(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.

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

Table 7. Marginal cost, Markup and Margin

	Nash-Bertrand			Full Collusion		
Brand	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; %): Cost decrease[8]

Kraft	90.58	92.40	92.86	92.99	93.61	94.44
Velveeta	88.74	90.87	91.09	90.97	91.56	91.83
Light N Lively	80.32	86.00	86.64	86.69	88.72	89.28
Kraft Free	83.86	87.10	87.82	89.32	90.12	91.61
Kraft Light	90.84	92.10	92.42	93.43	99.93	95.14
Velveeta Light	91.93	92.22	93.51	93.75	93.29	93.33
Borden	103.32	103.10	103.19	103.16	102.89	102.74
Lite Line	24.59	35.80	46.64	58.82	73.33	90.72
Land O'Lakes	57.91	76.40	71.46	65.24	88.36	98.07
Weight Watchers	22.08	33.09	47.25	62.82	76.86	91.83
Overall	67.48	79.85	80.72	80.75	82.67	83.76
MC shock	0.2	0.4	0.6	0.8	1.0	1.2

Table 9. Pass-Through Rate (Collusion): Cost decrease

Kraft	30.37	30.85	30.74	30.93	30.42	30.19
Velveeta	28.97	29.27	29.18	29.24	28.74	28.57
Light N Lively	25.46	25.90	26.08	26.13	26.45	26.78
Kraft Free	34.80	31.23	28.59	25.91	26.98	25.07
Kraft Light	31.29	32.23	30.98	29.49	30.34	29.87
Velveeta Light	29.22	30.84	30.97	31.27	30.83	29.97
Borden	30.16	30.54	30.45	30.38	30.12	29.23
Lite Line	22.87	23.61	23.72	24.69	23.70	24.29
Land O'Lakes	21.38	22.53	22.29	21.26	21.25	20.30
Weight Watchers	26.08	26.64	26.83	25.98	25.45	25.21
Overall	23.17	25.80	27.66	27.18	27.04	26.76
MC shock	0.2	0.4	0.6	0.8	1.0	1.2

[8] %, Median values for all markets. Marginal cost shocks are cents per serving.

Table 10. Pass-through Rates (Nash-Bertrand): Cost increase[9]

Kraft	91.90	93.73	95.39	96.22	96.62	97.02
Velveeta	89.86	91.84	92.86	93.60	94.07	94.51
Light N Lively	81.17	88.14	90.52	91.62	93.87	93.80
Kraft Free	87.57	90.22	92.36	92.08	92.80	94.24
Kraft Light	92.17	94.41	95.92	97.26	97.92	99.13
Velveeta Light	92.07	92.68	94.22	93.94	95.47	96.48
Borden	102.94	103.67	103.93	104.01	104.27	104.30
Lite Line	47.01	60.75	64.63	68.51	71.61	74.52
Land O'Lakes	86.65	95.39	97.40	98.93	99.85	100.42
Weight Watchers	63.93	74.38	86.69	91.68	93.75	96.55
Overall	85.73	89.32	91.19	92.78	94.25	95.59
MC Shock	0.2	0.4	0.6	0.8	1.0	1.2

Table 11. Pass through Rates (Collusion): Cost increase

Kraft	37.69	38.91	39.40	39.63	40.02	40.44
Velveeta	36.89	37.99	38.51	38.96	39.31	39.79
Light N Lively	29.92	34.59	36.52	37.76	38.42	39.37
Kraft Free	39.33	42.28	44.19	44.18	46.19	45.67
Kraft Light	42.31	44.03	46.09	46.66	47.18	47.10
Velveeta Light	40.70	42.87	42.74	43.70	44.59	45.08
Borden	35.62	37.35	37.98	37.79	38.39	39.03
Lite Line	23.03	29.85	32.69	33.53	35.16	36.82
Land O'Lakes	22.97	26.65	29.17	28.74	29.76	30.37
Weight Watchers	28.99	33.38	35.53	36.71	36.77	39.34
Overall	32.63	34.77	35.98	37.03	37.73	38.60
MC shock	0.2	0.4	0.6	0.8	1.0	1.2

[9] %, Median values for all markets. Marginal cost shocks are cents per serving.

Table 12. Compensating Variation: Cost decrease[10]

Bertrand-Nash (A)	0.12	0.25	0.43	0.50	0.63	0.77
Collusion (B)	0.05	0.10	0.17	0.19	0.23	0.28
B/A(%)	42%	40%	40%	38%	37%	36%
MC Shock (Cents)	0.2	0.4	0.6	0.8	1.0	1.2

Note: Cents/per serving/per person

Table 13. Compensating Variation: Cost increase

Bertrand-Nash (A)	-0.13	-0.26	-0.45	-0.52	-0.65	-0.79
Collusion (B)	-0.05	-0.12	-0.18	-0.21	-0.27	-0.33
B/A(%)*	38%	46%	40%	40%	41%	42%
MC Shock (Cents)	0.2	0.4	0.6	0.8	1.0	1.2

Note: Cents/per serving/per person.

[10] Median values for all markets.

Table 14. Results of Reduced-Form Models

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

Note: Each regression includes brand-fixed effects.

Table 15. Pass-Through Elasticities: Structural model

Nash(cost decrease)	Nash(cost increase)	Collusion(cost decrease)	Collusion(cost increase)
0.47	0.54	0.066	0.072

Table 16. 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