Consumer Cohorts and Demand Systems

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Abstract

The Norwegian purchases pattern of non-alcoholic beverages has changed substantially. The observed changes cannot be fully explained by changes in relative prices and income, and other variables are likely to be important. Cohort variables have not been given much attention in demand analysis. Our main contribution is to include age, period, and cohort (APC) variables into a demand system. The system is applied to purchases of non-alcoholic beverages. Wald tests show the importance of including APC variables. A Monte-Carlo analysis shows how replacing the APC variables with an age and a trend variable results in misleading age effects on milk purchases.

JEL: D12, J10, Q13

Key words: cohorts effects, demand system, milk.

An age cohort is formed by individuals born in the same period. In food demand analysis, time and age are frequently included as variables while cohort variables are excluded. However, cohort variables are likely to be important. Factors such as the availability, variety, and quality of food during childhood years have changed substantially over time, and childhood experiences are likely to influence future food consumption. Consequently, the exclusion of cohort variables may cause biased parameter estimates and associated misleading forecasts of demand. For example, let us assume that a positive age effect is found in the demand for milk in a study without cohort variables. The estimated age effect could be explained in different ways. It could be explained by increased health awareness among older individuals leading to more healthy drinking habits and increased demand for milk. If this explanation is true, then an increased average age in the population will result in increased future aggregate demand for milk. The positive age effect could alternatively be explained by cohort effects where older generations consume more milk than younger. Older generations are likely to consume more milk because of childhood experiences. During and after the Second World War, milk was considered to be an important part of any healthy diet. However, the nutritional value of milk has later been questioned and milk's nutritional status has declined among younger generations. If the latter explanation is true, then the replacement of older with newer generations will result in decreased future aggregate demand for milk. Therefore, it is important to differentiate between the effects of the age of an individual, the period the individual makes his purchase, and the cohort the individual belongs to in empirical demand analysis.

The best way to study cohort effects is to have a large panel data set with individuals of different age, and to follow these individuals over a long period. Unfortunately, this type of panel is rare, but repeated cross sections is a good substitute. Age-period-cohort (APC) analysis using times series of cross sections, i.e. pseudo panels, has been used to study consumption and saving (Attanasio 1998), life insurance (Chen, Wong, and Lee 2001), medical insurance (Propper, Rees, and Green 2001), eating habits (Mori and Clason 2004), and alcohol consumption (Kerr et al. 2004). Food consumption has been studied by Aristei, Perali, and Pieroni (2008) and Stewart and Blissard (2008) within a single-equation framework. However, this framework neglects substitution among different goods and is not entirely consistent with demand theory. The main contribution of this article is to incorporate APC variables into a system of demand equations.

Attanasio (1998); Chen, Wong, and Lee (2001); Propper, Rees, and Green (2001); and Mori and Clason (2004) followed Deaton (1985) and averaged the variable of interest over all individuals in a certain year within the cohort. Contrary to their approach, we follow Aristei, Perali, and Pieroni (2008) and Stewart and Blissard (2008) and include age, period, and cohort dummies for each household.

The specified demand system includes fluid milk, carbonated soft drinks, other soft drinks, and other non-durables and services. The Norwegian purchase pattern of non-alcoholic beverages has changed substantially over the last decades. In our sample, the yearly per capita purchases of fluid milk decreased from 148 to 88 liters and the purchases of carbonated soft drinks increased from 34 to 72 liters over the 1986 to 2001 period. Gustavsen and Rickertsen (2003) found that the own-price elasticity of fluid milk was -0.14 and the total expenditure elasticity was close to zero. Given highly inelastic aggregate demand, economic factors cannot fully explain the observed decline in fluid milk purchases, and the included APC variables are highly significant. To further investigate the effects of excluding cohort variables when the true data generating process includes age, period, and cohort variables, we performed a Monte Carlo analysis using our data and estimated model.

In the next section, we develop a demand system incorporating APC variables. The second section, describes our data set and the construction of the price variables. Next, we present our estimation results and results of hypothesis tests regarding the inclusion of APC variables in the demand system. In the fourth section, we perform our Monte-Carlo analysis before we conclude.

A Demand System Including APC Variables

A linear version of Deaton and Muellbauer's (1980) almost ideal demand (AID) system is used.[1] The expenditure share of good i in period t for a household, w_{it}, is given as

$$(1) \qquad w_{it} = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_{jt} + \beta_i \ln\left(\frac{x_t}{P_t}\right),$$

where p_j denotes the price per unit of good j, x is the per capita expenditure on the goods included in the system, and ln$P$ is a price index. As discussed in Asche and Wessells (1997), the Tornquist price index can be used. The index is specified as

(2) $$\ln P_t = \frac{1}{2}\sum_{i=1}^{n}(w_{it} + w_i^0)\ln(p_{it} / p_i^0)$$

where w_i^0 and p_i^0 are the shares and prices evaluated at the point of normalization. As recommended in Asche and Wessells (1997), we normalize at the mean for all households and periods.

Deaton (1997) constructed the age, period, and cohort variables by using the mean values of the variables in each cohort. To facilitate the incorporation of other variables than age, period, and cohort, we follow Aristei, Perali, and Pieroni (2008) and Stewart and Blissard (2008) and use the individual observations for each household. The per capita purchases of one good in a household X can be decomposed as

(3) $$X = \alpha_0 + \sum_{k=2}^{K}\delta_k C_k + \sum_{l=2}^{L}\pi_l A_l + \sum_{m=2}^{M}\eta_m Y_m.$$

Because of singularity one cohort, one age, and one period dummy variables are dropped and there remain K-1 cohort dummies C_k, L-1 age dummies A_l, and M-1 period dummies Y_m. Furthermore, there exists an additional linear relationship across the cohort, age, and period dummies. If we know the period of an observation and when the observed cohort was born, then we can infer the age of the cohort. Following Deaton (1997), one additional period dummy is dropped and the orthogonality restriction $m'\eta = 0$, is imposed, where η is the parameter vector of the period effects in equation (3), and m = (1, 2, …, 16) is a trend where m = 1 represents the year 1986 and m = 16 represents the year 2001. The period dummies are redefined to $Y_m^* = Y_m - [(m-1)Y_2 - (m-2)Y_1]$ for m = 3, …, 16. This procedure enforces the restriction $m'\eta = 0$ and, furthermore, the restriction that the period effects have to sum to zero. The age, period, and cohort dummies are defined in table 1.

To take account of seasonality in demand, three quarterly dummy variables, S_s, are included and we translate the constant term in equation (1) as [2]

$$\alpha_i = \alpha_{i0} + \sum_{k=2}^{11} \delta_{ik} C_k + \sum_{l=2}^{12} \pi_{il} A_l + \sum_{m=3}^{16} \eta_{im} Y_m^* + \sum_{s=2}^{4} \theta_{is} S_s. \tag{4}$$

Several households did not purchase all types of non-alcoholic beverages. To correct for this censoring, the two-step method of Shonkwiler and Yen (1999) was used. This method yields consistent two-step estimates for a system of equations with limited dependent variables.[3] In the first step, the probabilities of purchasing milk, carbonated soft drinks, and other soft drinks are estimated by probit models. In the second step, the probability density function $\phi(z_i'\psi_i)$ for equation i and the cumulative density function $\Phi(z_i'\psi_i)$ are used to correct for censoring. Inserting equation (4) into equation (1) the model becomes

$$\begin{aligned} w_{it} = {} & \alpha_{i0}\Phi(z_{it}'\psi_i) + \sum_{k=2}^{11} \delta_{ik}\Phi(z_{it}'\psi_i) C_k + \sum_{l=2}^{12} \pi_{il}\Phi(z_{it}'\psi_i) A_l + \sum_{m=3}^{16} \eta_{im}\Phi(z_{it}'\psi_i) Y_m^* \\ & + \sum_{s=2}^{4} \theta_{is}\Phi(z_{it}'\psi_i) S_s + \sum_{j=1}^{n} \gamma_{ij}\Phi(z_{it}'\psi_i) \ln p_{jt} + \beta_i \Phi(z_{it}'\psi_i) \ln\left(\frac{x_t}{P_t}\right) \\ & + \tau_i \phi(z_{it}'\psi_i) + u_{it} \end{aligned} \tag{5}$$

where u_{it} is a stochastic error term. The equation for other goods is not censored and $\Phi(z_{it}'\psi_i)$ = 1 and $\tau_4 = 0$.

Adding-up implies the following restrictions

$$\sum_{i=1}^{4} \alpha_{i0} = 1,\ \sum_{i=1}^{4} \beta_i = \sum_{i=1}^{4} \gamma_{ij} = 0 \,\forall j, \text{ and } \sum_{i=1}^{4} \delta_{ik} = \sum_{i=1}^{4} \pi_{il} = \sum_{i=1}^{4} \eta_{im} = \sum_{i=1}^{4} \theta_{is} = \sum_{i=1}^{3} \tau_i = 0 \,\forall k,l,m,s. \tag{6}$$

Homogeneity of degree zero in prices and total expenditures and symmetry imply the following restrictions

$$\sum_{j=1}^{4} \gamma_{ij} = 0 \,\forall i \text{ and } \gamma_{ij} = \gamma_{ji} \,\forall i,j. \tag{7}$$

Following Shonkwiler and Yen (1999), the own-price, e_{ij},, cross-price, e_{ij}, and total expenditure elasticities, E_i, are calculated as

$$
(8) \quad
\begin{aligned}
e_{ii} &= -1 + (\gamma_{ii} - \beta_i w_i)\Phi(z_i'\psi_i) / w_i \\
e_{ij} &= (\gamma_{ij} - \beta_i w_j)\Phi(z_i'\psi_i) / w_i \\
E_i &= 1 + \Phi(z_i'\psi_i)\beta_i / w_i .
\end{aligned}
$$

The elasticities are calculated at the mean values of the expenditure shares.

Data Description and Construction of Prices

The Norwegian household expenditure surveys cover the 1986–2001 period and are described in Statistics Norway (1996). In the surveys, the country is divided into sampling areas corresponding to the more than 400 counties of Norway. These sampling areas are grouped in 109 strata, and a sample area is randomly drawn from each stratum. Sampling areas are drawn with a probability proportional to the number of persons living in the area. Next, persons are randomly drawn from the 109 sampling areas such that the sample becomes self-weighting. When a person is drawn, the household of that person is included. Finally, these households are randomly drawn to record their expenditures in one of the 26 two-week survey periods of the year. Each year 2,200 persons are initially drawn. The non-response rate varies between 33% and 52%, and our total sample consists of 20,550 cross-sectional observations.

For food and beverage products, the quantities purchased and the corresponding expenditures are recorded, and these values can be used to calculate unit values. However, unadjusted unit values are affected by quality differences. For milk, the quality differences include the brand of milk, the size of the package of milk, and the place of purchase. Furthermore, unit values are missing for households not purchasing the product in the survey period. Therefore, we constructed quality-adjusted prices following Cox and Wohlgenant (1986); Park and Capps (1997); and Kuchler, Tegene, and Harris (2005).

The quality-adjusted prices are constructed in three steps. First, unit values are calculated by dividing expenditure by quantity for each household with a positive purchase of the good in the survey period. To avoid outliers, in each year we replace the unit values above the 0.99^{th} quantile with the 0.99 quantile unit value, and the unit values below the 0.01 quantile with the 0.01^{st} quantile unit value.[4]

Second, to filter out the effects of quality differences the unit values are regressed on total expenditure; total expenditure squared; age of household head; squared age of household head; household size; household type, yearly, seasonal, and regional dummy variables.

Third, the parameter estimates from step 2 are used to construct the quality-adjusted prices. The adjusted price for a good for household h, $\hat{p}_h$, is constructed as

$$(9) \qquad \hat{p}_h = \hat{\alpha} + \sum_{m=1987}^{2001} \hat{\alpha}_m Y_{hm} + \sum_{s=2}^{4} \hat{\beta}_s S_{hs} + \sum_{r=2}^{5} \hat{\gamma}_r R_{hr} + \hat{\varepsilon}_h ,$$

where Y_{hm} are year dummy variables, S_{hs} are quarterly dummy variables, R_{hr} are regional dummy variables, and $\hat{\varepsilon}_h$ is the household specific residual term from the unit value regression. The quality-adjusted prices calculated by (9) equal the estimated unit values minus the effects of variables assumed to reflect quality differences, i.e., the effects of total expenditure, total expenditure squared, age, age squared, household size, and household types. The quality-adjusted prices of households without purchases are set to the value of equation (9) excluding the residual term. These prices are the average of the quality adjusted prices as regards year, quarter, and region. We used this procedure to compute quality-adjusted prices for milk, carbonated soft drinks, and other soft drinks. The consumer price index for non-durables and services was used as the price of the group other non-durables and services.

Table 1 shows the description, the mean, and the standard deviation of each variable used to estimate step 1 and step 2 of our demand system. In the sample, 2% of the households did not purchase fluid milk, 18% did not purchase carbonated soft drinks, and 26% did not purchase other soft drinks. More than half the sample consists of couples with children and 20% of couples without children. About half the household that participated were between 30 and 50 years old.

The values of the expenditure shares show a highly asymmetric model where the expenditure share of other non-durables and services is 0.97. An alternative specification would be to specify a conditional demand system only including non-alcoholic beverages. It is unknown what the preferred specification would be; see also Alston et al. (2000) who discuss asymmetric versus conditional demand systems without being able to conclude which specification is preferred.

Table 1 about here

Estimation Results

We start by discussing the results of the probability of purchase equations. Next, we present the effects of the APC variables in the demand system and finally present the estimated price and total expenditure elasticities.

Probabilities of Purchase

The data are censored and probit models were used to estimate the probabilities of purchase. The estimated coefficients, the marginal effects dy/dx, and their associated *t* values are reported in the table in the appendix.[5] The marginal effects are evaluated at the mean values of the independent variables. Almost all the households purchased milk, and it is not surprising that the marginal effects are small. The largest effect on milk purchases is being a single. On average, singles have 6% lower probability of purchasing milk than families with children. All the parameters associated with the cohort variables were positive and they imply that older cohorts have higher probabilities of purchasing milk than the youngest cohort.

The non-purchase rate is higher for carbonated soft drinks than for milk and the marginal effects are also larger. The cohort variables have the largest effects on the probability of purchasing carbonated soft drinks. The marginal cohort effects are increasingly negative showing that the probability of purchase decreases with increasing cohorts. Other important variables are the number of persons in the household and total expenditures.

For other soft drinks, the number of individuals in the household and total expenditures have positive effects on the probability of purchase. The cohort effects are small an insignificant for the youngest cohorts, but negative and significant at 5% level for the three oldest cohorts.

Seasonal effects do not change the probability of purchasing milk, while the probabilities for purchasing carbonated soft drinks and other soft drinks increase in the second or third quarter.

Using the criteria that an observation is predicted as a purchase if the estimated probability of purchase exceeds 0.50 and not as a purchase otherwise, the model predicted purchases of milk, carbonated soft drinks, and other soft drinks correctly in 98%, 83%, and 75% of the cases, repectively.[6]

APC Effects on Purchases of Non-Alcoholic Beverages

The demand system (5) with the probability density and cumulative distribution functions from the first step was estimated using seemingly unrelated regression in Stata. Homogeneity, symmetry, and adding-up restrictions were imposed on the system. The results are shown in table 2 where all the coefficients are multiplied by 100 to improve the readability.

The reported cohort effects are relative to a household born between 1974 and 1978. All the effects in the milk equation are positive and, with the exception of the second cohort, significantly different from zero. Furthermore, the effect increases from 0.15 for the cohort born between 1969 to 1973 to 2.25 for the cohort born between 1924 to 1928. These coefficients imply that the cohort born between 1969 and 1973 and the cohort born between 1924 and 1928 allocate 0.15% and 2.25% more of their total expenditures to milk as compared with the reference cohort. For carbonated soft drinks there are no significant cohort effects while for other soft drinks there are significantly lower spendings among the oldest cohorts.

The age effects are relative to a household who is between 18 and 22 years old. All the effects in the milk equation are negative and, with the exception of the second age group, significantly different from zero. These coefficients show that milk purchases are declining with age, which is plausible given reduced caloric intake among older people. The oldest group, who is between 73 and 77 years old, allocates about 2% less of its total expenditure to milk than the reference group. The joint effect of positive cohort and negative age effects suggests that the replacement of older with younger generations and increased average age of the population will result in continuing declining per capita purchases of milk.

As expected, there is a negative age effect on purchases of carbonated soft drinks. The effect is smaller than for milk and consistent with reduced caloric intake with age. The joint effect of insignificant cohort and negative age effects will be reduced per capita purchases of carbonated soft drinks.

Most of the age effects on purchases of other soft drinks are significantly positive. The positive age effects suggest increased intake of these beverages with age indicating that older people, to some extent, substitute milk and carbonated soft drinks with other soft drinks. However, the age effects are smaller than for milk and carbonated soft drinks. The positive age effects will be reinforced by the mostly negative cohort effects and result in increased per capita purchases of other soft drinks.

There are several significant seasonal effects. The purchases of milk are lower during spring and summer than during winter while the purchases of carbonated soft drinks and other soft drinks are higher during these quarters. Purchases of other soft drinks are also lower during the fall than during the winter. Finally, the year effects are mainly fluctuations around zero, and there are no clear trends in the purchases of any of the beverage groups.

Table 3 shows the results of Wald tests for the effects of cohort, age, and period on purchases. The results show that these variables have highly significant effects on each of the expenditure shares with one exception. We cannot reject no cohort effects on purchases of carbonated soft drinks. These results demonstrates the importance of including APC variables in our demand system.

Price and Total Expenditure Elasticities

The price and total expenditure elasticities are reported in table 4. All the own-price and total expenditure elasticities have the expected signs and are significantly different from zero. The own-price elasticity of milk is about -0.6 and the total expenditure elasticity is about 0.1. The purchases of carbonated soft drinks and other soft drinks are more elastic with respect to price and total expenditure. Carbonated soft drinks and other soft drinks are gross complements while the cross-price elasticities between milk and the other non-alcoholic beverages not are significantly different from zero. Given a total expenditure share of 0.97, it is as expected that the own-price and the total expenditure elasticity of other goods both are very close to one in numerical value. It is also as expected that the *t* values for other goods are very high.

The general pattern of more price- and income elastic demand for carbonated soft drinks and other soft drinks than for milk is as reported in Gustavsen and Rickertsen (2003).

However, their estimated own-price and total expenditure elasticities for milk were even more inelastic with values of -0.14 and -0.03, respectively. Furthermore, they found significant cross-price elasticities between milk and carbonated soft drinks.

In the next section, we will investigate the effects of replacing the APC variables in our demand system with an age and a trend variable.

Table 2 about here

Table 3 about here

Table 4 about here

A Monte Carlo Analysis

To investigate the bias of excluding cohort variables when the data generating process includes age, cohort, and period dummies we performed a Monte Carlo analysis. First, we used the estimated parameters from equation (5) as reported in table 2 and the associated residual covariance matrix. We first drew one residual vector for each equation, assuming they followed a multivariate normal distribution MN(0, Σ), where Σ is the estimated covariance matrix.

Second, we used the estimated parameters from equation (5) together with the covariates and the residual vectors to construct the budget shares. Some of the budget shares were predicted to be negative and those were set to zero.

Third, we estimated equation (5) excluding the APC dummies but including (log) trend and (log) age variables using 1000 drawings and the associated parameter values for parameter i in equation j in iteration k, $\hat{\beta}_{ijk}$, were recorded. The associated bias was calculated as $\widehat{bias}_{ijk} = \frac{(\hat{\beta}_{ijk} - \beta^{*}_{ij}) \cdot 100}{\beta^{*}_{ij}}$ where β^{*}_{ij} is the estimated parameter value from equation (5) as reported in table 2.

Table 5 shows the mean and the median calculated bias for the parameters in equation (5). In addition the table shows the estimated coefficients and *t* values for the (log of) age and (log of) trend variables. The bias is especially high for the price parameters and for the pdf correction terms but minor for the expenditure term.

Both the age and trend variables are significantly different from zero in all equations except for the trend variable in the carbonated soft drink equation. When the APC variables are replaced by the age trend variables there seems to be some confounding going on in the equation for milk. In table 2 (and figure 1), we can see that the age effect for milk is strongly negative while the cohort effect is positive, i.e., the milk purchases are higher in older than in younger cohorts but they decline with age. This means that when cohort variables are excluded, we may easily conclude that milk purchase will increase with the average age of the population and the trend effect is negatively related to milk purchase.

Table 5 about here

Conclusions

The observed decreases in purchases of fluid milk and increases in purchases of carbonated soft drinks cannot be fully explained by changes in relative prices and income. Childhood experiences are likely to influence on future consumption, and our main contribution is to include age, period, and cohort variables into a demand system.

Our results show that the replacement of cohorts have substantial effects on beverage-specific purchases. Older generations purchase more milk than younger generations while age by itself has a negative impact on milk purchases. A household will purchase less milk as it gets older, but will still purchase more than an identical household from a younger generation. The replacement of generations will continue and further decreases in milk purchases are expected.

The results of our Monte Carlo simulations show that replacing APC variables with an age and a trend variable has minor effects on the price and income parameters but leads to confounded the age effects. Our results suggest that it may be useful to control for APC effects in models used to forecast food demand or analyze the effects of agricultural policies on production levels.

Notes

1. A quadratic almost ideal demand system (QAIDS) allowing for nonlinear Engle curves could also be considered. However, the focus of this article is on the inclusion of APC variables in a demand system. For ease of presentation as well as to facilitate the estimation of our system, a linear version of the AIDS model was used.

2. Demographic variables could also be included in the system. However, when we included demographic variables we ran into colinearity problems.

3. Other methods such as the method described in Dong, Gould, and Kaiser (2004) are based on the multivariate normal distribution and may estimate a system of censored demand equations more efficiently when the data are independently, identically, and normally distributed. Our data are pooled cross-sectional data which possibly contain a lot of non-normality and heteroscedasticity. Given non-normality and heteroscedasticity models based on the multivariate normal distribution will be inconsistent.

4. To avoid outliers, Cox & Wohlgenant (1986) deleted observations with prices more than five standard deviations from the average (about 2% of the observations). They used a cross section data set for one year. In our study, we have a pooled data set for 16 years. Then, we

believe it may be more appropriate each year to replace the values below the 0.01 quantile with the 0.01 quantile and values above the 0.99 quantile with the 0.99 quantile.

5. We also included prices and all the demographic variables in the probit equations. Due to identification problems, the estimation of the second stage did not converge and we excluded most of these variables from the first step model.

6. The percentage of correct predictions is, however, a questionable measure of the goodness of fit. For example, the naive predictor that every household purchased milk would do quite well on this criterion.

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Table 1. Description of the Sample

Variable	Description	Mean	Standard Deviation
	Variables Only Included in Step 1		
Pr_1	= 1 if household purchased fluid milk	0.98	0.14
Pr_2	= 1 if household purchased carbonated soft drinks	0.82	0.38
Pr_3	= 1 if household purchased other soft drinks	0.74	0.44
lnD_1	Log of number of persons in the household	1.02	0.51
D_2	= 1 if household consisted of single person	0.13	0.33
D_3	= 1 if household consisted of couple without children	0.20	0.40
D_4	= 1 if household consisted of couple with children	0.52	0.50
D_5	= 1 if household consisted of single parent	0.05	0.22
D_6	= 1 if household had other composition	0.11	0.31
lnA	Log of age of the head of the household	1.94	0.75
lnY	Log of trend variable	3.72	0.29
	Variables Only Included in Step 2		
w_1	Expenditure share, fluid milk	0.02	0.01
w_2	Expenditure share, carbonated soft drinks	0.01	0.01
w_3	Expenditure share, other soft drinks	0.01	0.01
w_4	Expenditure share, other non-durables and services	0.97	0.02
lnp_1	Log of price fluid milk (normalized)	-0.0027	0.20
lnp_2	Log of price carbonated soft drinks (normalized)	-0.0278	0.23
lnp_3	Log of price other soft drinks (normalized)	-0.0405	0.28
lnp_4	Log of consumer price index (normalized)	0.0035	0.14
A_1	= 1 if head of household is between 18 and 22 years old	0.02	0.14
A_2	= 1 if head of household is between 23 and 27 years old	0.08	0.27
A_3	= 1 if head of household is between 28 and 32 years old	0.13	0.34
A_4	= 1 if head of household is between 33 and 37 years old	0.15	0.36
A_5	= 1 if head of household is between 38 and 42 years old	0.16	0.36
A_6	= 1 if head of household is between 43 and 47 years old	0.13	0.34
A_7	= 1 if head of household is between 48 and 52 years old	0.11	0.31
A_8	= 1 if head of household is between 53 and 57 years old	0.09	0.28
A_9	= 1 if head of household is between 58 and 62 years old	0.07	0.25
A_{10}	= 1 if head of household is between 63 and 67 years old	0.05	0.21
A_{11}	= 1 if head of household is between 68 and 72 years old	0.02	0.15
A_{12}	= 1 if head of household is between 73 and 77 years old	0.01	0.08
Y_1	= Normalized dummy variable = 1 for year = 1986	0.06	0.24
Y_2	= Normalized dummy variable = 1 for year = 1987	0.06	0.24
Y_3	= Normalized dummy variable = 1 for year = 1988	-0.12	0.59
Y_4	= Normalized dummy variable = 1 for year = 1989	-0.25	0.88
Y_5	= Normalized dummy variable = 1 for year = 1990	-0.37	1.20
Y_6	= Normalized dummy variable = 1 for year = 1991	-0.49	1.52
Y_7	= Normalized dummy variable = 1 for year = 1992	-0.60	1.85
Y_8	= Normalized dummy variable = 1 for year = 1993	-0.73	2.17
Y_9	= Normalized dummy variable = 1 for year = 1994	-0.85	2.50
Y_{10}	= Normalized dummy variable = 1 for year = 1995	-0.97	2.82

Y_{11}	= Normalized dummy variable = 1 for year = 1996	-1.09	3.15
Y_{12}	= Normalized dummy variable = 1 for year = 1997	-1.21	3.47
Y_{13}	= Normalized dummy variable = 1 for year = 1998	-1.34	3.80
Y_{14}	= Normalized dummy variable = 1 for year = 1999	-1.46	4.12
Y_{15}	= Normalized dummy variable = 1 for year = 2000	-1.58	4.45
Y_{16}	= Normalized dummy variable = 1 for year = 2001	-1.71	4.77
	Variables Included in Both Steps		
$\ln(x/P)$	Log of deflated per capita expenditures	11.23	0.50
S_1	= 1 if household is surveyed in 1st quarter	0.24	0.43
S_2	= 1 if household is surveyed in 2nd quarter	0.27	0.45
S_3	= 1 if household is surveyed in 3rd quarter	0.22	0.41
S_4	= 1 if household is surveyed in 4th quarter	0.27	0.45
C_1	= 1 if head of household is born between 1974 and 1978	0.01	0.12
C_2	= 1 if head of household is born between 1969 and 1973	0.05	0.22
C_3	= 1 if head of household is born between 1964 and 1968	0.10	0.30
C_4	= 1 if head of household is born between 1959 and 1963	0.14	0.35
C_5	= 1 if head of household is born between 1954 and 1958	0.15	0.36
C_6	= 1 if head of household is born between 1949 and 1953	0.14	0.34
C_7	= 1 if head of household is born between 1944 and 1948	0.13	0.33
C_8	= 1 if head of household is born between 1939 and 1943	0.08	0.28
C_9	= 1 if head of household is born between 1934 and 1938	0.07	0.25
C_{10}	= 1 if head of household is born between 1929 and 1933	0.06	0.24
C_{11}	= 1 if head of household is born between 1924 and 1928	0.06	0.24

Table 2. Censored Demand System Parameter Estimates, Step 2

Variable		Milk		Carbonated Soft Drinks		Other Soft Drinks	
		Coefficient	t value	Coefficient	t value	Coefficient	t value
Constant, Price, Total Expenditure, and Season							
Intercept		20.61	90.26	8.00	31.67	4.22	20.34
$\ln p_1$		0.71	7.27	0.00	0.04	–0.05	–1.58
$\ln p_2$		0.00	0.04	–0.32	–7.68	0.08	3.45
$\ln p_3$		–0.05	–1.58	0.08	3.45	0.07	2.59
$\ln p_4$		–0.67	–6.14	0.24	3.94	–0.10	–2.20
$\ln x/P$		–1.70	–92.64	–0.58	–28.52	–0.34	–21.22
S_2		–0.05	–1.86	0.14	5.29	0.07	3.36
S_3		–0.06	–2.37	0.10	3.36	0.07	3.42
S_4		–0.02	–0.78	0.00	0.11	–0.06	–2.77
Age							
A_2	(23 – 27 years)	–0.09	–1.16	–0.14	–1.73	0.08	1.22
A_3	(28 – 32 years)	–0.21	–2.47	–0.37	–4.30	0.09	1.29
A_4	(33 – 37 years)	–0.41	–4.44	–0.37	–3.84	0.16	2.06
A_5	(38 – 42 years)	–0.68	–6.67	–0.35	–3.29	0.24	2.80
A_6	(43 – 47 years)	–0.95	–8.36	–0.34	–2.86	0.29	3.02
A_7	(48 – 52 years)	–1.28	–10.11	–0.48	–3.62	0.37	3.54
A_8	(53 – 57 years)	–1.49	–10.58	–0.65	–4.33	0.37	3.19
A_9	(58 – 62 years)	–1.70	–10.81	–0.81	–4.84	0.38	2.88
A_{10}	(63 – 67 years)	–1.77	–10.10	–1.02	–5.38	0.47	3.22
A_{11}	(68 – 72 years)	–1.96	–10.24	–1.25	–5.82	0.57	3.48
A_{12}	(73 – 77 years)	–2.02	–8.81	–1.23	–4.42	0.71	3.41
Cohort							
C_2	(1969 – 1973)	0.15	1.55	–0.01	–0.14	0.02	0.24
C_3	(1964 – 1968)	0.30	3.15	0.03	0.35	0.05	0.59
C_4	(1959 – 1963)	0.61	5.94	0.04	0.38	0.01	0.17
C_5	(1954 – 1958)	0.95	8.52	0.00	0.01	–0.02	–0.20
C_6	(1949 – 1953)	1.20	9.90	0.03	0.28	–0.09	–0.94
C_7	(1944 – 1948)	1.51	11.37	0.09	0.70	–0.13	–1.25
C_8	(1939 – 1943)	1.86	12.72	0.17	1.10	–0.19	–1.61
C_9	(1934 – 1938)	1.91	11.90	0.15	0.92	–0.29	–2.26
C_{10}	(1929 – 1933)	2.25	12.87	0.34	1.82	–0.29	–1.99
C_{11}	(1924 – 1928)	2.25	11.85	0.38	1.86	–0.34	–2.16
Period							
Y_3	(1988)	–0.12	–3.18	–0.20	–4.65	0.09	2.58
Y_4	(1989)	–0.02	–0.59	–0.04	–0.97	–0.02	–0.51
Y_5	(1990)	0.09	2.39	–0.03	–0.76	–0.08	–2.36
Y_6	(1991)	0.01	0.38	0.07	1.80	0.03	1.11
Y_7	(1992)	0.05	1.44	0.10	2.75	0.05	1.92
Y_8	(1993)	–0.03	–0.86	0.09	2.41	0.01	0.34
Y_9	(1994)	0.19	5.55	0.16	4.72	–0.08	–3.01
Y_{10}	(1995)	0.07	1.94	0.02	0.50	–0.09	–3.42
Y_{11}	(1996)	0.03	1.06	0.09	2.74	–0.01	–0.26
Y_{12}	(1997)	–0.02	–0.61	–0.03	–0.76	0.03	1.24
Y_{13}	(1998)	–0.15	–4.43	–0.18	–5.09	0.07	2.46
Y_{14}	(1999)	0.03	0.74	0.00	0.02	0.00	0.14
Y_{15}	(2000)	–0.03	–0.92	–0.03	–0.97	–0.00	–0.14
Y_{16}	(2001)	–0.02	–0.47	–0.02	–0.52	–0.00	–0.04
ϕ		–0.94	–10.87	0.33	4.69	0.60	11.07
R^2		0.73		0.50		0.39	

Note: All coefficients are multiplied by 100.

Table 3. Test Results of the Effects of Age, Period, and Cohort

H_0	χ^2	p value
H_0 for purchases of fluid milk		
No effects of age	217.60	0.00
No effects of period	93.96	0.00
No effects of cohort	304.53	0.00
No effects of age, period, and cohort	670.56	0.00
H_0 for purchases of carbonated soft drinks		
No effects of age	74.84	0.00
No effects of period	108.82	0.00
No effects of cohort	14.29	0.16
No effects of age, period, and cohort	297.71	0.00
H_0 for purchases of other soft drinks		
No effects of age	25.29	0.00
No effects of period	40.21	0.00
No effects of cohort	24.14	0.01
No effects of age, period, and cohort	82.01	0.00
H_0 for purchases of fluid milk, carbonated soft drinks, and other soft drinks		
No effects of age, period, and cohort	1066.11	0.00

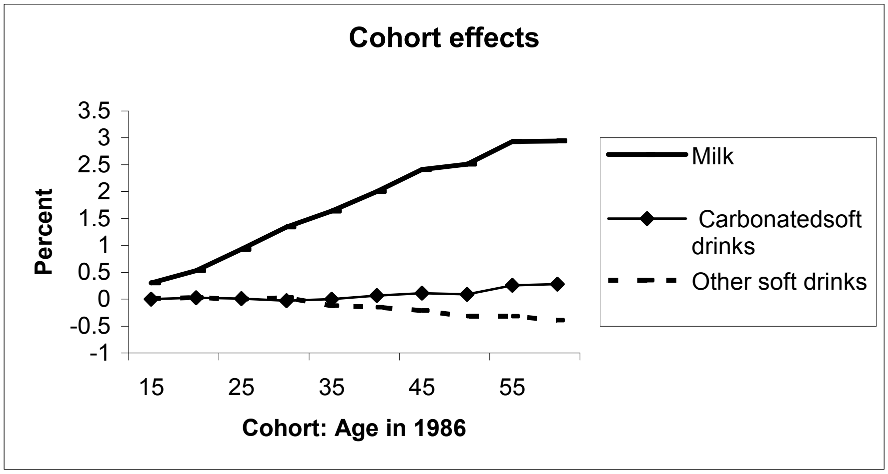
Table 4. Uncompensated Price and Expenditure Elasticities

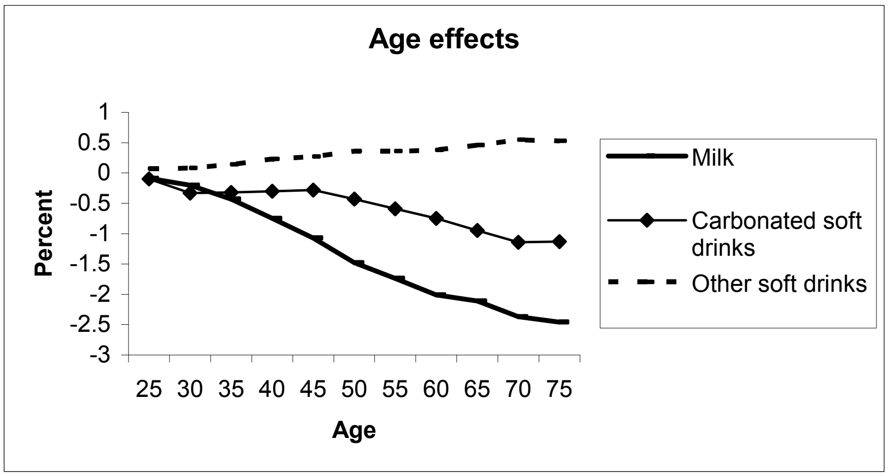
	Price				
	Fluid Milk	Carbonated Drinks	Other Soft Drinks	Other Goods	Expenditure
Fluid milk	-0.59	0.01	-0.02	0.51	0.08
	(-8.22)	(0.69)	(-1.18)	(6.84)	(8.41)
Carbonated soft drinks	0.01	-1.28	0.06	0.61	0.60
	(0.41)	(-49.42)	(3.22)	(10.90)	(23.14)
Other soft drinks	-0.07	0.10	-0.91	0.27	0.61
	(-1.33)	(3.16)	(-15.59)	(4.20)	(21.57)
Other goods	-0.01	0.00	-0.00	-1.02	1.00
	(-4.38)	(4.09)	(-2.31)	(-511.36)	(4508.29)

Note: The t values are reported in parentheses.

Table 5. Monte Carlo Results

Variable	Milk		Carbonated Soft Drinks		Other Soft Drinks	
	Mean bias %	Median bias %	Mean bias %	Median bias %	Mean bias %	Median bias %
Intercept	0.73	0.73	5.69	5.71	2.59	2.58
$\ln p_1$	17.60	17.57	10150.76	10033.96	–19.98	–21.04
$\ln p_2$	10033.96	10150.76	–27.13	–27.00	–25.24	–25.55
$\ln p_3$	–19.98	–21.04	–25.23	–25.55	–11.14	–11.29
$\ln p_4$	36.19	35.83	–72.10	–72.62	–18.20	–19.61
$\ln x/P$	1.03	1.06	2.83	2.80	1.47	1.52
S_2	–12.47	–11.69	3.01	3.35	–3.75	–3.24
S_3	4.56	4.51	–1.06	–0.67	–4.75	–4.49
S_4	–16.95	–14.77	141.96	130.14	–3.45	–4.81
ϕ	36.69	36.27	191.36	191.72	–50.02	–49.75
	Estimated coefficient (multiplied by 100) of log(trend) and log(age)					
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
lntrend	–0.22	–15.01	0.02	1.81	0.02	2.86
lnage	0.22	6.73	–0.19	–9.39	0.03	2.16





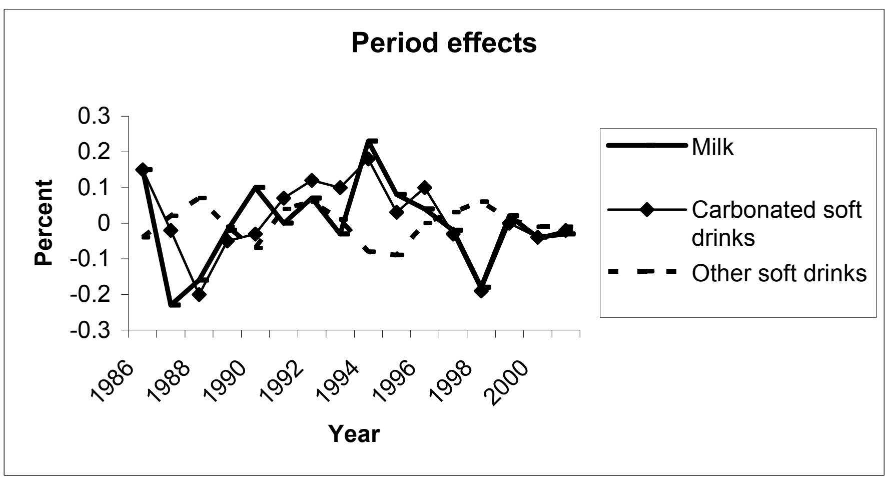


Figure 1. Cohort, age, and period effects

Appendix (or for referees' use)

Estimation Results, Step 1

	Milk		Carbonated Soft Drinks		Other Soft Drinks	
Variable	Coefficient	dy/dx	Coefficient	dy/dx	Coefficient	dy/dx
Intercept	1.69		–4.58		–5.22	
	(1.41)		(–7.15)		(–9.27)	
$\ln D_1$	0.23	0.01	0.60	0.14	0.66	0.21
	(1.47)	(1.48))	(8.61)	(8.64)	(11.05)	(11.08)
D_2	–0.93	–0.06	–0.38	–0.10	–0.08	–0.02
	(–4.24)	(–2.38)	(–3.81)	(–3.69)	(–0.92)	(–0.90)
D_3	–0.34	–0.01	–0.29	–0.07	–0.12	–0.04
	(–2.65)	(–2.13)	(–5.22)	(–4.82)	(–2.53)	(–2.47)
D_5	–0.35	–0.02	–0.07	–0.02	–0.12	–0.04
	(–2.75)	(–2.03)	(–1.04)	(–1.00)	(–2.23)	(–2.16)
D_6	–0.33	–0.01	–0.14	–0.03	–0.20	–0.07
	(–3.20)	(–2.48)	(–3.08)	(–2.92)	(–5.18)	(–4.94)
lnA	–0.78	–0.02	0.15	0.03	0.26	0.08
	(–2.01)	(–2.02)	(0.71)	(0.71)	(1.44)	(1.44)
lnY	–0.01	–0.00	0.09	0.02	0.04	0.01
	(–0.13)	(–0.13)	(3.11)	(3.10)	(1.65)	(1.65)
lnx	0.22	0.01	0.44	0.10	0.40	0.12
	(4.86)	(4.90)	(18.23)	(18.29)	(18.34)	(18.37)
S_2	–0.06	–0.00	0.12	0.03	0.10	0.03
	(–0.94)	(–0.91)	(3.80)	(3.92)	(3.34)	(3.40)
S_3	–0.03	–0.00	0.12	0.03	0.11	0.03
	(–0.47)	(–0.46)	(3.55)	(3.69)	(3.64)	(3.73)
S_4	–0.02	–0.00	0.02	0.00	–0.10	–0.03
	(–0.28)	(–0.27)	(0.61)	(0.61)	(–3.52)	(–3.47)
C_2	0.33	0.01	–0.14	–0.03	–0.10	–0.03
	(2.25)	(3.21)	(–1.12)	(–1.06)	(–0.98)	(–0.96)
C_3	0.52	0.01	–0.28	–0.07	–0.13	–0.04
	(3.06)	(4.81)	(–2.23)	(–2.02)	(–1.28)	(–1.24)
C_4	0.74	0.01	–0.45	–0.12	–0.16	–0.05
	(3.50)	(5.65)	(–3.29)	(–2.89)	(–1.37)	(–1.33)
C_5	0.91	0.02	–0.53	–0.14	–0.15	–0.05
	(3.53)	(5.87)	(–3.33)	(–2.91)	(–1.15)	(–1.11)
C_6	1.02	0.02	–0.55	–0.15	–0.27	–0.09
	(3.38)	(6.07)	(–3.12)	(–2.70)	(–1.76)	(–1.67)
C_7	1.12	0.02	–0.56	–0.16	–0.29	–0.10
	(3.29)	(6.19)	(–2.83)	(–2.44)	(–1.72)	(–1.63)
C_8	1.19	0.01	–0.72	–0.22	–0.35	–0.12
	(3.14)	(7.52)	(–3.36)	(–2.81)	(–1.87)	(–1.74)
C_9	1.46	0.01	–0.81	–0.25	–0.43	–0.15
	(3.49)	(9.20)	(–3.49)	(–2.90)	(–2.15)	(–1.99)
C_{10}	1.58	0.01	–0.87	–0.27	–0.48	–0.17
	(3.51)	(9.59)	(–3.48)	(–2.90)	(–2.21)	(–2.03)
C_{11}	1.74	0.02	–0.97	–0.31	–0.52	–0.18
	(3.61)	(9.65)	(–3.67)	(–3.07)	(–2.24)	(–2.06)
R^2	0.14		0.14		0.09	

Note: *t* values are reported in the parentheses.