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Coupon Redemption and Its Effect on Household Cheese Purchases

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Abstract

By endogenizing unit value and coupon redemption, we estimate U.S. household cheese purchase, quality choice, and coupon redemption equations simultaneously. Zero purchases and missing values are taken into account in the model to correct for the selectivity bias. The correlations among the three equations are found to be significant. Empirical findings show that high quality choice significantly decreases cheese purchases, while cheese coupon usage significantly increases purchases. We find that higher income households select higher quality cheese, while larger households choose lower quality cheese. Frequent coupon redeemers are found to purchase lower quality cheese. For coupon redemption, we find that African American households redeem less while Asian households redeem more comparing to the Caucasian households.

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Coupons, as special price promotions, are extensively used by food manufacturers and retailers to enhance consumer demand for food products. In 2000, 166 billion grocery coupons were distributed, and 3.5 billion of them were redeemed (The Food Institute, 2000). Knowledge of: (i) what affects consumers' decisions to redeem coupons and (ii) how the coupon redemption affects sales is important for planning coupon strategies. However, unlike generic food advertising, which has been examined substantially in the literature, there has not been much research on food (grocery) coupons, and the issues of (i) and (ii) have not been well studied.

Most previous studies on (i) and (ii) have focused on only one issue without linking it to the other (Goodwin, 1992; Cronovich, Daneshvary, and Schwer, 1997; Levedahl, 1988; Neslin 1990; Ward and Davis 1978). However, the decisions by the household on how much to purchase, what quality of commodity to select, and whether to redeem coupons are usually made at the same time. Any study of coupon redemption without considering demand would in general give biased results.

An exception to this is a study by Lee and Brown (1985), who looked at coupon redemption and its effect on the demand simultaneously for frozen concentrated orange juice. They developed a switching regression model linking the household's decision regarding coupon usage to its orange juice purchase decision using household survey data. In their model, households were separated as coupon using and non-using groups according to a decision equation of whether or not to use coupons. However, Lee and Brown (1985) did not address the selection-bias issue arising from non-purchasing households, which may have been due to the low rate of frozen concentrated orange juice nonpurchases. However, for some frequently purchased commodities like cheese, this issue is usually very serious.

In general, any demand analysis using household survey data must confront the issue of selectivity bias that arises from zero-purchasing households. If the percentage rate of non-purchasing households is high, excluding them from the estimation will give biased parameter estimates because those households either intentionally select not to purchase, or the zero purchase is from other nonrandom reasons (for instance, infrequency of purchase). The inclusion of zero-purchase households is usually necessary to correct for selectivity bias. However, the inclusion of those households brings a new problem, which is the missing information on unit value and coupon availability for those non-purchasing households.

The unit values are derived from the observed expenditures and quantities, and are used by most researchers as proxies for prices since prices are unavailable when the researcher's interest is for a general aggregated commodity rather than for specific individual products. For example, in this study, we are interested in the aggregated cheese commodity rather than a specific cheese product such as a one-pound package of sliced mozzarella. Even though the prices for all the specific individual products are observable, the price for the aggregated commodity from individual products is not. One needs to be cautious when using unit value as price because the unit value not only represents the market price, but also the quality of the purchased commodity (Deaton, 1988; Dong, Shonkwiler, and Capps, 1998). The quality part of unit value is determined by the composition of household purchases over the individual products. As a consequence, the unit value is endogenously determined by households, and thus it needs to be jointly estimated along with demand equation. However, for those non-purchasing households, the expenditures and quantities are zero and no information is available for unit values. The situation for coupons is even worse. We do not know whether zero coupon usage from those non-purchasing households comes from unavailability of the coupon, or from the household simply not choosing to use it even if it is available. Both coupon redemption and the unit value are perceived to have a direct effect on household purchases and must be estimated with the demand equation simultaneously.

In this study, we account for all the above issues by adopting a Tobit-type censored model to estimate coupon redemption jointly with purchase and unit value equations. We use the unit value as a proxy for the price, but take into account the quality issue by treating it as endogenous. The missing unit values and coupon redemptions are obtained simultaneously with the model parameters. The model is applied to household data on cheese purchases.

Econometric Model

The household demand for cheese is defined by the following equation:

(1) $$Y_i^* = \ln P_i^* \alpha_1 + C_i^* \alpha_2 + X_i \alpha_3 + \varepsilon_i ,$$

where Y_i^* is household i's purchase of cheese, X_i is [1 x K_1] vector of household characteristic, demographic, and socio-economic variables, $\ln P_i^*$ is the natural logarithm of the cheese unit value paid by household i, and C_i^* is the redeemed value of the coupon by household i in purchasing cheese. The Greek letters α_1, α_2, and α_3 are parameters to be estimated, and ε_i is the error term. There is no restriction imposed on equation (1), so

Y_i^* can take either positive or negative values. However, in household survey data, the observed purchase takes only non-negative values. We map the unrestricted "latent" variable Y_i^* to the non-negative observed purchase Y_i as below (Tobin, 1958):

$$(2) \qquad Y_i = \begin{cases} Y_i^*; & if\ Y_i^* > 0 \\ 0\ ; & \text{otherwise}. \end{cases}$$

As discussed in the previous section, prices are not observed directly in household survey data. Instead, the unit values derived from observed purchase quantity and expenditures are used in equation (1). The quality of the composite cheese commodity determined by household choice over different kinds of cheese products is captured by the unit values, but is not observable to researchers. Following Houthacker (1952), Theil (1955), Nelson (1991), Cox and Wohlgenant (1986), and Dong, Shonkwiler, and Capps (1998), we use household characteristic, demographic, and socio-economic variables as proxies for quality represented by the unit values paid for different types of cheese by households. In addition to the quality issue, the unit values are missing for those non-purchasing households. To account for these two issues, we define the unit value equation as:

$$(3) \qquad \ln P_i^* = \begin{cases} \ln P_i; & if\ Y_i^* > 0 \\ Z_i\beta + e_i\ ; & \text{otherwise}, \end{cases}$$

where P_i^* is the latent unit value, P_i is the observed unit value, Z_i is a [1 x K_2] vector of variables that could influence the household's choice of cheese quality, β is a vector of parameters, and e_i is the error term.

The coupon variable, like the unit value, is treated as endogenous. Coupon usage is assumed to be determined by household characteristics and other variables, and can be obtained jointly with the optimal amount of purchase and the appropriate quality so as to maximize the household's utility. Among purchasing households, some use coupons while others do not. However, for non-purchasing households, no information exists on coupon availability. Following Erdem, Keane, and Sun (1999)[1], if we assume that the probability that no coupon is available encompasses both the cases in which no coupon was available and the case where the coupon was available but the household chose not to use it, then we can define the coupon redemption decision as:

$$(4) \qquad C_i^* = \begin{cases} C_i; & \textit{if } Y_i^* > 0 \text{ and } W_i\gamma + \omega_i > 0 \\ W_i\gamma + \omega_i \ ; & \textit{if } Y_i^* \le 0 \text{ and } W_i\gamma + \omega_i > 0 \\ 0\,; & \textit{if } W_i\gamma + \omega_i \le 0\,, \end{cases}$$

where C_i^* is the latent coupon value. Unlike the price, C_i^* is allowed to be zero. C_i is the observed coupon value redeemed. If no coupon is available, or the household decides not to use it, it is zero. W_i is a [1 x K_3] vector of exogenous variables which could influence household coupon redemption, γ is parameter, and ω_i is the error term.

Equation (4) indicates that the coupon value redeemed by household *i* is determined by $W_i\gamma + \omega_i$. Since the redeemed coupon value cannot be negative, we define it as zero when $W_i\gamma + \omega_i \le 0$. Equation $W_i\gamma + \omega_i \le 0$ implies that the household decided not to use the coupon, or no coupon is available to it; otherwise the household is a coupon redeemer. For a redeemer, the redeemed coupon value is observed as C_i whenever there is a positive purchase, otherwise the value is unknown, but can be determined by $W_i\gamma + \omega_i$.

[1] To correct for selection bias when price and coupons are missing for non-purchasing households, Erdem, Keane, and Sun (1999) proposed a method to obtain the missing price and coupon jointly with brand choice utility parameters. In their procedure, price and coupons are both treated as exogenous to consumers.

The error terms, ε_i, e_i, and ω_i in equations (1), (3), and (4) are assumed to have a joint normal distribution with a mean vector zero and variance-covariance matrix as:

$$(5) \qquad \Omega = \begin{bmatrix} \sigma_{\varepsilon\varepsilon} & \sigma_{\varepsilon e} & \sigma_{\varepsilon\omega} \\ \sigma_{e\varepsilon} & \sigma_{ee} & \sigma_{e\omega} \\ \sigma_{\omega\varepsilon} & \sigma_{\omega e} & \sigma_{\omega\omega} \end{bmatrix}.$$

The maximum likelihood estimation procedure can be used to estimate this model. To build up the likelihood function, we divide the households into four possible regimes: (i) positive purchase with coupon, (ii) positive purchase without coupon, (iii) zero purchase with coupon, and (iv) zero purchase without coupon. Regime iii represents the case where the household has the coupon, but the value is not enough for it to make a positive purchase. In household survey data, regimes iii and iv are not identified. They are both recorded as zero purchase without the coupon availability information.

Regime i: positive purchase with coupon

This regime is defined by $Y_i^* > 0$ and $W_i\gamma + \omega_i > 0$. The contribution to the likelihood of this regime is simply the joint *pdf* of ε_i, e_i, and ω_i and can be written as:

$$(6) \qquad L1_i = \phi 3(\varepsilon_i, e_i, \omega_i; 0, \Omega),$$

where $\phi 3(.)$ is the trivariate normal pdf of ε_i, e_i, and ω_I with zero mean and variance-covariance matrix of Ω. In this regime, Y_i^*, P_i^*, and C_i^* are observed as Y_i, P_i, and C_i, respectively.

Regime ii: positive purchase without coupon

This regime is defined by $Y_i^* > 0$ and $W_i\gamma + \omega_i \leq 0$. The contribution to the likelihood of this regime can be written as:

(7) $$L2_i = \int_{-\infty}^{-W_i\gamma} \phi 3(\varepsilon_i, e_i, \omega_i; 0, \Omega)\, d\omega_i \ .$$

In this regime, Y_i^* is observed as Y_i , P_i^* is observed as P_i, and C_i^* is observed as 0.

Regime iii and iv: zero purchase with and without coupon

As we mentioned above, since the coupon availability information is not observable for zero purchase households, regimes iii and iv are not identified from each other in the data. We combine the two regimes and identify it as $Y_i^* \le 0$. The contribution to the likelihood of this combined regime can be written as:

(8) $$L3_i = \int_{-\infty}^{-\theta 1_i} \int_{-\infty}^{+\infty} \int_{-W_i\gamma}^{+\infty} \phi 3(v1_i, e_i, \omega_i; 0, \Omega 1)\, d\omega_i de_i dv1_i + \int_{-\infty}^{-\theta 2_i} \int_{-\infty}^{+\infty} \int_{-\infty}^{-W_i\gamma} \phi (v2_i, e_i, \omega_i; 0, \Omega 2)\, d\omega_i de_i dv2_i$$

where $\theta 1_i = (Z_i\beta)\alpha_1 + (W_1\gamma)\alpha_2 + X_i\alpha_3$, $\theta 2_i = (Z_i\beta)\alpha_1 + X_i\alpha_3$, $v1_i = \alpha_1 e_i + \alpha_2\omega_i + \varepsilon_i$,

and $v2_i = \alpha_1 e_i + \varepsilon_i$; $\Omega 1 = \begin{bmatrix} \sigma_{v1v1} & \sigma_{v1e} & \sigma_{v1\omega} \\ \sigma_{ev1} & \sigma_{ee} & \sigma_{e\omega} \\ \sigma_{\omega v1} & \sigma_{\omega e} & \sigma_{\omega\omega} \end{bmatrix}$, and $\Omega 2 = \begin{bmatrix} \sigma_{v2v2} & \sigma_{v2e} & \sigma_{v2\omega} \\ \sigma_{ev2} & \sigma_{ee} & \sigma_{e\omega} \\ \sigma_{\omega v2} & \sigma_{\omega e} & \sigma_{\omega\omega} \end{bmatrix}$. The first part in the right hand side of (8) is associated with regime iii, i.e., zero purchase with coupon. In this regime, $\ln P_i^* = Z_i\beta + e_i$ and $C_i^* = W_i\gamma + \omega_i$. The second part of (8) is associated with regime iv, i.e., zero purchase without coupon. In this regime $\ln P_i^* = Z_i\beta + e_i$ and $C_i^* = 0$. Even though these two regimes (iii and iv) are not identified from the data, the model is able to predict the probabilities of a given household for either regime iii or regime iv.

The joint log-likelihood function for all the regimes over all the households thus can be written as below:

(9) $$LL = \sum_{i \in S1} \ln L1_i + \sum_{i \in S2} \ln L2_i + \sum_{i \in S3} \ln L3_i$$

where S1 is the index subset of households with positive purchase and positive coupon, S2 is the index subset of households with positive purchase and zero coupon, and S3 is the index subset of households with zero purchase.

Next, we apply this model to study U.S. household cheese purchases. After introducing the data, we define the variables to use for purchase, unit value, and coupon equations, which are estimated simultaneously. As designed in the model, we investigate effects on individual equations of purchase, unit value and coupons as well as the interactive effects across the three equations, which is the main contribution of this study.

Empirical Model of U.S. Household Cheese Purchases

Data

Household data used in this study are drawn from the ACNielsen Homescan Panel, including household purchase information for cheese products and annual demographic information. The purchase data is purchase-occasion data collected by the households, who used hand-held scanners to record purchase information. This data includes the date of purchase, total expenditure, quantities purchased, and the values of any redeemed coupons. The final purchase data are reformulated to a weekly basis and combined with the household demographic information. The data are over a 208-week period from January 1996 through December 1999, and include more than 30,000 households. Given the large size of the panel, we select a 10% random sample of households and pool the data for estimation purposes.

Table 1 provides an overview of U.S. household cheese purchase information, including quantity, unit value derived from quantity and expenditure, and coupon value redeemed. The mean cheese purchase represents the mean of purchase amounts over all occasions, while the mean conditional purchase gives the mean over the purchase occasions only. Purchase frequency is the ratio of purchase occasions over total occasions. For U.S. households, the cheese purchase frequency is only 30.7%, indicating that the cheese purchase data are highly censored at zero. The cheese commodity used in this study is aggregated from numerous varieties provided in the data including American, Mozzarella, processed, ricotta, Muenster, farmers, brick, and cream cheese. The richness in cheese varieties gives enough quality variations in the cheese category purchased across households. These variations in cheese quality are captured in the variations of derived unit values. The mean derived unit value and the mean coupon redeemed value given in Table 1 are both calculated from the purchased occasions. The coupon redemption frequency computed from the purchase occasions is 3.7%.

The explanatory variables used in cheese purchase, unit value, and coupon equations are shown in Table 2. The same set of variables is used in the three equations except for the annual proportion of occasions using coupons (PROP_CPN) that appears only in unit value equation to capture an indirect effect of coupon on unit value (price or purchase quality).

Parameter Estimates

Parameter estimates were obtained by maximizing the log-likelihood function in (9) using the GAUSS software system. Numerical gradients of (9) were used in the optimization algorithm proposed by Berndt et al (1974). The standard errors of the estimated coefficients were obtained from the inverse of the negative numerically evaluated Hessian matrix. The estimated coefficients are presented in Table 3. The results show that the coefficients of unit value and coupon in the purchase equations are statistically significant at the 1% level, which provides evidence of strong direct effects of unit value and coupon on cheese purchases. All the elements in the variance and covariance matrix of the error terms in purchase, unit value, and coupon equations are also statistically significant at the 1% level, which implies that all three equations are correlated. Indeed, the correlation coefficient of cheese demand and coupon redemption is –0.748, implying that the coupon redemption decision is highly related to the household decision on how much cheese to purchase.

Since the effects of the exogenous variables overlap in this three-equation model, the estimated coefficients themselves are of little interest. From these coefficients, however, we can estimate elasticities for each explanatory variable.

Model Prediction and Elasticities

The endogeniety of unit value and coupon complicates model prediction and the evaluation of elasticities. However, it also provides important information that is unavailable from the conventional model. It allows us to obtain not only direct effects of the exogenous variables including household characteristic, demographic and social-economic variables on household cheese demand, but also indirect effects through the changes in unit value and coupon. For example, an increase in household income may give the household more money to spend, which may result in increased purchases of cheese. However, the increase in household income allows the household to buy a higher quality cheese variety. The final effect of income on cheese purchases would depend upon the net of these two effects.

The evaluation of elasticities is based on the expected values of amount purchased, unit value, and the value of the redeemed coupons. These expected values are derived as follows:

$$(10)\quad \begin{aligned} E(Y_i) = {} & prob(Y_i^* > 0, C_i^* > 0)[(Z_i\beta)\alpha_1 + (W_i\gamma)\alpha_2 + X_i\alpha_3 + E(v1_i \mid Y_i^* > 0, C_i^* > 0)] \\ & + prob(Y_i^* > 0, C_i^* = 0)[(Z_i\beta)\alpha_1 + X_i\alpha_3 + E(v2_i \mid Y_i^* > 0, C_i^* = 0)] \end{aligned},$$

(11) $E(C_i) = prob(C_i^* > 0)[W_i\gamma + E(\omega_i \mid C_i^* > 0)]$, and

(12) $E(\ln P_i) = Z_i\beta$,

where $E(.)$ is the expectation operation, and *prob*(.) is probability. In order to compute the effect of unit value and coupon on purchase amount, we derive the expected value conditional on unit value and coupon given as:

$$(13)\quad E(Y_i \mid \ln P_i, C_i) = prob(Y_i > 0 \mid \ln P_i, C_i)[\theta_i + E(\varepsilon_i > -\theta_i \mid \ln P_i, C_i)]$$

where $\theta_i = \ln P_i\,\alpha_1 + C_i\alpha_2 + X_i\alpha_3$.

Details of the final results and their derivations of equations (10)-(13) are provided in the appendix. The elasticities of explanatory variables with respect to (10)-(13) are presented in Tables 4 and 5.

Empirical Findings

1. Coupon Redemption and Unit Value (or Quality)

Table 4 provides the elasticities of coupon and unit value equations. The column labeled *E(C)* is associated with equation (11), which represents household coupon redemption. The column labeled *E(lnP)* is associated with equation (12), which represents the unit value or quality selected by households. The Column labeled *Prob(C>0)* is the probability of positive redemption of coupon.

Among the selected household characteristic variables, we find only BASE_AGE, AGE612, BLACK, and ASIAN have significant effects on coupon redemption.[2] The age of household's female head increases the coupon usage, which is similar to the findings by Lee and Brown (1985), Goodwin (1992), and Cronovich, Daneshvary, and Schwer (1997). Indeed, this is the most important determinant of coupon redemption of all variables as indicated by the largest elasticity value. For race, African American households use fewer coupons than the base race (Caucasian households), while Asians use coupons more. Similar results were also found in Cronovich, Daneshvary, and Schwer (1997). Income is found to have negative effect as indicated by Cronovich, Daneshvary, and Schwer (1997), but is insignificant as found in Goodwin (1992). Household size is insignificant, but the proportion of persons in the household between 6 and 12 is negative and significant. Lee and Brown (1985), Narasimhan (1984) and Bawa and Shoemaker (1987) also found a negative relationship between children and coupon usage.

With respect to the marketing related variables, only *TOTCHZ_GTLB_SH* (purchases of cheese in large packages) and *WINTER* are found to be insignificant. People shopping more frequently in convenient store (*TOTCHZ_CONV_SH*) are found to be less likely to use coupons, which is similar to Cronovich, Daneshvary, and Schwer (1997). Cheese purchased in small packages usually has a higher unit value than in large packages. We find more coupons are redeemed in the purchase of small packages (*TOTCHZ_HIB_SH*). Greater coupon redemption is also found in the purchase of shredded, diced, or cube cheeses (*TOTCHZ_SDC_SH*). Consumers using shopping lists were found to have a positive effect on coupon usage in Cronovich, Daneshvary, and

[2] We reference statistical significance as being at 5% level or higher if not explicitly indicated.

Schwer (1997). We do not have this information in our data; however, we find the number of purchases per week on cheese decrease coupon usage. It might be that households shopping more often per week are less likely to use a shopping list. The results also show that people living in a Metropolitan area are more likely to use more coupons.

Similar patterns of explanatory variables are found for the probability of coupon usage in comparison with its quantity. The change of the probability is defined as the extensive effect of explanatory variables.

As discussed above, the unit value used in this study is an indication of the commodity's qualities. As expected, we find that household income increases the quality of cheese purchased. Household size is found to be negative implying that a large household is likely to buy less expensive (i.e., lower quality) cheese. The proportion of persons under 12 years of age and employed female head are found to purchase higher quality cheese. For ethnicity, African American households tend to buy lower quality cheese than the base Caucasian households, while Asian households buy higher quality cheese, and Hispanic households have no significant effect.

Except for the winter seasonal variable, all the marketing related variables are found to have a significant influence on household cheese quality choices. As expected, we find the purchase of cheese in large packages (*TOTCHZ_GTLB_SH*) is negative, while for small packages (*TOTCHZ_HIB_SH*) is positive. This indicates that cheese in small packages has a higher unit value than in large package. Counter-intuitively, shredded, diced, or cube cheeses (*TOTCHZ_SDC_SH*) are found to have a lower unit value, which usually costs more. The results also show that cheese purchased in convenient stores has a higher unit value, and households buying cheese more frequently select lower quality cheese. People living in a metropolitan area pay a higher unit value for cheese.

The household's annual proportion of occasions using coupon (PROP_CPN) is found to have a negative effect on purchased cheese quality. This implies that those households with more coupon usage usually choose lower priced (or quality) cheeses, which implies that these households are more price sensitive than others.

We find Asian households have the biggest effect among all the variables on cheese unit value as evident from its largest elasticity value.

2. Purchase

Many dimensions of household cheese demand have been studied in literature. Yen and Jones (1997) used a double hurdle model to analyze U.S. household cheese market participation and consumption. Gould (1992) adopted an infrequency of purchase model to study at-home consumption of cheese using household survey data. However, neither of the above studies incorporated unit value (price and quality) effects into the cheese demand, which was due to the difficulty of handling the endogeneity and the missing values of the unite value.

Table 5 provides the elasticities of purchase equation. Column $E(Y|lnP,C)$ is associated with equation (13), which represents the direct effects of the explanatory variables. Unit value and coupon elasticities are only available under this situation. The cheese unit value elasticity is found to be negative and elastic (-3.239), while coupon is positive (0.3114). Both of them are statistically significant at the level of 1%.

It is worth noting that the unit value elasticity (-3.239) is not the price elasticity since it is mixed with the quality effect. If the quantity of cheese rather than its "taste" is the primary concern of the household, the optimal reaction to an increase in price is to move to less expensive products with little sacrifice of the cheese purchase amount. Under this situation, an increase in price will generate a less than proportionate increase in unit vale. In other words, the same quantity difference will be ascribed to a smaller unit value difference. Thus, the unit value elasticity will be larger in magnitude than the true price elasticity (Deaton, 1988).

Among the selected household characteristic variables, we find household income (*INCOME*), the age of household's female head (*BASE_AGE*), employment of female head (*FH_EMPL*), and African American household (*BLACK*) have significant direct effects on cheese purchases. Specifically, household income increases cheese purchases, while age, employment of female head, and African American household decreases cheese purchases when cheese quality (unit value) and coupon usage are given (fixed). Without considering unit value, both Gould (1992) and Yen and Jones (1997) found income and household size to have a significant and positive effect, similar to what we find here, but the household size in our study is insignificant.

With respect to the marketing related variables, we find all of them have significant effects on cheese purchase when unit value and coupon are given. Among them, only the purchase of cheese in small packages (*TOTCHZ_HLB_SH*) and households in metropolitan areas (*METRO*) are negative.

In summary, except for unit value and coupon, income has the greatest direct effect on cheese purchase among all the household characteristic variables and the number of purchases per week (*PURCH_PER_WEEK*) among all the marketing related variables based on the magnitude of elasticity.

Unit value and coupon are endogenously determined by individual households and depend on the household characteristic variables and the marketing related variables. We need a total effect of the explanatory variables from the direct effect given in the column labeled $E(Y|lnP,C)$, and the indirect effect through the changes of unit value and coupon. These total effects are give in the column labeled $E(Y)$, which is evaluated using equation (10).

Household size and income are found to be negative, though they are found to be positive as expected when unit value and coupon are given. This seemingly unintuitive result is due to the indirect effect on cheese purchases through unit value and coupon when household size and income change. Besides household and income, children between the ages of 6 to 12 (*AGE612*) and African American households are found to be significant and negative, while the age of the household's female head (*BAS_AGE*) and Asian households are found significant and positive. Other household characteristic variables are insignificant. The results also show that all the marketing related variables have a significant and negative total (mixed) effect on cheese purchase.

The column labeled $Prob(Y>0)$ gives the elasticities of probability to have a positive purchase. These results are also referred as extensive effects on household demand versus the intensive effects given by the differences between the columns labeled $E(Y)$ and $Prob(Y>0)$.

Conclusions

In this study, we examined the impact of coupons on cheese demand, which is an important issue that has not been extensively covered in the literature. Moreover, of the limited number of studies on coupons and demand, most have either examined what factors influence consumers' decisions to redeem coupons, or how coupon redemption affects demand. However, the decisions by the household on how much to purchase, what quality of commodity to select, and whether to redeem coupons are usually made at the same time. Any study of coupon redemption without considering demand would in general give biased results.

By endogenizing unit value and coupon redemption, we estimated U.S. household cheese purchase, quality choice, and coupon redemption equations simultaneously. Zero purchases and the missing values of unit value and coupons associated with those purchases were taken into account in the model to correct for selectivity bias. The correlations among the three equations were found to be significant, implying that ignoring them will give biased estimates.

The empirical findings revealed that quality choice and coupon usage have significant effects on household cheese purchases. High quality choice was found to significantly decrease cheese quantity purchased. Cheese coupon usage significantly increased the amount of purchases. We also found that higher income households select higher quality cheese, while larger households choose lower quality cheese. Frequent coupon redeemers were found to purchase lower quality product. For coupon redemption, we found that African American households redeem less, while Asian households redeem more compare to Caucasian households.

Appendix

The results of $E(Y)$, $E(C)$, $E(lnP)$, and $E(Y|lnP,C)$ defined by equations (10)-(13) are derived as followings.

1. *The Derivation of* $E(Y)$

Starting from equation (10), we have

$$\begin{aligned} E(Y_i) &= prob(Y_i^* > 0, C_i^* > 0)[(Z_i\beta)\alpha_1 + (W_i\gamma)\alpha_2 + X_i\alpha_3 + E(v1_i \mid Y_i^* > 0, C_i^* > 0)] \\ &\quad + prob(Y_i^* > 0, C_i^* = 0)[(Z_i\beta)\alpha_1 + X_i\alpha_3 + E(v2_i \mid Y_i^* > 0, C_i^* = 0)] \\ &= prob(v1_i > -\theta 1_i, \omega_i > -W_i\gamma)[\theta 1_i + E(v1_i \mid v1_i > -\theta_3, \omega_i > -W_i\gamma)] \\ &\quad + prob(v2_i > -\theta 2_i, \omega_i < -W_i\gamma)[\theta 2_i + E(v2_i \mid v2_i > -\theta_3, \omega_i < -W_i\gamma)] \end{aligned}$$

where the parameters are defined as in equation (8). By applying the results of Rosenbaum (1961), we have the final outcome of $E(Y)$, as:

$$\begin{aligned} E(Y_i) &= \Phi 2\left(\frac{-\theta 1_i}{\sqrt{\sigma_{v1v1}}}, \frac{-W_i\gamma}{\sqrt{\sigma_{\omega\omega}}}, \rho_{v1\omega}\right)\Bigg[\theta 1_i + \\ &\quad \sqrt{\sigma_{v1v1}}\,\frac{\phi 1\left(\frac{-\theta 1_i}{\sqrt{\sigma_{v1v1}}}\right)\Phi 1\left(\dfrac{\frac{-W_i\gamma}{\sqrt{\sigma_{\omega\omega}}} + \rho_{v1\omega}\frac{\theta 1_i}{\sqrt{\sigma_{v1v1}}}}{\sqrt{1-\rho_{v1\omega}^2}}\right) + \rho_{v1\omega}\phi 1\left(\frac{-W_i\gamma}{\sqrt{\sigma_{\omega\omega}}}\right)\Phi 1\left(\dfrac{\frac{-\theta 1_i}{\sqrt{\sigma_{v1v1}}} + \rho_{v1\omega}\frac{W_i\gamma}{\sqrt{\sigma_{\omega\omega}}}}{\sqrt{1-\rho_{v1\omega}^2}}\right)}{\Phi 2\left(\frac{-\theta 1_i}{\sqrt{\sigma_{v1v1}}}, \frac{-W_i\gamma}{\sqrt{\sigma_{\omega\omega}}}, \rho_{v1\omega}\right)}\Bigg] \\ &\quad + \Phi 2\left(\frac{-\theta 2_i}{\sqrt{\sigma_{v2v2}}}, \frac{W_i\gamma}{\sqrt{\sigma_{\omega\omega}}}, -\rho_{v2\omega}\right)\Bigg[\theta 2_i + \\ &\quad \sqrt{\sigma_{v2v2}}\,\frac{\phi 1\left(\frac{-\theta 2_i}{\sqrt{\sigma_{v2v2}}}\right)\Phi 1\left(\dfrac{\frac{W_i\gamma}{\sqrt{\sigma_{\omega\omega}}} - \rho_{v2\omega}\frac{\theta 2_i}{\sqrt{\sigma_{v2v2}}}}{\sqrt{1-\rho_{v2\omega}^2}}\right) - \rho_{v2\omega}\phi 1\left(\frac{W_i\gamma}{\sqrt{\sigma_{\omega\omega}}}\right)\Phi 1\left(\dfrac{\frac{-\theta 2_i}{\sqrt{\sigma_{v2v2}}} + \rho_{v2\omega}\frac{W_i\gamma}{\sqrt{\sigma_{\omega\omega}}}}{\sqrt{1-\rho_{v2\omega}^2}}\right)}{\Phi 2\left(\frac{-\theta 2_i}{\sqrt{\sigma_{v2v2}}}, \frac{W_i\gamma}{\sqrt{\sigma_{\omega\omega}}}, -\rho_{v2\omega}\right)}\Bigg] \end{aligned}$$

where $\rho_{v1\omega} = \dfrac{\sigma_{v1\omega}}{\sqrt{\sigma_{v1v1}\sigma_{\omega\omega}}}$ and $\rho_{v2\omega} = \dfrac{\sigma_{v2\omega}}{\sqrt{\sigma_{v2v2}\sigma_{\omega\omega}}}$; $\phi 1(.)$ and $\Phi 1$ are the univariate normal pdf and cdf, respectively; and $\Phi 2$ are the bivariate normal cdf.

2. *The Derivation of* $E(Y|lnP,C)$

Starting from equation (13), we have

$$
\begin{aligned}
E(Y_i \mid \ln P_i, C_i) &= prob(Y_i > 0 \mid \ln P_i, C_i)[\theta_i + E(\varepsilon_i > -\theta_i \mid \ln P_i, C_i)] \\
&= prob(\varepsilon_i > -\theta_i \mid e, \omega)[\theta_i + E(\varepsilon_i > -\theta_i \mid e, \omega)] \\
&= \Phi 1(\frac{-\theta_i - \mu_{\varepsilon|e\omega}}{\sigma_{\varepsilon|e\omega}})\theta_i + \sigma_{\varepsilon|e\omega}\phi 1(\frac{-\theta_i - \mu_{\varepsilon|e\omega}}{\sigma_{\varepsilon|e\omega}})
\end{aligned}
$$

where $\mu_{\varepsilon|e\omega}$ is the mean of ε given e and ω, and $\sigma_{\varepsilon|e\omega}$ is the standard deviation of ε given e and ω.

3. *The Derivation of* E(C)

Starting from equation (11), we have

$$
\begin{aligned}
E(C) &= prob(C_i^* > 0)[W_i\gamma + E(\omega_i \mid C_i^* > 0)] \\
&= \Phi 1(\frac{-W_i\gamma}{\sqrt{\sigma_{\omega\omega}}})(W_i\gamma) + \sqrt{\sigma_{\omega\omega}}\phi 1(\frac{-W_i\gamma}{\sqrt{\sigma_{\omega\omega}}})
\end{aligned}
$$

4. *The Derivation of* $E(lnP)$

$$
\begin{aligned}
E(\ln P_i) &= prob(Y > 0)E(\ln P_i \mid Y > 0) + prob(Y = 0)E(\ln P_i \mid Y = 0) \\
&= prob(Y > 0)[Z_i\beta + E(e \mid Y > 0)] + prob(Y = 0)[Z_i\beta + E(e \mid Y = 0)]. \\
&= Z_i\beta
\end{aligned}
$$

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Table 1. U.S. Household Cheese Purchase Characteristics

Variable	Mean
Purchase (lb)	0.42
Conditional Purchase (lb)	1.37
Purchase Frequency (%)	30.7
Unit Value for Purchase Occasions ($/lb)	3.27
Redeemed Coupon Value for Purchase Occasions ($)	0.12
Coupon Redemption Frequency (%)	3.74

Table 2. Description of the Explanatory Variables

Name	Description (units)	Mean
Household related variables		
HHSIZE	Number of persons in household	2.10
INCOME	Household income ($1,000)	38.8
BASE_AGE	Age of female head (years)	50.8
AGE05	Proportion of household members less than 5 years	0.03
AGE612	Proportion of household members aged from 6 to 12	0.05
SINGLEHH	Single person household (0/1)	0.24
COLLEGE	Female head completed college education (0/1)	0.36
FH_EMPL	Female head worked outside home (0/1)	0.54
BLACK	African American household (0/1)	0.06
ASIAN	Asian household (0/1)	0.01
SPANISH	Spanish household (0/1)	0.05
Marketing related variables		
METRO	Household resides in metropolitan location (0/1)	0.85
WINTER	Purchase made in Nov., Dec., or Jan. (0/1)	0.25
TOTCHZ_CONV_SH	Share of purchase at convenience store (%)	0.06
TOTCHZ_GTLB_SH	Share of purchase on package >16 oz (%)	0.28
TOTCHZ_HLB_SH	Share of purchase on package <=8 oz (%)	0.16
TOTCHZ_SDC_SH	Share of purchase on shredded, diced, or cube (%)	0.08
PURCH_PER_WEEK	Number of purchases per week	0.49
PROP_CPN	Annual proportion of occasions using coupon (%)	0.26
UNIT_VALUE	Derived prices from observed quantities and expenditures ($/lb)	3.27
COUPON	Values of redeemed coupon ($)	0.12

Table 3. Parameter Estimates

Variable	**Purchase Equation**		**UnitValue Equation**		**Coupon Equation**	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
CONSTANT	*-0.2351*	*0.1553*	*1.0921**	*0.0407*	*-0.7672**	*0.1598*
Household related variables						
HHSIZE	*-0.0067*	*0.0228*	*-0.0872**	*0.0071*	*-0.0469*	*0.0265*
INCOME	*0.0986**	*0.0099*	*0.0562**	*0.0030*	*-0.0115*	*0.0120*
BASE_AGE	*-0.1218**	*0.0294*	*-0.0080*	*0.0088*	*0.1476**	*0.0359*
AGE05	*0.0698*	*0.0665*	*0.1122**	*0.0212*	*0.0474*	*0.0821*
AGE612	*0.3328**	*0.0487*	*0.0388**	*0.0163*	*-0.3953**	*0.0628*
SINGLEHH	*-0.0268*	*0.0267*	*0.0077*	*0.0077*	*0.0159*	*0.0331*
COLLEGE	*-0.0029*	*0.0128*	*0.0019*	*0.0039*	*-0.0304*	*0.0160*
FH_EMPL	*-0.0232*	*0.0129*	*0.0145**	*0.0039*	*-0.0129*	*0.0161*
BLACK	*0.0081*	*0.0228*	*-0.0080*	*0.0092*	*-0.1679**	*0.0395*
ASIAN	*-0.0238*	*0.0731*	*0.0767**	*0.0197*	*0.2358**	*0.0791*
SPANISH	*0.0017*	*0.0267*	*0.0070*	*0.0080*	*-0.0571*	*0.0326*
Marketing related variables						
METRO	*-0.0990**	*0.0152*	*0.0589**	*0.0049*	*0.1639**	*0.0186*
WINTER	*0.0574**	*0.0126*	*-0.0043*	*0.0038*	*-0.0191*	*0.0157*
TOTCHZ_CONV_SH	*0.7538**	*0.0172*	*0.0275**	*0.0057*	*-0.5626**	*0.0220*
TOTCHZ_GTLB_SH	*1.4408**	*0.0171*	*-0.0818**	*0.0072*	*0.0355*	*0.0211*
TOTCHZ_HLB_SH	*0.1699**	*0.0250*	*0.2201**	*0.0049*	*-0.4152**	*0.0200*
TOTCHZ_SDC_SH	*0.5694**	*0.0173*	*-0.0641**	*0.0057*	*-0.7572**	*0.0228*
PURCH_PER_WEEK	*1.0041**	*0.0052*	*-0.0157**	*0.0025*	*-0.1154**	*0.0057*
PROP_CPN	--	--	*-0.2109**	*0.0064*	--	--
Model parameters						
α_1 *(UNIT_VALUE)*	*-1.5654**	*0.0831*				
α_2 *(COUPON)*	*1.1985**	*0.0024*				
Variance-Covariance matrix of error terms						
	ε		e		ω	
ε	*1.5100**	*0.0055*				
e	*0.0776**	*0.0083*	*0.1239**	*0.0019*		
ω	*-1.1420**	*0.0087*	*0.066*8*	*0.0225*	*1.5451**	*0.0020*

*denotes significance at the 5% level or higher. The standard errors are derived from the Delta Method (Rao, 1973)

Table 4. Elasticity Estimates with respect to the Unit Value and Coupon Equations

Variable	**E (C)**		**Prob (C > 0)**		**E (lnP)**	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Household related variables						
HHSIZE	-0.0563	0.0316	-0.0402	0.0226	-0.0872*	0.0071
INCOME	-0.0138	0.0143	-0.0099	0.0105	0.0562*	0.0030
BASE_AGE	0.1771*	0.0427	0.1265*	0.0314	-0.0080	0.0088
AGE05	0.0014	0.0016	0.0010	0.0016	0.0028*	0.0006
AGE612	-0.0229*	0.0038	-0.0163*	0.0025	0.0019*	0.0008
SINGLEHH	0.0055	0.0116	0.0047	0.0099	0.0243	0.0246
COLLEGE	-0.0104	0.0054	-0.0090	0.0047	0.0060	0.0124
FH_EMPL	-0.0044	0.0056	-0.0038	0.0048	0.0460*	0.0124
BLACK	-0.0541*	0.0118	-0.0484*	0.0110	-0.0252	0.0287
ASIAN	0.0902*	0.0332	0.0723*	0.0248	0.2519*	0.0672
SPANISH	-0.0193	0.0107	-0.0168	0.0095	0.0223	0.0254
Marketing related variables						
METRO	0.0608*	0.0067	0.0498*	0.0056	0.1919*	0.0157
WINTER	-0.0065	0.0054	-0.0056	0.0046	-0.0135	0.0121
TOTCHZ_CONV_SH	-0.0401*	0.0019	-0.0286*	0.0011	0.0016*	0.0003
TOTCHZ_GTLB_SH	0.0120	0.0072	0.0086	0.0052	-0.0230*	0.0020
TOTCHZ_HLB_SH	-0.0777*	0.0036	-0.0555*	0.0027	0.0343*	0.0008
TOTCHZ_SDC_SH	-0.0772*	0.0024	-0.0551*	0.0017	-0.0054*	0.0005
PURCH_PER_WEEK	-0.0673*	0.0033	-0.0480*	0.0023	-0.0076*	0.0012
PROP_CPN	--	--	--	--	-0.0556*	0.0017

*denotes significance at the 5% level or higher. The standard errors are derived from the Delta Method (Rao, 1973)

Table 5. Elasticity Estimates with respect to the Purchase Equation

Variable	E(Y|lnP, C)		E (Y)		Prob (Y > 0)	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Price and Coupon						
UNIT_VALUE	*-3.2390**	*0.2847*	--	--	--	--
COUPON	*0.3114**	*0.0225*	--	--	--	--
Household related variables						
HHSIZE	*0.0887*	*0.0631*	*-0.0526**	*0.0153*	*0.1497**	*0.0235*
INCOME	*0.2001**	*0.0357*	*-0.0071*	*0.0074*	*0.0098*	*0.0108*
BASE_AGE	*-0.1650**	*0.0636*	*0.0831**	*0.0216*	*-0.0912**	*0.0329*
AGE05	*0.0019*	*0.0193*	*0.0012*	*0.0015*	*-0.0030*	*0.0020*
AGE612	*0.0206*	*0.0208*	*-0.0105**	*0.0034*	*0.0105**	*0.0041*
SINGLEHH	*-0.0012*	*0.0010*	*0.0054*	*0.0056*	*-0.0090*	*0.0058*
COLLEGE	*-0.0010*	*0.0005*	*-0.0031*	*0.0028*	*-0.0035*	*0.0028*
FH_EMPL	*-0.0019**	*0.0005*	*0.0028*	*0.0028*	*-0.0125**	*0.0027*
BLACK	*-0.0033**	*0.0010*	*-0.0258**	*0.0078*	*-0.0039*	*0.0051*
ASIAN	*0.0019*	*0.0036*	*0.0315**	*0.0100*	*-0.0187*	*0.0155*
SPANISH	*-0.0015*	*0.0010*	*-0.0063*	*0.0062*	*-0.0059*	*0.0057*
Marketing related variables						
METRO	*-0.0029**	*0.0006*	*0.0352**	*0.0031*	*-0.0363**	*0.0031*
WINTER	*0.0029**	*0.0006*	*-0.0072**	*0.0026*	*0.0158**	*0.0028*
TOTCHZ_CONV_SH	*0.0969**	*0.0215*	*-0.0236**	*0.0038*	*0.0428**	*0.0042*
TOTCHZ_GTLB_SH	*1.4617**	*0.0275*	*-0.1183**	*0.0112*	*0.5646**	*0.0116*
TOTCHZ_HLB_SH	*-0.0865**	*0.0129*	*-0.0157**	*0.0047*	*-0.0555**	*0.0055*
TOTCHZ_SDC_SH	*0.0749**	*0.0200*	*-0.0388**	*0.0033*	*0.0515**	*0.0047*
PURCH_PER_WEEK	*1.6051**	*0.0329*	*-0.1580**	*0.0114*	*0.6169**	*0.0120*
PROP_CPN	*0.1194**	*0.0236*	*-0.0240**	*0.0028*	*0.1106**	*0.0040*

*denotes significance at the 5% level or higher. The standard errors are derived from the Delta Method (Rao, 1973)

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