Effects of consumer cohorts and age on meat expenditures in the United States

Ji Yong Lee[1], Yiwei Qian[2], Geir Wæhler Gustavsen[3,5,6],

Rodolfo M. Nayga, Jr.[2,3], and Kyrre Rickertsen[3,5]

[1] Department of Agricultural and Resource Economics, Kangwon National University, Korea

[2] Department of Agricultural Economics and Agribusiness, University of Arkansas

[3] Norwegian Institute of Bioeconomy Research, Ås, Norway

[5] School of Economics and Business, Norwegian University of Life Sciences, Ås, Norway

[6] Corresponding author : Geir Wæhler Gustavsen, Norwegian Institute of Bioeconomy Research, Box 115, NO-1431, Ås, Norway. E-mail: geir.gustavsen@nibio.no. Phone (+47) 907 01 453

This work was supported by the Norwegian Research Council grant 233800/E50

Abstract

Meat demand is likely influenced by the birth cohort and age of the individual. In this study, we examine the demand for beef, pork, poultry, and other meat in the US using the 1984-2012 Consumer Expenditure Survey and the almost ideal demand system with the incorporation of age, period, and cohort (APC) effects. We find that the model with APC effects performs better than the models without APC effects. The results indicate that cohorts born in earlier time periods are expected to purchase significantly less poultry compared to cohorts born in later time periods, when they are measured at the same age. Over the life cycle, purchase of poultry is expected to increase with age while the opposite is true for red meat. We also find that the own-price elasticity for beef is highest among the products examined, while the own-price elasticity for other meat is lowest and the inclusion of APC effects increases the absolute value of the own-price elasticities for beef, pork, and poultry, but reduces the own-price elasticity for other meat. Our forecasts indicate that the aggregate poultry purchase will continue to increase until 2022, while the aggregate purchase of red meat will slightly increase until 2017, but will either decrease or stay at same level from year 2017 to 2022.

KEYWORDS

meat, cohort effect, age effect, demand elasticities

JEL CLASSIFICATION

D12, J10, Q13

1 | INTRODUCTION

Household demand for food depends on prices, income, and socio-economic variables, but demand may also change over time and with the age and birth cohort of the individuals in the household. For example, individuals could have different purchasing patterns when they are older as opposed to when they are younger. This pattern could exist because older people usually eat less and focus more on their health and nutrition than younger people. Furthermore, there could be variations in the purchase pattern in different birth cohorts because peoples' purchasing habits for different foods are likely to be shaped by the culture and the events of the era in which they grow up (Alwin and McCammon, 2004). In general, age effects will reflect biological and social processes across the life cycle while period effects reflect variation over the years that influences all groups simultaneously such as availability of new products. Cohort effects, on the other hand, reflect changes across a group who experienced an event at the same time. Additionally, studies have shown that food demand can be affected by age, period, and cohort (APC) in different ways (Blisard, 2001; Gustavsen and Rickertsen, 2014, 2018a, and 2018b; Gustavsen, 2015; Kerr et al., 2004).

The main objective of this study is to examine age and birth cohort effects on meat purchase behavior in the United States (US). This is an important topic because meat products have important health effects. Previous research indicates that the purchase of red meat with a high proportion of saturated fats is associated with an increased risk of obesity (Wang and Beydoun, 2009), and a high risk of cardiovascular disease and cancer mortality (Pan et al., 2012; Zheng and Lee, 2009). Furthermore, meat is an important product for the US agricultural sector; therefore, future demand for meats can affect the sector's profitability and investments. In the past decades, the overall per capita meat purchase has continued to rise, with red meat representing the largest proportion of meat purchase in the US (Putnam, Allshouse, and Kanto, 2002; Daniel et al., 2011). However, the composition of meat purchase has changed. Data from the United States Department of Agriculture (USDA) show that in the period 1970-2014, the per capita purchases of beef and pork decreased, while the per capita purchase of poultry increased (USDA, 2018). It is important to examine cohort and age effects on meat demand because cohort and age composition of the US population have changed significantly over the years (Mather, 2012). However, few studies exist on the analysis of age and cohort effects on US meat purchase. Furthermore, these effects have never been investigated within a demand system framework. Blisard (2001) found that older cohorts spend more on meat, poultry, fish, and eggs than younger cohorts in the US, but his conclusion was only based on simple trend comparisons.

Our study focuses on beef, pork, poultry, and other meat in the US, using the almost ideal demand system (AIDS) of Deaton and Muellbauer (1980), with the incorporation of APC effects, following Gustavsen and Rickertsen (2014). Specifically, we estimated a two-stage demand system and calculated the unconditional price and expenditure elasticities, following the approach in Edgerton (1997), Rickertsen (1998), and Carpentier and Guyomard (2001). In the first stage, we estimated a system consisting of two goods: food and all other goods. From this, we constructed the age, cohort, price, and expenditure effects on food demand. In the second stage, we estimated a system consisting of four meat groups and other foods. From the second stage, we constructed conditional cohort, age, price, and expenditure effects on the goods within the second-stage system[1]. Then, we used the conditional elasticities from these two stages to calculate the unconditional effects and elasticities. In a two-stage system consisting of one upper system of broad aggregates, and one subsystem of food aggregates, a change in the price of beef

[1] In both stages, we followed Gustavsen and Rickertsen (2014), and treated the period effects as fluctuations around zero.

will directly affect the demand for beef through the subsystem. This is the conditional price effect. But in addition, this price change causes a change in the price of food at the first stage, which causes a change in the demand for food and hereby a change in the expenditure allocated to the food subsystem. The change in total food expenditure causes an indirect change in the demand for beef. The unconditional effect is then the sum of the direct (conditional) effect and the indirect effect.

To estimate our model, we used the 1984–2012 Consumer Expenditure Interview Survey (CEIS) and the 1984 – 2012 Consumer Expenditure Diary Survey (CEDS). Our results suggest that the inclusion of APC effects can make an important difference in the elasticity estimates from a meat demand system. This implies that food demand researchers and analysts should be made aware of the importance of APC effects and should take these into account when performing meat demand analyses and sales forecasting.

The next section presents the data sources and the variables used in the analysis. The empirical strategy used to identify the demand system are then discussed in the subsequent section, followed by the results of our main model where we compare the results with those from other specifications of the model. Finally, the last section consists of the conclusion and suggestions for future research.

2 | DATA

Several datasets from the US Bureau of Labor Statistics (BLS) were combined for the analysis. In order to calculate the unconditional elasticities and effects, the expenditure shares of the meat products are required; thus, the US Consumer Expenditure Diary Survey (CEDS) was employed. This is a repeated cross-sectional dataset that includes bi-weekly detailed food-at-home expenditure and socio-demographic information for households and individual characteristics for each household head.[2] The CEDS covers the period from 1984 to 2012. The sample size from this dataset is 105,640. However, the CEDS does not include the total expenditures for households, and we used the US Consumer Expenditure Interview Survey (CEIS) from 1984 to 2012 to calculate these expenditures. This is also a repeated cross-sectional dataset that includes data on total food expenditure and total expenditure for households. The sample size of this dataset is 384,696, and sample weights calculated by BLS were applied in both datasets. Since the samples included in CEIS were different from those in CEDS, it was impossible to calculate the unconditional elasticities and age and cohort effects by calculating the expenditure shares for detailed food items for each household. Instead, the conditional price elasticities of demand for food were calculated with respect to total expenditure on nondurables and services using the CEIS data, as well as the conditional price elasticities of demand for the various meat products with respect to total food expenditure using the CEDS data. Finally, these elasticities were combined to calculate the unconditional price elasticities.

For both CEDS and CEIS, all households in which the household's head was born between 1940 and 1996 were included. All the household heads were 16 years old or more. The households were divided into nine cohort groups according to the year of the birth of the household head. Notably, the base cohort is the youngest cohort and consists of households in which the heads were born after 1985. Cohort 40_44 consists of households in which the heads were born between 1940 and 1944, and this cohort is the oldest cohort in our sample. The

[2] The Consumer Expenditure Surveys do not contain detailed expenditure on different food groups. A household head is defined as the person who earned the highest income in the household in a particular year. If a household has two persons who earned the same amount of income, the household head is defined as the reference person, who is the first member mentioned by the respondent when asked to: "Start with the name of the person or one of the persons who owns or rents the home" in the CEDS and CEIS questionnaires. In the sample, we drop the observations with zero or negative income.

subsequent cohorts were created in the same way until the Cohort 80_84, which consists of households with heads born between 1980 and 1984. Additionally, the households were divided into 12 age groups using five-year intervals, and the youngest age group (16-20 years) was used as the base group.

Next, the Consumer Price Index (CPI) dataset from 1984 to 2012, which is also from the BLS, was used.[3] Specifically, the following data were used: (1) monthly non-adjusted national CPI for total food; (2) monthly non-adjusted national CPI for all goods except food; and (3) monthly non-adjusted domestic CPIs for beef, pork, poultry, other meat, and other food. To make the CPIs comparable across time, we deflated the CPIs for the detailed meat groups with the national food CPIs. We then merged the CPI datasets with CEDS and CEIS by region and date.

Table A1 in the Appendix presents the definitions of the variables in the CEDS and their descriptive statistics. As exhibited in Table A1, 61% of households purchase beef products, 55% pork products, 54% poultry products, and 57% other meat during the two-week observation period.[4] Furthermore, 56% of household heads were born between 1950 and 1969. Cohort 55_59, which includes households' heads who were born between 1955 and 1959, is the largest cohort group, comprising about 15% of the sample.

Table A2 in the Appendix presents the descriptive statistics of the variables using the CEIS. The average household expenditure share on food is about 18%. The descriptive statistics

[3] The CPI in 1982–1984 equals 100.
[4] The beef category includes uncooked ground beef, uncooked beef roasts, uncooked beef steaks, and other uncooked beef and veal. The pork category includes bacon, sausages, ham, pork chops, and other pork roasts, and picnics. The poultry category includes chicken, turkey, duck, and other poultry. The other meat category includes frankfurters, lunchmeat, lamb, mutton, and other organ meat. Food consumed away-from-home is not included. Fish is included in the group other food.

also indicate that the distributions of cohort, age, regions, and household types are similar in CEDS and CEIS.

3 | MODEL

3.1 | Almost ideal demand system

We used Deaton and Muellbauer's (1980)'s AIDS mand the methodology developed in Gustavsen and Rickertsen (2014). The expenditure share of good *i* in period *t* for each household, w_{it}, is defined as:[5]

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

where p_{jt} denotes the price of good *j* in time *t*, x_t is the total per capita expenditure on the goods included in the system, and P_t is a price index. To calculate P_t, we followed Hoderlein and Mihaleva (2008) and constructed household specific Stone-Lewbel price indices. If the between-group utility function is weakly separable and the within group sub-utility functions are of the Cobb Douglas functional form, the Stone-Lewbel price index for each household is:

$$P(v) = {}^{1}/_{k} \prod_{i=1}^{n} \left({}^{v_i}/_{w_i} \right)^{w_i} \qquad (2)$$

with a scaling factor k given by $k = \prod_{i=1}^{n} \overline{w}_i^{\,-\overline{w}_i}$, where n is the number of goods, v_i is the national monthly price of the *i*th good, and $\overline{w}_i$ is the expenditure share of good *i* of the reference household.[6] Following Nayga and Capps (1994) and Eales and Unnevehr (1988), we assume price exogeneity given the assumption that an individual household is a price taker and should have no impact on prices.

---

[5] The subscript of household *h* is deleted for notational simplicity.
[6] The reference household is defined as a household with the average expenditure share for each good (Hoderlein and Mihaleva, 2008).

The Stone-Lewbel price index cannot be calculated if one or more expenditure shares w_i are equal to zero. Since this dataset is highly censored, the regression imputation approach with censored expenditures was adopted with the use of unit values to proxy for prices (Cox and Wohlgenant, 1986; Alfonzo and Peterson, 2006; Lopez, 2011). The calculated values of the Stone-Lewbel price indices for all the uncensored observations was used in our analysis, and then regressed on the set of demographic characteristics shown in Table A1. The regression results were then used to predict the price indices for the households having censored observations.

3.2 | APC effects

The linear APC decomposition (Deaton and Paxson, 2000; Deaton, 1997; Aristei et al., 2008; Gustavsen and Rickertsen, 2014) was used. The expenditure share of one good, *w,* in a household is decomposed as:

$$\alpha_i = \alpha_0 + \sum_{k=2}^{9} \delta_k C_k + \sum_{l=2}^{12} \pi_l A_l + \sum_{m=2}^{29} \varphi_m Y_m \quad (3)$$

where *C, A,* and *Y* are matrices with dummy variables representing cohort, age and year, respectively. Because of the collinearity issue, one cohort, one age, and one year dummy variable were dropped from the equation. There also exists an additional linear relationship across the age, year, and cohort dummies. Notably, the age of the cohort is determined if the year of an observation and the year of birth of the observed cohort are known. Deaton (1997) assumed that the trends in the data can be decomposed into age and cohort effects, and that period effects capture fluctuations that average to zero in the long run. Thus, following Deaton (1997), one additional year dummy was dropped and the orthogonality restriction was imposed.[7] The year dummies were redefined as $Y'_m = Y_m - [(m-1)Y_2 - (m-2)Y_1]$ for m = 3,.., 29, where m = 3 represents the year 1986, and m = 29 represents the year 2012. This procedure enforces the restriction so that the year effects sum to zero and only reflect fluctuations.

As discussed above, several households did not purchase all types of meat products in the two-week observation period. To correct for this censoring problem, the two-step method of Shonkwiler and Yen (1999) was applied. In the first step, the probabilities of purchasing good *i,* were estimated by probit models. In the second step, the probability density functions (pdf), $\phi(z'_{it}\psi_i)$, for good *i,* and the cumulative density functions (cdf), $\Phi(z'_{it}\psi_i)$, were used to correct the censoring. After correcting for this censoring, substituting Equation (2) into Equation (1), and including seasonal variables *S*, the model becomes:

$$w_{it} = \alpha_{i0}\Phi(z'_{it}\psi_i) + \sum_{k=2}^{9}\delta_{ik}\Phi(z'_{it}\psi_i)C_k + \sum_{l=2}^{12}\pi_{il}\Phi(z'_{it}\psi_i)A_l + \sum_{m=3}^{29}\varphi_{im}\Phi(z'_{it}\psi_i){Y'}_m + \sum_{s=2}^{4}\theta_{is}\,\Phi(z'_{it}\psi_i)S_s + \sum_{j=1}^{n}\gamma_{ij}\,\Phi(z'_{it}\psi_i)\ln p_{jt} + \beta_i\,\Phi(z'_{it}\psi_i)\ln\left(\frac{x_t}{P_t}\right) + \tau_i\phi(z'_{it}\psi_i) + \varepsilon_{it} \tag{4}$$

where ε_{it} is the error term, τ_i is the coefficient of the inverse Mills ratio multiplied by the cdf, $\Phi(z'_{it}\psi_i)$, the inverse Mills ratio is then equal to $\phi(z'_{it}\psi_i)/\Phi(z'_{it}\psi_i)$, so it can be simplified to the coefficient of the pdf, $\phi(z'_{it}\psi_i)$. Included in the vector *z* are cohort dummies, dummies for household type, family size, log income before taxes, a dummy for urban area, seasonality dummies, log of the five price indexes used in the second stage, log of year, log of age, and regional dummy variables.

[7] Other ways to include APC effects are discussed in Gustavsen (2015).

Homogeneity of degree zero in prices and total expenditure and symmetry were imposed by the following restrictions (Gustavsen and Rickertsen, 2014) on Equation (4):

$$\sum_{j=1}^{5} \gamma_{ij} = 0 \ \forall i \text{ and } \gamma_{ij} = \gamma_{ji} \ \forall i, j \tag{5}$$

and adding up implies the following restrictions:

$$\sum_{i=1}^{5} \alpha_{i0} = 1, \ \sum_{i=1}^{5} \delta_{ik} = 0 \ \forall k, \ \sum_{i=1}^{5} \pi_{il} = 0 \ \forall l, \ \sum_{i=1}^{5} \varphi_{im} = 0 \ \forall m, \ \sum_{i=1}^{5} \theta_{is} = 0 \ \forall s,$$

$$\sum_{i=1}^{5} \gamma_{ij} = 0 \ \forall j, \ \sum_{i=1}^{5} \beta_i = 0, \text{ and } \sum_{i=1}^{5} \tau_i = 0. \tag{6}$$

3.3 | Conditional elasticities, age effects and cohort effects

Following Chalfant (1987) and Jonas and Roosen (2008), the conditional expenditure, E_i, uncompensated own-price, e_{ii}, and uncompensated cross-price elasticities, e_{ij}, are defined as:

$$E_i = \Phi(z_i'\psi_i) \cdot \left(\beta_i / w_i\right) + 1, \qquad e_{ii} = \Phi(z_i'\psi_i) \cdot \left(\gamma_{ii} / w_i - \beta_i\right) - 1$$

$$\text{and } e_{ij} = \Phi(z_i'\psi_i) \cdot \left((\gamma_{ij} - \beta_i w_j) / w_i\right) \tag{7}$$

where the marginal effects of cohort and age on the logarithm of purchased quantity is defined as the cohort and age effects; see Appendix for the derivation of the cohort and age effects. The conditional cohort effect, CE_{ik}, for good *i* and cohort *k* is given as:

$$CE_{ik} = \delta_{ik} / w_i \tag{8}$$

and the conditional age effect, AE_{il}, for good *i* and age *l* is given as:

$$AE_{il} = \pi_{il} / w_i. \tag{9}$$

After the conditional elasticities and cohort/age effects were calculated using the CEDS, Equation (4) was regressed using the CEIS data to calculate the conditional elasticities for the group food. Since there are no censoring issues in the CEIS data, the probabilities of purchases were not calculated in the analysis. The model in the first stage is thus as follows:

$$w_{it} = \alpha_{i0} + \sum_{k=2}^{9} \delta_{ik} C_k + \sum_{l=2}^{12} \pi_{il} A_l + \sum_{m=3}^{29} \varphi_{im} Y'_m + \sum_{s=2}^{4} \theta_{is} S_s + \sum_{j=1}^{2} \gamma_{ij} \ln p_{jt} + \beta_i \ln\left(\frac{x_t}{P_t}\right) + \varepsilon_{it} \quad (10)$$

where w_{it} is the expenditure share of food and non-food in period *t* for each household, x_t is the total per capita expenditure, P_t is the SL price index for food and non-food, and $\ln p_{jt}$ is log of food and non-food price in time *t*.

3.4 | Unconditional elasticities, age effects, and cohort effects

A two-stage budgeting procedure implies that changes in prices and/or total expenditure at the first stage affect the second stage (Edgerton, 1997; Rickertsen 1998; Carpentier and Guyomard 2001; Gustavsen and Rickertsen, 2003). In our case, food is the commodity group *F* at the first stage, while beef, pork, poultry, other meat, and other foods are the food components at the second stage. In stage 2, following Carpentier and Guyomard (2001) and Gustavsen and Rickertsen (2003), the unconditional expenditure elasticities UE_i and the unconditional price elasticities ue_{ij} are derived as follows:

$$UE_i = E_i \cdot E_F \quad (11)$$

and

$$ue_{ij} = e_{ij} + w_j \left({}^{1}\!/_{E_j} + e_{FF} \right) E_i E_j + w_j w_F E_F E_i (E_j - 1) \quad (12)$$

where E_i is the conditional expenditure elasticity of good *i* at the second stage, E_F is the food expenditure elasticity at the first stage; e_{ij} is the conditional price elasticity between good *i* and good *j* at the second stage, w_j is the expenditure share of good *j* at the second stage, e_{FF} is the own-price elasticity of food at the first stage, and w_F is the expenditure share of food at the first stage.

Additionally, the unconditional cohort effects UCE_{ik} and age effects UAE_{il} are calculated by using a procedure that corresponds to the procedure that was used in Gustavsen and Rickertsen (2003) to calculate unconditional effects based on seasonal dummy variables. The cohort effect in one subsystem affects other subsystems through the expenditure terms. The total cohort effect can then be seen as the conditional cohort effect inside the subsystem plus an effect due to different expenditures by different cohorts. The effects are calculated as:

$$UCE_{ik} = CE_{ik} + E_i CE_{Fk} \tag{13}$$

$$UAE_{il} = AE_{il} + E_i AE_{Fl} \tag{14}$$

where CE_{Fk} denotes the first-stage cohort effect of food for cohort group *k* and AE_{Fl} denotes the first-stage age effect of food for age group *l*. Since the statistical power varies due to different sample sizes from CEDS and CEIS, this procedure was bootstrapped 1,000 times using the same sample size to obtain the average value of the unconditional elasticities and the associated standard errors of the unconditional elasticities.[8]

4 | RESULTS

The conditional cohort and age effects for the first stage are reported in Table A3 in Appendix. We combined these results and used Equation (13) to calculate the unconditional cohort effects reported in Table 1. These cohort effects are defined as percentage changes in quantities purchased for each meat product relative to the base cohort, *ceteris paribus*. The most significant cohort effects are for poultry. The cohorts born between 1940 and 1979 purchased less poultry

[8] We randomly sampled 1,000 times, with replacement from the original data, and conducted the analysis with the different bootstrap samples. Using the standard deviation of the bootstrap distribution, we then calculated the standard error of the average value of the unconditional elasticities. To further test the robustness of the results, we also conducted a similar bootstrapping process by changing the number of observations that are randomly picked and found the results to be robust across different number of observations.

than the youngest cohort. The significant cohort effects ranged from seven to 29%. Only the cohort born between 1960 and 1964 and the cohort born between 1975 and 1979 purchased less beef than the youngest cohort—they purchased 18% and 13% less, respectively. The cohort born between 1940 and 1959 purchased 11 – 22% more of the other meat group than the youngest cohort. Additionally, some older cohorts, e.g., cohort 1960-1969, purchased less of other food than the youngest cohort. These results are also illustrated in Figure 1.. The figure shows that for other meat, the purchased quantities are higher for older cohorts compared to the youngest cohort. For poultry, the purchased quantities are lower for older cohorts. The figure also indicates, as expected, that beef and pork are substitutes. For example, the cohort 1970 to 1974 purchased more beef, but less pork; while the cohorts 1960 to 1969 and 1980 to 1984 purchased less beef, but more pork.

The unconditional age effects are also shown in Table 1 and illustrated in Figure 2. The unconditional age effects are the expected percentage difference in demand between the age groups in question, and the reference group *ceteris paribus*. The reference group is the youngest group, which consists of people who are less than 20 years old. There are many significant age effects for pork and other meat, and all these effects are negative, which suggests decreasing purchases with age. The purchases of pork decreased up to 30% for people between 21 and 65 years of age, as compared to the youngest age group. In contrast, the purchases of other meat decreased from eight to 26% for people between 26 and 75 years of age, as compared with the youngest age group. For other people, there are insignificant decreases. Furthermore, for beef, there are negative age effects between 9 and 15%, up to the age of 45 years. For poultry, age groups between 46 and 75 years purchased more than the youngest age group, with effects ranging from 8 to 23%. Finally, there are negative age effects for other foods up to the age of 60 years. These results indicate that older households cut down on all types of food expenses except for chicken, possibly because they tend to buy less expensive food within each category. It is also possible that older households have slower metabolism and lower energy needs. Older households could on average also have higher propensity to be sick and have more problems digesting meat.

The unconditional price and total expenditure elasticities are reported in Table 2, and the corresponding conditional elasticities are reported in Table A4 in the Appendix. All the unconditional own-price and total expenditure elasticities had the expected signs and are significantly different from zero. The own-price elasticity for beef, pork, and other food are -1.35, -1.07, and -1.28, respectively; hence, the demands for these products tend to be price elastic in absolute values. The demand for poultry and other meat, however, are less price-elastic (own-price elasticity of -0.78 and -0.67) in absolute values. Overall, the total expenditure elasticities for all types of meat are between 0.68 and 0.78. Notably, beef is the most expenditure-elastic product and pork was the least one.

We ran the entire model again without any age, cohort, or period dummy variables to evaluate the effects on the estimated price and expenditure elasticities of excluding the cohort and age variables. The results of this model are presented in Table 3. The results show that the absolute value of own-price elasticity for beef, pork, and other food become less elastic; while the elasticity for poultry and other meat do not change much. The total expenditure elasticities for all meat types also just slightly change.

In Table 4, we investigate to what extent the differences between own-price and expenditure elasticities are statistically different between models with different specifications of the APC variables. Doing this investigation may be seen as a robustness check. In addition, it would be interesting to find out in what direction the elasticities go if APC variables are not included. Hence, we compared four models: (1) Model 1: a model including all APC dummy variables, i.e., the model in Table 2; (2) Model 2: a model including none of the dummy variables, i.e., the model in Table 3; (3) Model 3: a model including continuous age and period variables, i.e., log(age), log(period), and cohort dummy variables; and (4) Model 4: a model including only continuous age and period variables, i.e., log(age) and log(period).[9] Results from Models 2, 3, and 4 reflect significant differences on both own-price and total expenditure elasticities, as compared to those from Model 1. The results show that Model 1 produced higher expenditure and own-price elasticities for all meat types than the other models. Furthermore, the differences in the own-price elasticity for beef across the different models are the largest.

We also tested for statistical difference between the models by using a likelihood ratio test. The results are presented in Table 5. Since the sample size and number of control variables are quite different for CEDS and CEIS, we separately calculated values of their log likelihood and Akaike Information Criterion (AIC). The results indicate that Model 1, which is our original model with the APC effects included, has the highest log likelihood values and lowest AIC in both datasets; hence Model 1 seems to fit best. The likelihood ratio test shows that the change in the variable list in Models 2, 3, and 4 significantly reduced the model fitness, which again suggests that Model 1 is the best model.

Given that APC effects have generally not been included in previous meat demand studies in the US, we compared our own-price and total expenditure elasticities with the elasticities found in other US or North American meat demand studies to further decipher whether the inclusion of APC effects substantially changes the elasticities. Most of the previous

---

[9] Age is defined as age for the household head in the year. The value of period for 1983 is defines as 0, for 1984 as 1, and so on.

studies used microdata and similar research periods as ours and then measured the unconditional elasticities (Okrent and Alston, 2012; Mutondo and Henneberry, 2007; Marsh, Schroeder, and Mintert, 2004; Tonsor, Mintert, and Schroeder, 2010). Two exceptions are Gallet (2010, 2012) who used a meta-analysis method. The elasticities are shown in Table 6. Our values are similar to the values reported in some studies (Gallet, 2010; Gallet, 2012; Mutondo and Henneberry, 2007; Marsh, Schroeder, and Mintert, 2004) in that the own-price elasticity for beef is the highest among the meat products. Our results also show that the own-price elasticity for poultry is the lowest among beef, pork, and poultry, similar to what has been found in some other studies (Gallet, 2010; Gallet, 2012; Mutondo and Henneberry, 2007; Marsh, Schroeder, and Mintert, 2004; Tonsor, Mintert, and Schroeder, 2010). The absolute values of the own-price elasticity for beef, pork, and poultry are larger in our study than in other studies; however, the own-price elasticity for other meat appears to be lower in our study than in other studies (Gallet, 2012; Okrent and Alston, 2012). The differences in the expenditure elasticities are large across studies. For instance, both Marsh, Schroeder, and Mintert (2004) and Tonsor, Mintert, and Schroeder (2010) indicate negative expenditure elasticities for poultry; only the study by Mutondo and Henneberry (2007) shows similar expenditure elasticities as ours, which is close to one. These variations are not surprising given differences in methodology and datasets used in these studies.

4.1 | Forecast simulation

To investigate the cohort and age effect on future purchase, we used the estimates of our main model (Model 1) to forecast future purchases. Specifically, we forecasted the percentage change of purchased quantities of beef, pork, poultry, and other meat. Since we used 5-year intervals for the age and cohort groups, we forecasted the purchases five years and 10 years after 2012, which is the last year in our sample. We made three assumptions for the simulations: (1) It is plausible that the new cohorts have preferences more similar to the cohorts born closest in time, and we assumed that a cohort younger than our youngest cohort will purchase the same quantities of products as our youngest cohort when measured at the same age. (2) There will be no changes in relative prices and real total expenditure, which corresponds to an assumption of no changes in the price index and total expenditure of food over time. (3) There will be no population scale change for age and head of household, i.e. there is assumed an equal number of people in each age group and equal number of people in each household. We then specified the 5-year forecast model for period *t* as follows:[10]

$$q_{i,k,l,t+5} = {q_{i,k,l,t} \cdot (1 + UAE_{i,l+1})} \Big/ {(1 + UAE_{i,l})} \tag{14}$$

where $q_{i,k,l,t+5}$ denotes the 5-year forecast of the average purchased quantity per capita measure for product *i*, cohort group *k*, and age group *l*; $q_{i,k,l,t}$ denotes the average quantity measure per capita for product *i* in 2012, which is equal to the average expenditure per capita of product *i* divided by the national price index of product *i* for each cohort and age group; $UAE_{i,l+1}$ denotes the unconditional age effect of age group $l + 1$, which is 5 years older than age group l; and $UAE_{i,l}$ denotes the unconditional age effect of age group l. We also specify a 10-year forecast model for period *t* as follows:

$$q_{i,k,l,t+10} = {q_{i,k,l,t} \cdot (1 + UAE_{i,l+2})} \Big/ {(1 + UAE_{i,l})} \tag{15}$$

where $UAE_{i,l+2}$ denotes the unconditional age effect of age group $l + 2$, which is 10 years older than age group l on average. We used the forecasts of the average purchased quantities per capita

[10] Since cohort effects are fixed for each cohort, we only include age effect for each cohort group in the model.

for each cohort and then derived the percentage change of purchased quantities per capita from 2012 to 2017 and 2022.

In addition to the average purchased quantities per capita, we also calculated the 5-year and 10-year forecasts of aggregate household quantities. Based on the population forecast from the United Nations (2015), the population of the US will increase by three percent from 2012 to 2017 and seven percent from 2012 to 2022, respectively. This increase in the population will lead to increases in meat purchases.

In Table 7, we report the 5- and 10-year per capita percentage changes of purchased quantities of beef, pork, poultry, and other meat, as well as the corresponding changes in aggregate purchased quantities compared with the year 2012. For the 5-year forecast, the per capita purchases of beef, pork, and poultry will change by -0.9%, -0.6%, and 1%, respectively. Due to increases in the population, the aggregate purchase will increase more (2.8%, 3.1%, and 4.8% for beef, pork, and poultry, respectively). The per capita purchases for other meat will decrease (-3.5%) but aggregate purchases will slightly increase. For the 10-year forecast, the aggregate purchases of beef, pork, and poultry will be higher than the purchases in 2012 (2.3%, 3.5%, and 5.8%), but the aggregate purchases for beef will be slightly less than the five-year forecast. The 10-year forecasts for per capita purchases of beef and pork indicate that beef purchases will keep decreasing while pork purchases will stay at about the same level as in 2012, but per capita purchase for poultry will keep increasing (2.1%).[11] Additionally, both per capita

[11] According to the US Department of Agriculture, the per capita consumption of beef was 57.1 pounds in 2012 and 56.9 pounds in 2017, i.e., a decrease of 0.4%. The per capita consumption of pork was 45.3 pounds in 2012 and 50.1 pounds in 2017, i.e., an increase of about 10.5%. The per capita consumption of poultry was 96.7 pounds in 2012 and 108.5 pounds in 2017, i.e., an increase of about 12.2%. While the magnitude of our results is a little different from the observed statistics, they show similar trends of decreasing consumption of beef and increasing consumption of poultry.

and aggregate forecasts show that the purchase of other meat (-6.6% and -3.2%) will decrease.[12] These forecasts are consistent with the reported trends of less red meat purchase, but more poultry purchase in the US (Haley, 2001; Putnam, Allshouse, and Kanto, 2002; Daniel et al., 2011). Our results indicate that the trend of increasing poultry purchase is likely to continue at least until 2022.

Finally, given the aging of the US population and the decrease in birth rates, we changed the number of people in the oldest age group and the new youngest age group to consider the current age composition and also check the robustness of our results. Specifically, we increased by 10% the number of people in the oldest age group and decreased by 10% the number of people in the youngest age group. Table A6 in the Appendix shows the estimated results with the different age composition. The changes in per capita purchases for beef, pork, and other meat in the 10-year forecast are slightly greater in absolute values, but slightly smaller for poultry. Generally, our results seems to be robust to the changes in the number of people in the age groups.

5. DISCUSSION AND CONCLUSIONS

In this study, we evaluated the importance of cohort and age effects on meat expenditures in the US by using a two-stage demand model. Our results suggest that: (1) The model with the inclusion of APC effects performs better than the other models; (2) cohorts born in earlier time periods are expected to purchase significantly less poultry compared to cohorts born at later time periods, when they are measured at the same age; (3) beef and pork are substitute products for

[12] We have tested the differences in the changes of purchased quantities between 5 and 10 years to check whether red meat aggregate purchase is going down. We rejected the hypothesis of equal changes of purchased quantities between the two periods across the products using 500 observations (p-value < 0.01 for each type of meat).

some cohorts; (4) over the life cycle, purchase of poultry is expected to increase with age while the opposite is true for red meat; (5) the own-price elasticity for beef is highest among the meat products, while the own-price elasticity for other meat is the lowest; (6) the inclusion of APC effects increases the absolute value of the own-price elasticities for beef, pork, and poultry, but reduces the own-price elasticity for other meat; (7) the aggregate purchase of poultry will keep increasing until year 2022; and (8) the aggregate purchase of red meat will slightly increase until 2017, but either decrease or stay at same level from year 2017 to 2022.

These results may be an important part of the explanation for why Americans have eaten less red meat and more poultry over the period 1970-2007 (Haley, 2001; Putnam, Allshouse, and Kanto, 2002; Daniel et al., 2011). Daniel et al. (2011) indicated that Americans consumed 19% less red meat (85–105 g per capita per day) over the period of 1970 to 2007, but consumed 120% (25–55 g per capita per day) more poultry over the same period. Another important finding of our study is that when people get older, they are more likely to purchase more poultry and less likely to purchase other meat. Moreover, younger cohorts are also more likely to consume poultry than older cohorts. Vertical integration and expansion of the poultry industry might have influenced the cohort effect. For example, Tyson expanded in the 1950's and 1960's and made chicken more affordable and accessible. This could partly explain the low effects for the oldest cohorts. These results suggest that when older cohorts with a lower purchase of poultry are replaced by younger cohorts with higher purchase of poultry, aggregate purchase for poultry will increase. In contrast, beef and pork purchase do not show the same tendency since some cohorts prefer to purchase more beef, while other cohorts prefer to purchase more pork. This result implies that even though people will decrease their purchases of beef and pork when they are over 20 years of age, the aggregate purchase trends for beef and pork will still be harder to decipher. But we caution that the APC effects are not causal effects. They are just proxy variables for a many factors such as health consciousness, religion, and other attitudinal variables.

Importantly, our results suggest that the inclusion of APC variables can make a significant difference in the elasticity estimates. We find significant differences for the own-price elasticity for poultry and total expenditure elasticity for all products, which suggests the importance of incorporating APC variables in demand system analysis with a time dimension. Hence, food demand researchers and analysts should be made aware of the importance of APC effects and should take these into account when performing meat demand analyses and sales forecasting. This is a critical concept to grasp given that results from food demand studies are not only used for marketing and business purposes, but also for policy and welfare analysis.

As for the public health implications of our findings, the decrease of red meat purchase at older age could be a good sign for public health since overconsumption of red meat is associated with diet-related diseases, especially for older people. Notably, younger cohorts who consume more poultry than older cohorts may also consume more when they are older. Notwithstanding the public health implications, this is also good news for the poultry industry; although more research on the nutritional and health effects of poultry purchase vis-à-vis other meat products is needed.

Future research could further test the robustness of our findings by adding other products in the demand system or using a different type of demand system. Furthermore, we normalized any period effects to be zero, and so our age and cohort effects may actually include some of the period effects. A drawback in this study is that because of data limitations, we determined the cohort and age groups by assuming that the person in the household with the highest income was the head of the household. With this in mind, it would be interesting to examine and test the robustness of the results of our study using other datasets that have more definitive information on who is actually purchasing the foods in the household. In addition, we included food away from home in the non-food group in the first stage of our demand system. Future research could include food away from home in the food group to further test the robustness of our results. Lastly, the assumptions we used in our simulation analysis can be deemed restrictive and so future studies could test the sensitivity of our results to relaxation of some of these assumptions.

REFERENCES

Alfonzo, L., & Peterson, H. H. (2006). Estimating food demand in Paraguay from household survey data. *Agricultural Economics*, *34*, 243-257.

Alwin, D. F., & McCammon, R. J. (2004). Generations, cohorts, and social change. In J. T. Mortimer & M. J. Shanahan (Eds.), *Handbook of the life course* (pp. 23-49). New York: Springer.

Aristei D., Perali, F., & Pieroni, L. (2008). Cohort, age and time effects in alcohol consumption by Italian households: a double-hurdle approach. *Empirical Economics*, *35*, 29–61.

Blisard, N. (2001). *Income and food expenditures decomposed by cohort, age, and time effects*. Technical Bulletin Number 1896. USDA. Washington D. C.

Carpentier, A., & Guyomard, H. (2001). Unconditional elasticities in two-stage demand systems: an approximate solution. *American Journal of Agricultural Economics*, *83*, 222-229.

Chalfant, J. A. (1987). A globally flexible, almost ideal demand system. *Journal of Business & Economic Statistics*, *5*, 233-242.

Cox, T. L., & Wohlgenant, M. K. (1986). Prices and quality effects in cross-sectional demand analysis. *American Journal of Agricultural Economics*, *68*, 908-919.

Daniel, C. R., Cross, A. J., Koebnick, C., & Sinha, R. (2011). Trends in meat consumption in the USA. *Public Health Nutrition*, *14*, 575-583.

Deaton, A. (1997). *The analysis of household surveys: A microeconometric approach to development policy*. Published for the World Bank. Baltimore: John Hopkins University Press.

Deaton, A., & Muellbauer, J. (1980). An almost ideal demand system. *The American Economic Review*, *70*, 312–326.

Deaton, A., & Paxson, C. (2000). Growth and saving among individuals and households. *Review of Economics and Statistics*, *82*, 212–225.

Eales, J. S., & Unnevehr, L. J. (1988). Demand for beef and chicken products: Separability and structural change. *American Journal of Agricultural Economics*, *70*, 521-532.

Edgerton, D. L. (1997). Weak separability and the estimation of elasticities in multi-stage demand systems. *American Journal of Agricultural Economics*, *79*, 62-79.

Gallet, C. A. (2010). Meat meets meta: a quantitative review of the price elasticity of meat. *American Journal of Agricultural Economics*, *92*, 258-272.

Gallet, C. A. (2012). A meta-analysis of the price elasticity of meat: evidence of regional differences. *Business and Economic Research*, *2*, 14-25.

Gustavsen, G. W. (2015). Consumer cohorts and demand elasticities. *European Review of Agricultural Economics*, *42*, 217-237.

Gustavsen, G. W., & Rickertsen, K. (2003). Forecasting ability of theory-constrained two-stage demand systems. *European Review of Agricultural Economics*, *30*, 539-558.

Gustavsen, G. W., & Rickertsen, K. (2014). Consumer cohorts and purchases of nonalcoholic beverages. *Empirical Economics*, *46*, 427-449.

Gustavsen, G. W., & Rickertsen, K. (2018a). Wine consumption in Norway: An age-period-cohort analysis. *Journal of Wine Economics*, *13*, 41-56.

Gustavsen, G. W., & Rickertsen, K. (2018b). Consumer cohorts and the demand for meat and dairy products. *Proceedings in Food System Dynamics*, 169-181.

Haley, M. M. (2001). Changing consumer demand for meat: the US example, 1970-2000. In A. Regni (Ed.), *Changing structure of global food consumption and trade, Agriculture and trade report*. Washington, D.C.:USDA.

Hoderlein, S., & Mihaleva, S. (2008). Increasing the price variation in a repeated cross section. *Journal of Econometrics*, *147*, 316-325.

Jonas, A., & Roosen, J. (2008). Demand for milk labels in Germany: organic milk, conventional brands, and retail labels. *Agribusiness*, *24*, 192-206.

Kerr, W. C., Greenfield, T. K., Bond, J., Ye, Y., & Rehm, J. (2004). Age, period and cohort influences on beer, wine and spirits consumption trends in the US National Alcohol Surveys. *Addiction*, *99*, 1111-1120.

Lopez, J. A. (2011). A comparison of price imputation methods under large samples and different levels of censoring. Agricultural & Applied Economics Association's Annual Meeting, Pittsburgh, PA.

Marsh, T. L., Schroeder, T. C., & Mintert, J. (2004). Impacts of meat product recalls on consumer demand in the USA. *Applied Economics*, *36*, 897-909.

Mather, M. (2012). *Fact sheet: the decline in US fertility*. Population Reference Bureau, World population data sheet. Available at:

http://www.prb.org/publications/datasheets/2012/world-population-data-sheet/fact-sheet-us-population.aspx

Mutondo, J. E., & Henneberry, S. R. (2007). A source-differentiated analysis of US meat demand. *Journal of Agricultural and Resource Economics*, *32*, 515-533.

Nayga Jr., R. M., & Capps, O. (1994). Test of weak separability in disaggregated meat products. *American Journal of Agricultural Economics*, *76*, 800-808.

Okrent, A., & Alston, J. (2012). *The demand for disaggregated food-away-from-home and food-at-home products in the United States*. USDA-ERS Report 139, Washington, D. C.

Pan, A., Sun, Q., Bernstein, A. M., Schulze, M. B., Manson, J. E., Stampfer, M. J., Willett, W. C., & Hu, F. B. (2012). Red meat consumption and mortality: Results from 2 prospective cohort studies. *Archives of Internal Medicine*, *172*, 555-563.

Putnam, J., Allshouse, J., & Kantor, L. S. (2002). US per capita food supply trends: more calories, refined carbohydrates, and fats. *Food Review*, *25*, 2-15.

Rickertsen, K. (1998). The demand for food and beverages in Norway. *Agricultural Economics*, *18*, 89-100.

Shonkwiler, J. S., & Yen, S. T. (1999). Two-step estimation of a censored system of equations. *American Journal of Agricultural Economics*, *81*, 972-982.

Tonsor, G. T., Mintert, J. R., & Schroeder, T. C. (2010). US meat demand: household dynamics and media information impacts. *Journal of Agricultural and Resource Economics*, *35*, 1-17.

United Nations. (2015). *Population pyramids of the world from 1950 to 2100*. Department of Economic and Social Affairs, Population Division. World Population Prospects. Available at: http://populationpyramid.net/united-states-of-america

USDA. (2018). *Food availability (per capita) data system.* Available at: https://www.ers.usda.gov/data-products/food-availability-per-capita-data-system/food-availability-per-capita-data-system/#Food Availability

Wang, Y., & Beydoun, M. A. (2009). Meat consumption is associated with obesity and central obesity among US adults. *International Journal of Obesity*, *33*, 621-628.

Zheng, W., & Lee, S. (2009). Well-done meat intake, heterocyclic amine exposure, and cancer risk. *Nutrition and Cancer*, *61*, 437-446.

TABLE 1 Unconditional cohort and age effects

	Beef	Pork	Poultry	Other Meat	Other Food
Cohort 40_44	0.01	0.10	-0.29*	0.22*	0.00
	(0.08)	(0.09)	(0.06)	(0.09)	(0.05)
Cohort 45_49	-0.05	0.06	-0.23*	0.21*	-0.01
	(0.07)	(0.09)	(0.05)	(0.09)	(0.05)
Cohort 50_54	-0.09	0.04	-0.20*	0.18*	-0.02
	(0.07)	(0.08)	(0.05)	(0.08)	(0.04)
Cohort 55_59	-0.08	0.02	-0.23*	0.11*	-0.05
	(0.07)	(0.07)	(0.05)	(0.07)	(0.04)
Cohort 60_64	-0.18*	0.06	-0.15*	0.09	-0.06*
	(0.06)	(0.07)	(0.04)	(0.06)	(0.03)
Cohort 65_69	-0.06	-0.02	-0.19*	0.02	-0.07*
	(0.04)	(0.06)	(0.04)	(0.06)	(0.02)
Cohort 70_74	0.03	-0.08	-0.18*	0.03	-0.05
	(0.04)	(0.06)	(0.03)	(0.05)	(0.03)
Cohort 75_79	-0.13*	0.07	-0.07*	0.05	-0.03
	(0.04)	(0.06)	(0.02)	(0.04)	(0.02)
Cohort 80_84	-0.02	-0.01	-0.04	0.02	-0.02
	(0.03)	(0.05)	(0.03)	(0.04)	(0.02)
Age 21_25	-0.03	-0.20*	0.01	0.00	-0.07*
	(0.03)	(0.05)	(0.02)	(0.03)	(0.01)
Age 26_30	-0.09*	-0.28*	-0.01	-0.08*	-0.12*
	(0.03)	(0.05)	(0.03)	(0.03)	(0.01)
Age 31_35	-0.15*	-0.27*	-0.01	-0.08*	-0.14*
	(0.05)	(0.06)	(0.03)	(0.04)	(0.02)
Age 36_40	-0.15*	-0.28*	0.02	-0.09*	-0.14*
	(0.05)	(0.06)	(0.03)	(0.04)	(0.03)
Age 41_45	-0.11*	-0.29*	0.05	-0.13*	-0.13*
	(0.05)	(0.06)	(0.04)	(0.05)	(0.03)
Age 46_50	-0.09	-0.30*	0.08*	-0.13*	-0.12*
	(0.07)	(0.07)	(0.04)	(0.06)	(0.03)
Age 51_55	-0.08	-0.26*	0.11*	-0.14*	-0.10*
	(0.07)	(0.07)	(0.05)	(0.07)	(0.03)
Age 56_60	-0.05	-0.24*	0.13*	-0.18*	-0.09*
	(0.08)	(0.08)	(0.06)	(0.08)	(0.04)
Age 61_65	-0.04	-0.20*	0.15*	-0.17*	-0.07
	(0.09)	(0.08)	(0.06)	(0.08)	(0.05)
Age 66_70	-0.07	-0.15	0.18*	-0.16*	-0.06
	(0.10)	(0.09)	(0.07)	(0.08)	(0.06)
Age 71_75	-0.07	-0.15	0.23*	-0.26*	-0.06
	(0.13)	(0.13)	(0.09)	(0.13)	(0.08)

Notes: We bootstrapped the model 1,000 times and the mean value and standard deviation of the estimates are reported. Standard deviations are printed in the parentheses. An * denotes significance at the 5% level of significance. The base groups are the following: Age < 21 years and the cohort born after 1984.

TABLE 2 Unconditional price and expenditure elasticities in the system with age, cohort and period variables

	Beef	**Pork**	**Poultry**	**Other Meat**	**Other Food**	**Expenditure**
Beef	-1.35*	0.26*	-0.13*	0.30*	-0.01	0.78*
Pork	0.19*	-1.07*	-0.04	-0.22*	-0.01	0.68*
Poultry	-0.09*	-0.04	-0.78*	-0.27*	-0.00	0.69*
Other meat	0.15*	-0.15*	-0.19*	-0.67*	-0.01	0.71*
Other food	-0.34*	-0.23*	-0.14*	-0.45*	-1.28*	0.72*

Note: An * indicates statistical significance at the 5% level of significance.

TABLE 3 Unconditional price and expenditure elasticities in the system without age, cohort and period variables

	Beef	**Pork**	**Poultry**	**Other Meat**	**Other Food**	**Expenditure**
Beef	-0.98*	0.14*	-0.04*	-0.04	0.02*	0.80*
Pork	0.11*	-0.98*	-0.07*	0.02	0.01*	0.69*
Poultry	-0.03*	-0.06*	-0.80*	-0.15*	0.02*	0.71*
Other meat	-0.02*	0.01	-0.11*	-0.69*	0.01*	0.72*
Other food	0.43*	0.44*	0.58*	0.39*	-0.52*	0.73*

Note: An * indicates statistical significance at the 5% level of significance.

TABLE 4 Mean values and differences of unconditional own-price and expenditure elasticities

	Mean Value M1	Difference M2	Difference M3	Difference M4
Own-price elasticity				
Beef	-1.35	-0.37*	-0.55*	-0.46*
Pork	-1.07	-0.10*	-0.11*	-0.12*
Poultry	-0.78	0.02*	-0.00	-0.00
Other meat	-0.67	0.01	-0.04*	0.09*
Expenditure elasticity				
Beef	0.78	-0.01*	-0.01*	-0.02*
Pork	0.68	-0.02*	-0.01*	-0.02*
Poultry	0.69	-0.02*	-0.01*	-0.02*
Other meat	0.71	-0.02*	-0.01*	-0.02*

Notes: The columns show the mean values of the elasticities of Model 1 (Mean Value M1 column), the differences in mean values of the elasticities between Model 1 and Model 2 (Difference M2 column), between Model 1 and Model 3 (Difference M3 column) and between Model 1 and Model 4 (Difference M4 column). M1 includes age, cohort and period dummies; M2 excludes age, cohort and period dummies; M3 includes log(age), log(period) and cohort dummies; M4 includes log(age) and log(period) variables. Difference = (Mean value in M1) - (Mean value in M2 /M3/M4)). To calculate the standard errors, we bootstrap the model 1,000 times. An * denotes significance at the 5% level of significance.

TABLE 5 Log-likelihood values, AIC values and results of likelihood ratio tests

	Log Likelihood Value	Degrees of Freedom	AIC Value	Likelihood Ratio Test Value
Model 1				
Stage 1	52080.1	54	-104052	
Stage 2	610507.2	252	-1220510	
Model 2				
Stage 1	51354.8	7	-102695	1450.6*
Stage 2	609181.5	37	-1218289	2651.2*
Model 3				
Stage 1	51580.8	18	-103125	998.7*
Stage 2	610164.4	83	-1220163	685.5*
Model 4				
Stage 1	51360.1	9	-102702	1440.0*
Stage 2	609314.4	47	-1218535	2385.4*

Notes: Model 1 includes age, cohort and period dummies; M2 excludes age, cohort and period dummies; Model 3 includes log(age), log(period) and cohort dummies; Model 4 includes log(age) and log(period) variables. The likelihood ratio test value is for Model 1 tested against the other models. An * denotes significance at the 5% level of significance.

TABLE 6 Comparison of our elasticities with elasticities from selected other studies

	Our Study	Gallet (2012)	Gallet (2010)	OA	MH	MSM	TMS
Own-price elasticity							
Beef	-1.35	-1.08	-0.99	-0.70	-0.71	-0.78	-0.42
Pork	-1.07	-0.91	-0.91	-1.26	-0.46	-0.49	-0.74
Poultry	-0.78	-0.74	-0.78	-0.81	-0.30	-0.08	-0.09
Other meat	-0.67	-0.96	NA	-1.05	NA	NA	NA
Expenditure elasticity							
Beef	0.78	NA	NA	NA	1.26	0.59	0.91
Pork	0.68	NA	NA	NA	0.81	0.28	0.01
Poultry	0.69	NA	NA	NA	1.04	-0.35	-0.58
Other meat	0.71	NA	NA	NA	NA	NA	NA

Notes: Column headings: OA denotes Okrent and Alston (2012); MH denotes Mutondo and Henneberry (2007); MSM denotes Marsh, Schroeder, and Mintert (2004); and TMS denotes Tonsor, Mintert, and Schroeder (2010).

TABLE 7 The percentage change of purchased quantities between the simulation results of 5-year and 10-year forecast and the observed quantities in year 2012

	5-Year Per Capita	**10-Year Per Capita**	**5-Year Aggregate**	**10-Year Aggregate**
Beef	-0.94	-1.32	2.75	2.30
	(1.05)	(1.98)	(1.09)	(2.05)
Pork	-0.57	-0.19	3.14	3.47
	(1.02)	(1.94)	(1.06)	(2.01)
Poultry	0.99	2.06	4.76	5.81
	(0.60)	(1.17)	(0.63)	(1.21)
Other meat	-3.47	-6.59	0.13	-3.17
	(1.28)	(2.42)	(1.33)	(2.51)

Note. Standard errors constructed with 500 bootstrap repetitions are in parentheses.

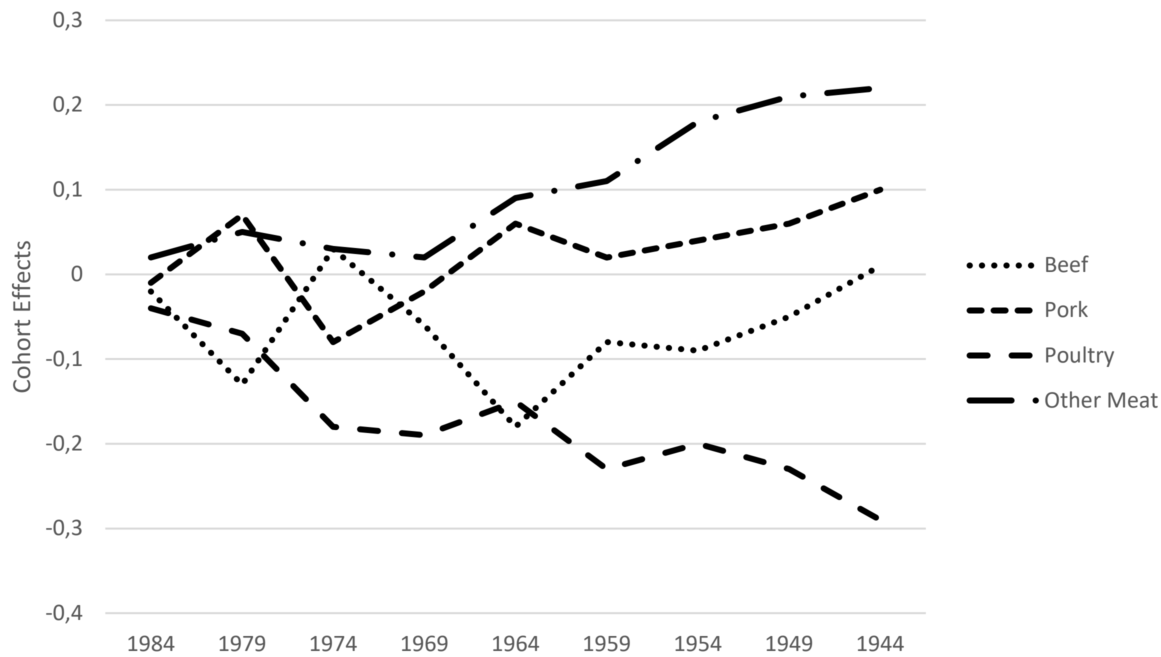

FIGURE 1 Cohort effects relative to the youngest cohort

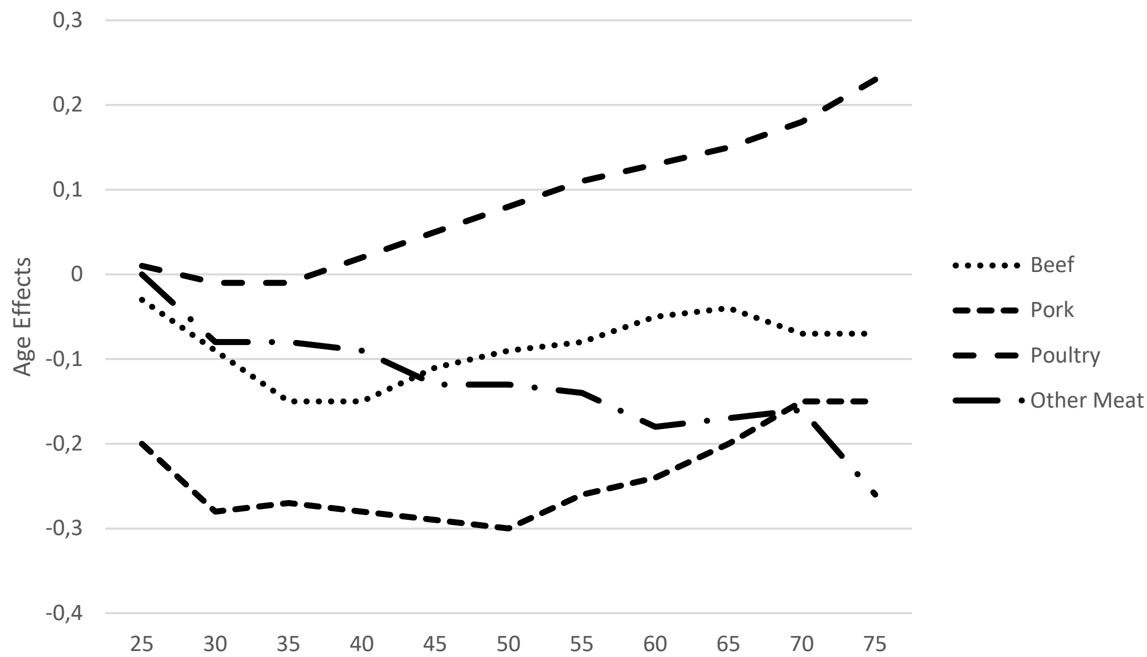

FIGURE 2 Age effects relative to the youngest age