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The quantity and variety of households' meat purchases: A censored demand system approach

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Abstract

This study investigates the demand for 10 disaggregated meat products by U.S. households. A censored demand system which imposes budget constraints in both observed and latent shares is estimated along with a detailed explanation of the estimation procedure. Additional details about the methodology not provided in previous studies should help researchers to empirically apply the model. An innovation of the study is to introduce the censored demand system model for studying the variety of a household's food purchases. Most households buy between seven and eight different products and hardly change the variety of their purchases with changes in meat expenditure.

JEL classifications: C34, C51, D12

Keywords: Demand elasticity; Food variety; Household meat purchase; Censored demand system; AIDS model; Maximum likelihood; Simulated probability

1. Introduction

A large body of research reports price and expenditure elasticities for meat products. Despite this wealth of studies, researchers continue to provide new insights by estimating progressively disaggregated demand systems. Analyses for table cut beef, ground beef, and other meat groups indicate that subgroups of products vary noticeably from each other in own- and cross-price elasticities (Brester and Wohlgenant, 1991; Eales and Unnevehr, 1988) as well as in substitutability between meat products from various livestock species (Wohlgenant, 1989).

While reporting more disaggregated elasticities can provide new insights, we are still left with only a partial picture of households' demand for meat products, especially when many households do not buy all types of meat. Demand elasticities measure the change in the expected level of demand with a change in prices or expenditures, including households who buy and do not buy the product. They do not indicate whether most households are buying most products or concentrating their purchases on a fairly small subset of the available goods. Nor do we know how changes in prices and expenditures will affect the particular mix of products bought. That is, we cannot learn much from elasticities about the variety of households' purchases.

In a recent review of the literature, Weiss (2011) lists some of the reasons why economists are interested in the variety of households' food purchases and consumption. First, variety may be associated with consumers' utility. The extent to which a nation's citizens consume a diversity of goods has been linked to the economic well-being of a country (Theil and Finke, 1983). Second, according to Weiss (2011), marketers would like to understand consumers' desire for variety. This may serve as a criterion for market segmentation and product innovation as well as help firms to more effectively meet consumers' needs. Finally, variety in food consumption is important for dietary health. Foote et al. (2004) show that Americans who consume a more varied diet are more likely to consume an adequate amount of key nutrients. This includes variety in meat consumption. Moreover, among its "Key Recommendations," the *Dietary Guidelines for Americans, 2010* (USDA, 2010) encourages consumers to "Choose a variety of protein foods, which include seafood, lean meat and poultry, . . . " (p. 34). However, healthy eating patterns outlined in the Guidelines feature less red and processed meat and more seafood than typical American diets.

Jackson (1984) long ago provided a demand system-based theoretical framework for analyzing variety in food

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consumption and purchases. However, as Weiss (2011) notes, researchers have not followed this approach because it has been mathematically too challenging to estimate a demand system in which some households did not purchase some goods (i.e., a censored demand system). To avoid this problem, empirical studies have heretofore used a single variable to measure variety, such as a simple count of the number of food items actually bought. Studies employing this approach include Jackson (1984), Shonkwiler et al. (1987), and Lee (1987), among others. While tractable, the disadvantage of this approach is that information is lost on the particular mix of meat products that households are most likely to buy at different prices and/or levels of expenditure.

Recent advances in censored demand systems make it possible to estimate a highly disaggregated demand system of meat products, using household level data, and characterize how variety in purchases changes with prices and expenditures. In this study, building on Dong et al. (2004), we introduce the Amemiya–Tobin approach to estimate a censored AIDS model for 10 meat products and investigate which products among the food system are most likely to be purchased by households at given levels of total meat expenditures. Compared with Dong et al. (2004), we also provide a more complete derivation of the likelihood function to facilitate model estimation. The additional details provided in this study should make it easier for interested readers to understand and implement the procedure.

2. Previous studies on meat demand

Numerous empirical studies investigate U.S. demand for meats (e.g., Arnade and Gopinath, 2006; Eales and Unnevehr, 1988; Hahn and Mathews, 2007; Kesavan et al., 1993; Moschini and Meilke, 1989; Nayga and Capps, 1994; Prichett et al., 2007; Tonsor et al., 2010). However, only a few studies have addressed demand by cuts of meat using cross-sectional data and a censored demand system. Coffey et al. (2011) employed a maximization algorithm to estimate a censored demand system for 12 disaggregated household meat products. Yen and Huang (2002) estimated the demand for beef cuts using a censored translog demand system and data collected from the U.S. Department of Agriculture's 1987–1988 Nationwide Food Consumption Survey. Salvanes and DeVoretz (1997) investigated the demand for alternative classifications of disaggregated meat products, such as red meat, white meat, fresh fish, and residual food. They represent one of the few attempts to accommodate censoring of expenditure shares in a meat demand system, using the two-step estimation procedure of Heien and Wessells (1990). However, because none of these studies imposed the budget constraint on the observed shares, all reported results may be biased. Dong et al. (2004) represent the only study to impose the budget constraints in both the observed and latent systems, while estimating Mexican meat demand using a censored AIDS model.

3. Meat purchase variety and the data

Building on previous research, we investigate U.S. households' demand for 10 meat products by estimating a utility maximizing system of demand functions (henceforth, demand system). Nielsen Homescan data from 2006 are used in this study. Nielsen selects a panel of households to be demographically and geographically representative of the continental United States. Participating households are given a scanner to keep in their home, and after a shopping occasion, panelists use these scanners to record purchases of food items, including the quantities bought and the purchase date. In addition to detailed information about each recorded transaction, Nielsen also provides information on each household's demographic characteristics.

In this study, we aggregate transactions recorded in our Nielsen data over a variety of meat products for each household to an annual basis. The final data represent the at-home meat purchases of 7,498 households across the continental United States in 2006. Similar to Nayga and Capps (1994), we separate the households' beef purchases into ground beef, beef steak, and other beef. Pork is disaggregated into pork loin and other pork. Poultry is broken up as chicken parts and other poultry. We also include lunch meats, seafood, and other meats in the study to set up a complete meat demand system. Thus, our 10 product categories are: (1) ground beef, (2) beef steak, (3) other beef, (4) pork loin cuts (tenderloin, chops, ham), (5) other pork, (6) chicken parts (breast, quarter and legs, wings), (7) other poultry, (8) lunch meats, (9) seafood, and (10) other meats.[1]

Table 1 gives the purchase quantity, expenditure, price, expenditure share, and purchase frequency for the 7,498 households over 2006 for all 10 meat products. In terms of quantities, other poultry is the most purchased product followed by other meats, chicken parts, and ground beef. U.S. households also spend the most money on other poultry followed by seafood, other meats, and other pork. Beef steak has the highest price followed by lunch meat, seafood, and other pork. Other meats are the most frequently purchased meat product followed by other poultry, seafood, and lunch meat. The prices used in this study are the calculated unit values for the purchased meat products for each household. The use of unit values in household demand analysis is common as researchers typically lack data on exogenous prices (Crawford et al., 2003; Deaton, 1988, 1990; McKelvey, 2011). However, the effect of a unit value on demand represents both the effect of the exogenous price and the effect of endogenous quality (Nelson, 1991). To account for this issue, we follow Dong et al. (1998) as well as Cox and Wohgnant (1986) who run a regression of unit values on household demographic variables, and then use the predicted unit value in the demand analysis to account for the endogeneity caused by households' choices of product quality. If a house-

[1] Meat products are included in the 10 categories only if they can be separated from other food products. For example, meats that are mixed with other food items in ready-to-eat meals are excluded.

Table 1
Meat product share, price, and purchase frequency

	Quantity (lb)		Expenditure ($)				Price ($/lb)	
Meat Product	Mean	St. dev.	Mean	St. dev.	Purchase frequency	Expenditure share	Mean	St. dev.
Beef ground	18.3	23.7	42.1	52.2	0.80	0.09	2.48	0.68
Beef steak	9.8	16.0	45.4	76.4	0.71	0.08	4.66	1.99
Other beef	12.3	17.3	33.9	48.9	0.75	0.07	2.89	1.28
Pork loin	12.0	16.4	27.8	36.2	0.72	0.06	2.67	1.06
Other pork	17.9	24.4	48.5	59.4	0.86	0.10	3.44	2.63
Chicken parts	18.8	30.7	30.4	45.2	0.74	0.06	1.91	1.00
Other poultry	33.6	39.1	67.3	85.3	0.93	0.15	2.36	1.23
Lunch meats	10.8	13.2	42.0	50.2	0.90	0.10	4.36	1.80
Seafood	16.0	19.8	65.6	89.2	0.92	0.15	4.07	2.58
Other meats	22.7	23.5	59.0	62.3	0.95	0.14	2.81	1.27

Homescan average household meat home-use purchases are 172.2 lb per year in 2006. USDA-ERS (2011) disappearance data show the average household consumption is 226.4 lb in 2009.

Table 2
Household variables used in the censored demand system

Variable	Mean	Std. err.
HHSIZE: Household size	2.31	1.29
AGF: Age of female head	53.34	11.32
AGEC1317: Percentage of person aged between 13 and 17	0.11	0.32
FED: = 1 if female head gained college education; = 0 if not	0.35	0.48
PVL130: = 1 if income below 130% of poverty line; = 0 if not	0.07	0.26
BLACK: = 1 if household is African American; = 0 if other	0.13	0.34
ASIAN: = 1 if household is Asian; = 0 if not	0.04	0.20
HISP: = 1 if household is Hispanic; = 0 if not	0.06	0.23
OTHER: = 1 if household is not White, Black, Asian, and Hispanic; = 0 otherwise	0.07	0.26
EAST: = 1 if household resides in the East; = 0 if other	0.22	0.42
CENTRAL: = 1 if household resides in the Central; = 0 if not	0.17	0.37
WEST: = 1 if household resides in the West; = 0 if not	0.23	0.42
SOUTH: = 1 if household resides in the South; = 0 if not	0.38	0.53

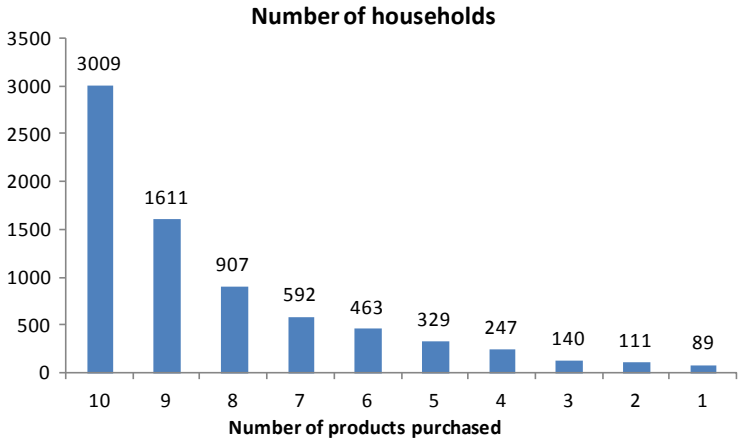

Fig. 1. Distribution of households on numbers of purchased meat products.

hold did not purchase a meat product, this procedure can also predict the missing unit value based on the household's demographic variables for that product's price (the first-order price approach). The household demographic variables used in the share and the unit value prediction equations are provided in Table 2. Fig. 1 shows the distribution of households that purchased different numbers of the 10 meat products. About 60% of the 7,498 households did not buy all of the 10 meat products in 2006, but only about 12% households bought five products or less.

Taking advantage as much as possible of the wealth of information in our disaggregated household purchase data and recognizing that many of our 7,498 households did not buy all 10 products, we utilize the method outlined in Dong et al.

(2004) to impose the budget constraints in both the observed and latent systems and obtain unbiased price and expenditure elasticities. This method is outlined below. Our study also contributes to the body of literature on the variety of households' food purchases by using a censored demand system approach empirically for the first time.

4. Censored demand model for variety

Defining a demand system in which households can buy 10 different meat products implies that each household could belong to anyone of $2^{10} - 1 = 1{,}023$ different purchase regimes, if at least one meat product has to be purchased. Each regime represents a different bundle of products. Households buying all 10 products belong to one of these 1,023 regimes. However, there are 10 different ways that a household could buy nine out of 10 products. There are 45 different ways to buy only eight of 10 different types of meat, 120 different ways to buy 7 out of 10 available products, and so on. In total, for 1,022 out of 1,023 regimes, a household's demand for one or more products is censored at zero.

There are two censored demand system approaches: the Kuhn–Tucker approach and the Amemiya–Tobin approach (Amemiya, 1974). Following Wales and Woodland (1983) and Dong et al. (2004), we apply the Amemiya–Tobin approach to study meat demand and purchase variety using Homescan data. Suppose N households can purchase up to $M + 1$ meat products. Likewise, assume $M + 1$ latent share (S^*) equations derived from utility maximization of the following form (omitting household subscripts):

$$S^* = U + \varepsilon, \tag{1}$$

where U is the nonstochastic component of S^* and $\varepsilon$is a random error. Both S^* and ε are $(M + 1) \times 1$ vectors. For the AIDS model proposed by Deaton and Muellbauer (1980), $U = A + \gamma \ln P + \eta \ln Y$, where $A = \alpha + \beta X$, $Y = \frac{y}{P^*}$, P is a $[M + 1]$ column vector of commodity prices, X is a $[L \times 1]$ vector of demographic characteristics, y represents total expenditures, and P^* is a translog price index defined by:

$$\ln P^* = \alpha_0 + \alpha' \ln P + \frac{1}{2}(\ln P)'\gamma(\ln P). \tag{2}$$

The equation parameters are: α $[(M+1) \times 1]$, $\beta[(M + 1) \times L]$, $\gamma[(M + 1) \times (M + 1)]$, $\eta[(M + 1) \times 1]$, and $\alpha_0[1 \times 1]$.

Due to adding-up (the budget constraint), $I_{(M+1)}\, U = 1$ and $I_{(M+1)}\, \varepsilon = 0$, where I is a $1 \times (M + 1)$ unit vector. $I_{(M+1)}\, U = 1$ can be obtained through the following parameter restrictions: $I_{(M+1)}\alpha = 1$, $I_{(M+1)}\beta = 0$, $I_{(M+1)}\gamma = 0$, and $I_{(M+1)}\eta = 0$. Theoretical constraints such as homogeneity and symmetry are also imposed on Eq. (1). The symmetry constraint is $\gamma = \gamma'$. Given the symmetry and adding-up constraints, the homogeneity constraint is automatically satisfied.

Since $I_{(M+1)}\varepsilon = 0$, the joint density function of ε is singular, and one of the $M + 1$ latent share equations must be excluded from model estimation. The parameters associated with the excluded share equation can be retrieved from the other estimated parameters using the adding-up and symmetry constraints. By excluding one of the share equations from the estimation, we assume that the remaining M share equations' error terms are distributed multivariate normal with a joint probability density function (*PDF*). That is, they are expressed as $\varepsilon \sim MN(0, \Sigma)$, where Σ is an $M \times M$ error covariance matrix.

The mapping of latent shares (S^*) to observed shares (S) must follow the convention that the elements of S lie between zero and one and sum to unity for each observation (household). From Wales and Woodland (1983), the following mapping imposes these two characteristics:

$$S_i = \begin{cases} \dfrac{S_i^*}{\sum_{j\in\Psi} S_j^*}, & \text{if } S_i^* > 0 \\ 0, & \text{if } S_i^* \le 0 \end{cases} \quad (i = 1, 2, \ldots, M+1), \tag{3}$$

where Ψ is the set of all positive latent shares. As noted by Wales and Woodland (1983), there may be ways other than shown in Eq. (3) to map S^* to S. However, the one chosen here is both simple and has the property that the resulting *PDF* is independent of whichever subset of S^* is used, or whichever element of S^* is excluded, in its derivation.

Unlike the latent system, not all theoretical constraints are held on the observed demand system. On the one hand, since S^* is homogenous of degree zero in prices and total expenditure, S is also homogenous of degree zero in prices and total expenditure. Therefore, in addition to adding-up, homogeneity holds on both S^* and S. However, due to the nonnegativity constraint, symmetry generally holds only in the latent system, not in the observed system.

4.1. Model estimation

Ever since Wales and Woodland (1983) introduced the above censored demand system, difficulties associated with the model's estimation have hindered its use in empirical applications. Maximum likelihood estimation of the model requires the evaluation of a complicated likelihood function and its derivatives. Following Dong et al. (2004), we focus on the simplification of this likelihood function, so that the system can be easily estimated using the smooth recursive probability simulation procedure. Since Dong et al. (2004) only briefly showed how to simplify the likelihood function, it may be hard to follow their procedure. In this study, we provide details about the transformation of the probability integral in the likelihood function in an online Appendix to facilitate the estimation of the model. The complete GAUSS

codes used for this study are also available from the authors upon request.

4.2. Demand elasticities for the expected observed meat purchases

The calculation of the elasticities for the expected shares in this censored demand system can be very complicated as shown in Dong et al. (2004), and is best done by simulation. Following Dong et al. (2004), we assume that there are T replicates of the $[M+1]$ error term vector ε in (1). The tth simulated latent share, S_t^*, evaluated at the sample means of our exogenous variables (indicated by a bar over the variable) is

$$S_t^* = A + \gamma \ln \overline{P} + \eta \ln \frac{\overline{y}}{\overline{P^*}} + \varepsilon_t, \tag{4}$$

where ε_t is the tth replicate of ε. The tth replicate of the ith observed share then is

$$S_{it} = \begin{cases} \dfrac{S_{it}^*}{\sum_{j\in\Psi} S_{jt}^*}, & \text{if } S_{it}^* > 0 \\ 0, & \text{if } S_{it}^* \le 0 \end{cases}. \tag{5}$$

The expected observed share vector for T replicates is then calculated as a simple average of these simulated values:

$$E(S) = \frac{1}{T}\sum_{t=1}^{T} S_t. \tag{6}$$

Suppose we have a small change in price $j(\Delta P_j)$, the elasticity vector with respect to this price change is:

$$\eta_j = -\delta_j + \frac{\Delta E(S)}{\Delta P_j} \cdot \frac{P + \Delta P_j/2}{E(S) + \Delta E(S)/2}, \tag{7}$$

where δ_j is a vector of 0's with the jth element one, and $\Delta E(S)$ is the change in the simulated $E(S)$ given the change of price, ΔP_j.

The calculation of elasticities for the latent system is straightforward. In fact, we can use the conventional formulae derived for an uncensored system provided, for example, in Green and Alston (1990) to compute the Marshallian and Hicksian demand elasticities. The latent shares are not bounded between zero and one, and the relationship between the expected shares and the latent shares is given by Eq. (3).

5. Results

The model was estimated by maximum likelihood using GAUSS and Nielsen Homescan data. Estimates are obtained for 216 parameters. Using symmetry and adding-up conditions, the remaining 34 parameters are recovered. The standard deviations of the parameters are calculated using the inverse of the negative simulated Hessian matrix. The full set of parameter estimates and their associated standard errors are provided in Table A1. Marshallian and Hicksian elasticities for the latent system are presented in Tables A2 and A3.[2] Below, we focus on the simulated elasticities for the observed system which are derived using the parameter estimates in Table A1 and our Homescan data. These are presented in Tables 3–5 including the expenditure elasticities, Marshallian price elasticities, Hicksian price elasticities, and elasticities for demographic variables. The results confirm that adding-up and homogeneity hold for the elasticities of both observed demand and latent demand systems. However, as discussed above, due to the nonnegativity constraint, symmetry holds in the latent system and not in the observed system. Finally, our findings on the variety of households' meat purchases are presented in Tables 6–8.

5.1. Meat expenditure elasticities

Expenditure elasticities for all goods are positive and statistically different from zero at the 1% level. As shown in the last column of Table 3, among the 10 groups of animal products, six (ground beef, beef steak, other beef, pork loin, other pork, and chicken parts) had elasticities greater than one. Other poultry, lunch meats, seafood, and other meats have expenditure elasticities less than one. The demand for beef steak is most sensitive to changes in meat expenditure, and the demand for seafood is the least sensitive to changes in meat expenditure.

5.2. Marshallian price elasticities

All 10 Marshallian (uncompensated) own-price elasticities are negative, less than one in magnitude, and statistically significant at the 1% level. As shown along the diagonal elements of the 10 columns of Table 3, the demand for lunch meats is more sensitive to own-price changes than are the demands for other meats and seafood. These estimates are quite consistent with the results of other studies in the meat demand literature, for example, by Brester and Wohlgenant (1991) and Piggott and Marsh (2004). Interestingly, pork demand tends to be slightly more sensitive to own-price changes than are the demands for the meats of other animals. A 10% decrease in the price of pork loin or other pork appears to cause about a 7.8% increase or an 8% increase in the quantities demanded of the two meats, respectively. That is, the own-price elasticities for pork products are more price sensitive than those for beef or poultry products, which differs from the findings of Coffey et al. (2011).

Also shown in Table 3 are the 90 cross-price elasticities for our 10 meat products. Seventy-one percent (64 out of 90) of these Marshallian cross-price elasticities are statistically significant at the 5% level or better. Among these 64 significant

[2] Comparing these results with the results for our observed system may shed light on the links between households' theoretical and actual meat purchases. However, that is beyond the scope of the current article.

Table 3
Marshallian price elasticities

Product	Unit value										
	Beef ground	Beef steak	Other beef	Pork loin	Other pork	Chicken parts	Other poultry	Lunch meats	Seafood	Other meats	Total expenditures
Beef ground	**−0.756**	**−0.150**	**0.075**	**0.083**	−0.005	**0.097**	**−0.061**	0.022	**−0.175**	**−0.243**	**1.112**
	(−20.4)	(−7.00)	(3.95)	(4.57)	(−0.29)	(5.66)	(−3.26)	(0.97)	(−8.89)	(−8.80)	(106.5)
Beef steak	**−0.167**	**−0.521**	−0.023	**−0.040**	**−0.071**	**−0.062**	**−0.214**	−0.041	0.011	**−0.117**	**1.244**
	(−7.69)	(−16.9)	(−1.36)	(−2.47)	(−3.92)	(−3.86)	(−11.6)	(−1.83)	(0.51)	(−4.46)	(119.9)
Other beef	**0.084**	−0.024	**−0.682**	−0.004	**−0.077**	−0.002	**−0.194**	**−0.058**	**−0.115**	**−0.132**	**1.203**
	(3.46)	(−1.10)	(−25.3)	(−0.22)	(−3.82)	(−0.10)	(−9.76)	(−2.36)	(−5.31)	(−4.87)	(102.2)
Pork loin	**0.107**	**−0.054**	−0.007	**−0.779**	**−0.119**	0.023	**−0.180**	0.001	**−0.079**	**−0.115**	**1.202**
	(3.99)	(−2.33)	(−0.32)	(−26.9)	(−5.90)	(1.24)	(−8.54)	(0.04)	(−3.50)	(−3.92)	(95.6)
Other pork	−0.006	**−0.048**	**−0.046**	**−0.066**	**−0.800**	**−0.095**	0.006	**0.078**	**−0.062**	**−0.066**	**1.105**
	(−0.35)	(−2.90)	(−3.18)	(−5.27)	(−40.9)	(−7.50)	(0.38)	(4.85)	(−3.39)	(−3.14)	(120.2)
Chicken parts	**0.116**	**−0.073**	−0.001	0.023	**−0.142**	**−0.732**	**−0.155**	0.013	**−0.117**	**−0.071**	**1.140**
	(5.24)	(−3.54)	(−0.03)	(1.38)	(−7.95)	(−28.9)	(−7.60)	(0.56)	(−5.22)	(−2.53)	(93.4)
Other poultry	−0.022	**−0.101**	**−0.073**	**−0.059**	0.020	**−0.058**	**−0.689**	**0.079**	**−0.076**	**0.052**	**0.926**
	(−1.92)	(−8.99)	(−7.59)	(−6.60)	(1.84)	(−5.93)	(−33.1)	(6.02)	(−4.96)	(3.09)	(104.7)
Lunch meats	0.038	0.000	−0.015	0.022	**0.092**	0.028	**0.113**	**−0.911**	**−0.105**	**−0.168**	**0.906**
	(1.95)	(0.01)	(−0.93)	(1.43)	(6.23)	(1.87)	(6.28)	(−30.2)	(−5.97)	(−6.93)	(90.6)
Seafood	**−0.085**	**0.061**	**−0.026**	−0.006	−0.007	**−0.033**	**−0.060**	**−0.073**	**−0.477**	**−0.052**	**0.756**
	(−5.96)	(3.95)	(−2.13)	(−0.54)	(−0.46)	(−2.64)	(−3.31)	(−4.84)	(−16.1)	(−2.60)	(66.5)
Other meats	**−0.087**	**−0.032**	**−0.028**	**−0.022**	**−0.023**	−0.011	**0.033**	**−0.083**	**−0.045**	**−0.579**	**0.879**
	(−7.27)	(−2.98)	(−3.20)	(−2.60)	(−2.47)	(−1.25)	(2.89)	(−6.75)	(−3.87)	(−24.0)	(95.4)
Predicted shares	**0.086**	**0.082**	**0.066**	**0.056**	**0.098**	**0.063**	**0.147**	**0.100**	**0.132**	**0.172**	

Notes: T-ratios are in parentheses. Bold font indicates significant at level of 0.05 or above.

cross-price elasticities, 13 suggest gross substitutes and 51 suggest gross complements. For example, our results suggest that ground beef is a gross substitute for other beef, pork loin, and chicken parts. However, meat products are more often gross complements than gross substitutes. Beef steaks are purchased along with ground beef, pork loins, other pork, chicken parts, other poultry, and other meats. A similar complementary relationship exists between other beef and other pork, other poultry, seafood, and other meats.

5.3. Hicksian price elasticities

Hicksian (compensated) price elasticities are calculated from the Marshallian elasticities using the Slutsky equation. As shown in Table 4, similar to the Marshallian demand elasticities, the Hicksian own-price elasticities are all negative and statistically significant at the 1% level. Householders are most responsive to changes in the own-price of lunch meats and least responsive to changes in the own-price of seafood. From the cross-price elasticities, we find that, among beef products, other beef is a net substitute for steak and ground beef, but ground beef and steak are net complements. Among beef, pork and poultry, we find that ground beef is a net substitute for pork and poultry, other beef is a net substitute for pork loin and chicken parts, and steak is a net substitute for other pork. Pork loin and chicken parts are net substitutes, as are other pork and other poultry. Lunch meats are a net substitute for all meat products except seafood and other meats. Other meats are net substitutes for all the meats except for ground beef and lunch meats. Seafood is found to be a net substitute for beef steak, pork products, other poultry, and other meats. Findings also suggest that beef steak is a net complement to other poultry.

It is worth recalling that the data used in this study are meat purchase data. Therefore, the demand analyzed in this study is for meat purchases, not for consumption. One therefore needs to be cautious about interpreting the results. For example, the findings of a complementary relationship between beef steak and beef ground implies that the two products are purchased together. It does not necessarily imply that they are consumed together.

5.4. Demographic influence

In addition to prices and the level of meat expenditures, household demographic variables also influence meat purchases. A total of 120 demographic effects (12 demographic variables for 10 meat products) are analyzed in the demand system model. As shown in Table 5, elasticities for 80 of these effects (67%) are statistically significant at the 5% level or better. Demographic information similar to those displayed in Table 5 cannot be obtained using marketing data, which is what distinguishes Nielsen Homescan data from most data sources. According to the results shown in Table 5, the age of the female household head is the most important demographic factor influencing a household's meat purchases. Younger heads of households prefer more ground beef, beef steak, poultry products, lunch meats, and other meats. Household size is also a significant factor. Large households tend to buy ground beef,

Table 4
Hicksian price elasticities

	Unit value									
Product	Beef ground	Beef steak	Other beef	Pork loin	Other pork	Chicken parts	Other poultry	Lunch meats	Seafood	Other meats
Beef ground	**−0.660**	**−0.059**	**0.148**	**0.146**	**0.103**	**0.166**	**0.102**	**0.134**	−0.029	−0.052
	(−17.8)	(−2.75)	(7.78)	(7.98)	(5.96)	(9.72)	(5.41)	(5.75)	(−1.46)	(−1.87)
Beef steak	**−0.060**	**−0.419**	**0.059**	0.030	**0.051**	0.016	−0.032	**0.084**	**0.175**	**0.097**
	(−2.76)	(−13.6)	(3.45)	(1.91)	(2.79)	(0.99)	(−1.71)	(3.78)	(8.08)	(3.70)
Other beef	**0.187**	**0.074**	**−0.603**	**0.063**	**0.040**	**0.073**	−0.017	**0.062**	**0.044**	**0.075**
	(7.71)	(3.43)	(−22.4)	(3.43)	(2.01)	(3.99)	(−0.86)	(2.53)	(2.03)	(2.77)
Pork loin	**0.210**	0.044	**0.072**	**−0.712**	−0.001	**0.098**	−0.004	**0.121**	**0.079**	**0.092**
	(7.85)	(1.91)	(3.42)	(−24.5)	(−0.07)	(5.28)	(−0.18)	(4.59)	(3.51)	(3.12)
Other pork	**0.089**	**0.042**	0.026	−0.004	**−0.692**	**−0.026**	**0.168**	**0.189**	**0.084**	**0.124**
	(5.56)	(2.53)	(1.79)	(−0.34)	(−35.4)	(−2.04)	(10.3)	(11.7)	(4.62)	(5.91)
Chicken parts	**0.214**	0.020	**0.074**	**0.087**	−0.031	**−0.661**	0.012	**0.127**	0.033	**0.125**
	(9.66)	(0.94)	(3.97)	(5.23)	(−1.73)	(−26.1)	(0.59)	(5.47)	(1.46)	(4.48)
Other poultry	**0.057**	**−0.026**	−0.012	−0.006	**0.110**	0.000	**−0.553**	**0.172**	**0.046**	**0.212**
	(4.89)	(−2.27)	(−1.24)	(−0.72)	(10.1)	(0.02)	(−26.5)	(12.9)	(2.96)	(12.5)
Lunch meats	**0.116**	**0.074**	**0.044**	**0.073**	**0.181**	**0.085**	**0.247**	**−0.821**	0.014	0.012
	(5.92)	(3.99)	(2.75)	(4.78)	(12.2)	(5.65)	(13.6)	(−27.2)	(0.80)	(0.51)
Seafood	−0.020	**0.123**	0.024	**0.036**	**0.067**	0.014	**0.051**	0.003	**−0.377**	**0.078**
	(−1.38)	(7.92)	(1.92)	(3.25)	(4.73)	(1.15)	(2.82)	(0.19)	(−12.7)	(3.91)
Other meats	−0.012	**0.039**	**0.029**	**0.027**	**0.063**	**0.044**	**0.162**	0.005	**0.071**	**−0.428**
	(−0.97)	(3.60)	(3.25)	(3.17)	(6.66)	(4.81)	(14.3)	(0.40)	(6.01)	(−17.7)

Notes: T-ratios are in parentheses. Bold font indicates significant at level of 0.05 or above.

Table 5
Demographic elasticities

	Demographic variables												
Product	Int	Hhsize	Agf	Agec 1317	Fed	Pvl130	Black	Asian	Other	Hisp	East	Central	West
Beef ground	**1.142**	**0.188**	**−0.168**	−0.003	**−0.017**	0.006	**−0.042**	**−0.014**	**−0.013**	0.005	**−0.030**	**0.013**	**−0.023**
	(4.87)	(8.37)	(−4.07)	(−0.90)	(−2.32)	(1.76)	(−10.0)	(−6.01)	(−3.95)	(1.70)	(−5.03)	(3.23)	(−3.95)
Beef steak	**−2.991**	**−0.134**	**−0.141**	−0.001	0.000	**0.009**	**−0.041**	0.000	−0.002	0.005	−0.006	**−0.016**	0.012
	(−13.5)	(−5.78)	(−3.26)	(−0.34)	(−0.01)	(2.28)	(−8.42)	(0.18)	(−0.53)	(1.34)	(−0.97)	(−3.31)	(1.95)
Other beef	**−1.830**	0.004	**0.284**	−0.003	0.004	−0.003	**−0.020**	**0.008**	0.002	**0.010**	−0.011	0.003	**0.037**
	(−6.81)	(0.17)	(6.79)	(−0.61)	(0.57)	(−0.76)	(−4.47)	(4.20)	(0.86)	(3.30)	(−1.67)	(0.51)	(6.19)
Pork loin	**−2.339**	**0.083**	**0.428**	**−0.012**	−0.008	**−0.010**	**−0.016**	0.000	−0.004	**−0.010**	**−0.015**	**0.012**	**−0.028**
	(−7.88)	(3.22)	(9.57)	(−2.73)	(−1.06)	(−2.49)	(−3.91)	(0.11)	(−1.19)	(−2.53)	(−2.50)	(2.56)	(−4.36)
Other pork	**−1.398**	**0.071**	**0.296**	**−0.010**	**−0.018**	−0.001	**0.023**	**0.005**	−0.002	0.002	0.005	**0.025**	**−0.021**
	(−5.09)	(3.30)	(7.78)	(−2.55)	(−2.63)	(−0.16)	(7.01)	(2.79)	(−0.78)	(0.65)	(0.85)	(6.20)	(−3.70)
Chicken parts	**−0.526**	**−0.081**	**−0.291**	−0.004	**0.031**	0.005	**0.025**	**0.011**	0.002	0.003	**0.046**	**−0.017**	**−0.020**
	(−2.38)	(−3.15)	(−6.05)	(−0.98)	(3.79)	(1.13)	(5.41)	(5.49)	(0.49)	(0.70)	(7.43)	(−3.15)	(−2.93)
Other poultry	**2.075**	−0.006	**−0.301**	0.006	**0.020**	**−0.009**	**0.016**	**−0.006**	0.001	−0.003	−0.008	0.008	**0.023**
	(14.9)	(−0.33)	(−10.8)	(1.48)	(3.09)	(−2.51)	(4.45)	(−3.46)	(0.18)	(−1.08)	(−1.43)	(1.85)	(4.25)
Lunch meats	**1.391**	0.010	**−0.124**	0.006	**−0.025**	0.002	**−0.032**	**−0.011**	**−0.009**	0.006	**−0.028**	**0.012**	0.009
	(7.33)	(0.44)	(−3.20)	(1.29)	(−3.34)	(0.65)	(−7.01)	(−4.71)	(−2.73)	(1.70)	(−4.40)	(2.76)	(1.48)
Seafood	**−0.935**	**−0.183**	**0.322**	0.008	**0.033**	0.003	**0.037**	**0.013**	**0.014**	−0.008	**0.061**	**−0.025**	0.000
	(−7.41)	(−6.66)	(9.44)	(1.41)	(3.75)	(0.77)	(8.13)	(6.04)	(4.54)	(−1.82)	(8.85)	(−3.80)	(0.03)
Other meats	**1.431**	**0.070**	**−0.076**	0.000	**−0.019**	−0.001	**0.007**	−0.001	0.002	−0.002	**−0.016**	−0.006	−0.005
	(5.39)	(4.30)	(−2.60)	(−0.13)	(−3.98)	(−0.42)	(2.93)	(−1.04)	(1.03)	(−1.14)	(−4.32)	(−1.94)	(−1.21)

Notes: T-ratios are in parentheses. Bold font indicates significant at level of 0.05 or above.

pork products, and other meats. Female heads of households who have earned a college degree are more inclined to buy chicken parts, other poultry, and seafood.

Households with an income below 130% of the poverty line are more likely to purchase beef steaks, and less likely to purchase pork loin and other poultry. Race and region are also significant determinants of households' meat purchases. African American households are less likely to buy beef products, pork loin, and lunch meats. Results suggest that Asian households may have a greater taste for other beef, other pork, chicken parts, and seafood. Purchases of chicken parts and seafood are also positively associated with living in the Eastern region of the United States, while purchases of pork loin, other pork and lunch meats are positively associated with living in the Central

Table 6
Top ten highest purchase probability regimes

		Purchase regime									
Regime	Probability	Beef ground	Beef steak	Other beef	Pork loin	Other pork	Chicken parts	Other poultry	Lunch meats	Seafood	Other meats
1	0.0412	1	1	1	1	1	1	1	1	1	1
2	0.0408	1	1	1	1	1	1	1	1	0	1
3	0.0310	1	1	1	1	1	1	1	0	1	1
4	0.0306	1	1	1	1	1	1	1	1	1	0
5	0.0285	1	1	1	1	1	1	0	1	1	1
6	0.0273	1	1	1	1	1	0	1	1	1	1
7	0.0244	1	0	1	1	1	1	1	1	1	1
8	0.0209	1	1	0	1	1	1	1	1	1	1
9	0.0198	1	1	1	0	1	1	1	1	1	1
10	0.0186	1	1	1	1	1	0	1	1	0	1

region. Households in the Western region of the United States exhibit a greater demand for other beef and other poultry.

5.5. Meat purchase variety

As noted above, empirical research on the variety of households' food purchases has been limited by researchers' (in)ability to estimate a censored demand system, compelling them to instead rely on summary measures of variety like the number of available products actually bought. The drawback of this approach is that information is lost on which products are in a household's consumption bundle and in what quantities. Thus, in order to gain a more complete picture of meat purchase variety, we begin by asking which of the 1,023 different consumption bundles defined in this study are most probable. As discussed above, defining a demand system in which households can buy 10 different meat products implies that each household could belong to 1,023 different purchase regimes, if at least one meat product is purchased. Among all the possibilities, Table 6 lists the 10 consumption bundles that have the highest likelihood. From the results in this table, we see that the regime with the highest purchase probability is the one in which all 10 products are purchased. The second highest purchase probability regime is the one in which all the products except seafood are purchased. Notably, in all of the 10 cases shown in Table 6, households buy at least 8 out of 10 products, suggesting that many households purchase a fairly varied mix of meat products.

Next, in order to understand how evenly meat demand is spread over all available products, we simulate the relationship between total meat expenditures and meat product purchases using the estimated model parameters. The results are given in Table 7. The numbers in Table 7 are the purchase amounts for each of the 10 meat products at different levels of total meat expenditure. That is, we used our parameter estimates to predict latent budget shares for each household at the average meat prices provided in Table 1 and at different levels of total meat expenditure. We then used Eq. (3) to calculate the expected budget shares, and converted these shares into quantities again using the total meat expenditure level and average meat prices. From Table 7, we see that other poultry, seafood, and other meats are the first three meat products to be purchased. As expenditure increases, the next purchased products, in order, are lunch meats, other pork, ground beef, chicken parts, other beef, and pork loin. Beef steak is the last product purchased when total meat expenditure reaches $47. According to Nielsen Homescan, U.S. households' annual total meat expenditures average $462. Therefore, at meat's current retail price level, it appears that U.S. households are inclined to purchase a fairly diverse mix of meat products at even low levels of expenditure (compared to mean expenditure), though there is a definite order in which products tend to enter a household's consumption bundle and the share of the budget devoted to each item varies as expenditures increase.[3]

Finally, since past empirical analyses of households' demand for variety have often utilized a count of available products bought, we simulate the expected number of different products purchased at different levels of meat expenditure. These results are provided in Table 8. Similar to Table 7, we first used our model results and average prices to simulate latent budget shares for each household at different levels of meat expenditure. The probability of a positive purchase for each of the 10 products was then calculated by observing the percentage of households in our data for whom the predicted latent share was positive. Finally, in the last column of Table 8, the expected number of products purchased is the mean number of meat products purchased, over all the households. This last statistic is essentially the same measure of variety used in past studies, such as Shonkwiler et al. (1987) and Lee (1987). Table 8 is quite consistent with Table 7. For other poultry, lunch meat, seafood, and other meats, the purchase probabilities jump to about 0.6 at a very low expenditure level, and then increase slightly to their peak, and then begin to decrease slightly as total meat expenditure increases. For other products, the purchase probabilities are monotonically increasing with total meat expenditure. The greatest rate of increase in

[3] Since the AIDS system is only locally flexible, simulation results far from the sample mean of total meat expenditure ($462) may suffer from inaccuracy.

Table 7
Total meat expenditure effects on meat quantity purchases

	Meat product purchase (lb)									
Total meat expenditure ($)	Beef ground	Beef steak	Other beef	Pork loin	Other pork	Chicken parts	Other poultry	Lunch meats	Seafood	Other meats
0.00	0	0	0	0	0	0	0	0	0	0
1.00	0	0	0	0	0	0	0.1	0	0.1	0.1
2.00	0	0	0	0	0	0	0.2	0.1	0.2	0.2
3.00	0	0	0	0	0	0	0.3	0.1	0.3	0.4
4.00	0	0	0	0	0	0	0.4	0.1	0.3	0.5
5.00	0	0	0	0	0.1	0	0.5	0.2	0.4	0.6
6.00	0	0	0	0	0.1	0	0.6	0.2	0.5	0.7
7.00	0.1	0	0	0	0.1	0	0.7	0.2	0.6	0.8
8.00	0.1	0	0	0	0.1	0	0.8	0.3	0.7	0.9
9.00	0.1	0	0	0	0.1	0	0.9	0.3	0.7	1.0
10.00	0.1	0	0	0	0.1	0	1.0	0.4	0.8	1.1
11.00	0.1	0	0	0	0.2	0	1.1	0.4	0.9	1.2
12.00	0.2	0	0	0	0.2	0	1.2	0.4	1.0	1.3
13.00	0.2	0	0	0	0.2	0.1	1.3	0.5	1.0	1.4
14.00	0.2	0	0	0	0.2	0.1	1.4	0.5	1.1	1.5
15.00	0.2	0	0	0	0.2	0.1	1.5	0.5	1.2	1.6
16.00	0.2	0	0	0	0.3	0.1	1.6	0.6	1.2	1.7
17.00	0.3	0	0	0	0.3	0.1	1.7	0.6	1.3	1.8
18.00	0.3	0	0	0	0.3	0.1	1.8	0.6	1.4	1.9
19.00	0.3	0	0	0	0.3	0.1	1.9	0.7	1.5	2.0
20.00	0.3	0	0	0	0.4	0.2	2.0	0.7	1.5	2.1
25.00	0.4	0	0	0	0.5	0.2	2.4	0.9	1.9	2.5
27.00	0.5	0	0	0	0.5	0.3	2.6	0.9	2.0	2.7
28.00	0.5	0	0.1	0	0.6	0.3	2.7	1.0	2.1	2.8
29.00	0.5	0	0.1	0	0.6	0.3	2.8	1.0	2.1	2.9
32.00	0.6	0	0.1	0	0.7	0.4	3.1	1.1	2.3	3.1
33.00	0.7	0	0.1	0.1	0.7	0.4	3.2	1.1	2.4	3.2
35.00	0.7	0	0.1	0.1	0.7	0.5	3.4	1.2	2.5	3.4
36.00	0.7	0	0.1	0.1	0.8	0.5	3.4	1.2	2.6	3.5
37.00	0.8	0	0.2	0.1	0.8	0.5	3.5	1.2	2.6	3.5
38.00	0.8	0	0.2	0.1	0.8	0.5	3.6	1.3	2.7	3.6
39.00	0.8	0	0.2	0.1	0.9	0.5	3.7	1.3	2.7	3.7
40.00	0.8	0	0.2	0.1	0.9	0.6	3.8	1.3	2.8	3.8
45.00	1.0	0	0.3	0.2	1.0	0.7	4.2	1.5	3.1	4.2
46.00	1.0	0	0.3	0.2	1.1	0.7	4.3	1.5	3.1	4.3
47.00	1.0	0.1	0.3	0.2	1.1	0.7	4.4	1.5	3.2	4.3
48.00	1.1	0.1	0.3	0.2	1.1	0.8	4.5	1.6	3.3	4.4
49.00	1.1	0.1	0.3	0.2	1.1	0.8	4.6	1.6	3.3	4.5
50.00	1.1	0.1	0.3	0.2	1.2	0.8	4.7	1.6	3.4	4.6

the purchase probability among all the products is for beef steak. This can be explained by the expenditure elasticities provided in Table 3. The expenditure elasticities for other poultry, lunch meat, seafood, and other meats are all less than one, which is consistent with a decrease in purchase probabilities when expenditure increases. The expenditure elasticities for all other products are greater than one, which suggests that purchase probabilities are monotonically increasing in meat expenditure. Beef steak has the largest expenditure elasticity, so its purchase probability logically increases with expenditure at the greatest rate.

Consistent with our results in Tables 6 and 7, we also see in Table 8 that the expected number of products purchased is 5.5 even at a very low level of meat expenditure ($0.50). This indicates that, when households begin to purchase meat, they already purchase at least half of the 10 meat products to maximize their utilities. However, when meat expenditure increases, the expected number of meat products purchased is quite stable and increases at a very slow rate. As noted above, according to Nielsen Homescan data, households spent $462 on meat, on average, and the average number of meat products purchased is 8.1. Notably, the expected number of meat products purchased from Table 8 is around this same level of expenditure, about 7.8.

Overall, from the above results, it is clear that U.S. households are inclined to buy a varied mix of all of the 10 meat products; however, they choose only seven or eight to maximize their utilities. Increasing expenditure (and likely income) will not have much impact on the variety of their meat purchases, although, education and advertisement which

Table 8
Total meat expenditure effects on meat purchase numbers and probabilities

	Meat product purchase probability										
Total meat expenditure ($)	Beef ground	Beef steak	Other beef	Pork loin	Other pork	Chicken parts	Other poultry	Lunch meats	Seafood	Other meats	Expected purchased number of meat products
0	0	0	0	0	0	0	0	0	0	0	0
0.50	0.33	0.09	0.14	0.14	0.36	0.25	0.64	0.64	0.67	0.58	5.56
1.00	0.36	0.12	0.18	0.18	0.40	0.28	0.66	0.66	0.70	0.60	5.78
2.00	0.40	0.16	0.23	0.22	0.44	0.32	0.68	0.67	0.72	0.61	6.01
3.00	0.43	0.19	0.26	0.25	0.47	0.35	0.69	0.68	0.73	0.61	6.16
4.00	0.44	0.21	0.28	0.27	0.48	0.37	0.70	0.68	0.74	0.61	6.26
5.00	0.46	0.23	0.30	0.29	0.50	0.38	0.70	0.69	0.75	0.62	6.34
10.00	0.50	0.29	0.35	0.34	0.53	0.42	0.71	0.69	0.77	0.62	6.60
15.00	0.52	0.33	0.39	0.37	0.56	0.45	0.72	0.70	0.78	0.62	6.75
20.00	0.53	0.36	0.41	0.40	0.57	0.46	0.72	0.70	0.79	0.62	6.86
25.00	0.54	0.38	0.43	0.42	0.58	0.48	0.72	0.70	0.79	0.62	6.94
30.00	0.55	0.39	0.45	0.43	0.59	0.49	0.73	0.70	0.79	0.62	7.01
35.00	0.56	0.41	0.46	0.44	0.60	0.50	0.73	0.70	0.79	0.62	7.06
40.00	0.57	0.42	0.47	0.45	0.60	0.50	0.73	0.70	0.80	0.62	7.11
45.00	0.57	0.43	0.48	0.46	0.61	0.51	0.73	0.70	0.80	0.62	7.15
50.00	0.58	0.44	0.49	0.47	0.62	0.52	0.73	0.70	0.80	0.61	7.19
55.00	0.58	0.45	0.50	0.48	0.62	0.52	0.73	0.70	0.80	0.61	7.22
60.00	0.59	0.46	0.51	0.49	0.62	0.53	0.73	0.70	0.80	0.61	7.25
65.00	0.59	0.47	0.51	0.49	0.63	0.53	0.73	0.69	0.80	0.61	7.27
70.00	0.59	0.48	0.52	0.50	0.63	0.54	0.73	0.69	0.80	0.61	7.30
75.00	0.60	0.48	0.52	0.50	0.63	0.54	0.73	0.69	0.80	0.61	7.32
80.00	0.60	0.49	0.53	0.51	0.64	0.54	0.73	0.69	0.80	0.61	7.34
85.00	0.60	0.49	0.53	0.51	0.64	0.55	0.73	0.69	0.80	0.61	7.36
90.00	0.61	0.50	0.54	0.52	0.64	0.55	0.73	0.69	0.80	0.61	7.38
95.00	0.61	0.50	0.54	0.52	0.64	0.55	0.73	0.69	0.80	0.61	7.40
100.00	0.61	0.51	0.55	0.53	0.65	0.56	0.73	0.69	0.80	0.61	7.41
105.00	0.61	0.51	0.55	0.53	0.65	0.56	0.73	0.69	0.80	0.60	7.43
150.00	0.63	0.55	0.58	0.56	0.66	0.58	0.73	0.68	0.79	0.60	7.53
200.00	0.64	0.57	0.60	0.58	0.67	0.59	0.72	0.68	0.79	0.59	7.61
250.00	0.65	0.59	0.61	0.59	0.68	0.60	0.72	0.67	0.78	0.59	7.66
300.00	0.65	0.60	0.62	0.60	0.69	0.61	0.72	0.67	0.77	0.58	7.70
350.00	0.66	0.61	0.63	0.61	0.69	0.62	0.72	0.67	0.77	0.58	7.73
400.00	0.66	0.62	0.64	0.62	0.69	0.62	0.71	0.66	0.76	0.57	7.76
450.00	0.66	0.63	0.65	0.63	0.70	0.63	0.71	0.66	0.75	0.57	7.78
500.00	0.67	0.64	0.65	0.63	0.70	0.63	0.71	0.66	0.75	0.57	7.80
600.00	0.67	0.65	0.66	0.64	0.70	0.64	0.71	0.65	0.74	0.56	7.83
700.00	0.68	0.66	0.67	0.65	0.71	0.64	0.70	0.65	0.73	0.56	7.86
800.00	0.68	0.67	0.68	0.66	0.71	0.65	0.70	0.64	0.72	0.55	7.87
900.00	0.68	0.68	0.68	0.66	0.71	0.65	0.70	0.64	0.71	0.55	7.89

alter households' preferences may change their purchase variety.

6. Conclusions and implications

This study extends previous research on meat demand by using household level data to model U.S. households' purchases of 10 disaggregated meat products. Unlike previous studies, we estimate a censored demand system which imposes budget constraints in both observed and latent shares. A further innovation is to empirically analyze the variety of households' food purchases using a demand system-framework for the first time.

Findings on U.S. households' demand for meat products are similar, in some respects, to those of existing studies. However, we obtain a more complete picture of consumer behavior. Among our results, disaggregated expenditure and price elasticities reveal that all 10 meat products defined for this study are normal goods or luxuries. Beef steak purchases increase the most with income and seafood purchases the least. Selected cuts of pork, particularly pork loin and other pork products, exhibit price responses that are more sensitive to price changes than other animal meat products.

Beyond price and income elasticities, economists are also interested in the variety of a household's food purchases. One reason, as discussed above, is that variety is important to diet quality. Federal dietary guidelines encourage Americans to choose lean meats. Previous research has analyzed the number of different types of product bought as well as other summary

measures of variety. The drawback of this approach is that information is lost on which products are likely included in a household's consumption bundle. In this study, as recommended by Federal dietary guidance, we find that Americans are inclined to buy relatively lean products like seafood and poultry, even at low expenditure levels. They are also inclined to buy processed products, such as lunch meat, and red meats, particularly ground beef and beef steaks. Many consumers may enjoy a juicy hamburger or a juicy steak. The problem is that such foods can also be high in fat and calories. Furthermore, given our findings that Americans prefer to consume a wider variety of meat products over a narrower variety, it may be difficult to persuade them to buy only lean types of meat. As an alternative, nutritionists may want to consider encouraging households to identify and choose leaner cuts of all types of meat; rather than restricting the variety of their purchases. Ground beef, for example, can be purchased with 20% or 7% fat. There are six cuts of beef that meet the American Heart Association's criteria for being heart-healthy, including sirloin steak, bottom round steak, top sirloin stir-fry, boneless top sirloin petite roast, top sirloin filet, and top sirloin kabob (Radke, 2013).

Empirically, this study employs the methodology of Dong et al. (2004) to impose the budget constraints in both the observed and latent systems, and thereby obtain unbiased price and expenditure elasticities. However, compared with the original presentation of this methodology in Dong et al. (2004), the present study provides an improved, more detailed explanation of the methodology. This should enable researchers to extend the method to estimate highly disaggregated demand systems and study purchase variety for other foods.

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The views expressed here are those of the authors, and may not be attributed to the Economic Research Service or the U.S. Department of Agriculture

Appendix

Table A1. Parameter estimates

Parameter	Equation									
	Beef ground	Beef steak	Other beef	Pork loin	Other pork	Chicken parts	Other poultry	Lunch meats	Seafood	Other meats (dropped)
Int	0.1888	−0.3791	−0.1697	−0.1957	−0.1454	−0.0232	0.5992	0.3381	0.0500	0.7369
	(0.0309)	(0.0347)	(0.0276)	(0.0290)	(0.0386)	(0.0222)	(0.0312)	(0.0307)	(0.0229)	(0.0905)
Hhsize	−0.0411	0.0322	0.0006	−0.0117	−0.0160	0.0154	0.0027	−0.0026	0.0554	−0.0350
	(0.0050)	(0.0054)	(0.0044)	(0.0039)	(0.0053)	(0.0045)	(0.0067)	(0.0060)	(0.0083)	(0.0169)
Agf	−0.0201	−0.0157	0.0303	0.0394	0.0429	−0.0278	−0.0626	−0.0191	0.0555	−0.0228
	(0.0053)	(0.0053)	(0.0041)	(0.0042)	(0.0054)	(0.0048)	(0.0063)	(0.0059)	(0.0061)	(0.0160)
Agec 1317	−0.0038	−0.0014	−0.0021	−0.0094	−0.0120	−0.0037	0.0112	0.0079	0.0129	0.0005
	(0.0043)	(0.0046)	(0.0036)	(0.0035)	(0.0048)	(0.0039)	(0.0075)	(0.0060)	(0.0091)	(0.0167)
Fed	−0.0057	0.0003	0.0015	−0.0019	−0.0068	0.0091	0.0126	−0.0106	0.0169	−0.0153
	(0.0026)	(0.0028)	(0.0022)	(0.0020)	(0.0027)	(0.0023)	(0.0039)	(0.0033)	(0.0044)	(0.0090)
Pvl130	0.0102	0.0170	−0.0034	−0.0114	−0.0008	0.0067	−0.0251	0.0047	0.0074	−0.0054
	(0.0056)	(0.0074)	(0.0050)	(0.0047)	(0.0065)	(0.0057)	(0.0101)	(0.0077)	(0.0107)	(0.0219)
Black	−0.0411	−0.0402	−0.0157	−0.0113	0.0237	0.0181	0.0264	−0.0365	0.0523	0.0243
	(0.0040)	(0.0046)	(0.0033)	(0.0027)	(0.0035)	(0.0034)	(0.0058)	(0.0052)	(0.0060)	(0.0132)
Asian	−0.0427	0.0018	0.0204	0.0009	0.0174	0.0270	−0.0320	−0.0420	0.0554	−0.0063
	(0.0071)	(0.0063)	(0.0048)	(0.0049)	(0.0062)	(0.0048)	(0.0094)	(0.0088)	(0.0090)	(0.0211)
Other	−0.0277	−0.0035	0.0040	−0.0061	−0.0056	0.0030	0.0018	−0.0235	0.0443	0.0133
	(0.0070)	(0.0067)	(0.0047)	(0.0050)	(0.0069)	(0.0058)	(0.0092)	(0.0085)	(0.0094)	(0.0216)
Hisp	0.0097	0.0085	0.0142	−0.0111	0.0041	0.0037	−0.0089	0.0119	−0.0201	−0.0121
	(0.0055)	(0.0062)	(0.0042)	(0.0045)	(0.0060)	(0.0052)	(0.0083)	(0.0069)	(0.0106)	(0.0200)
East	−0.0164	−0.0027	−0.0044	−0.0054	0.0034	0.0213	−0.0068	−0.0185	0.0482	−0.0187
	(0.0034)	(0.0036)	(0.0030)	(0.0024)	(0.0033)	(0.0027)	(0.0054)	(0.0043)	(0.0053)	(0.0115)
Central	0.0108	−0.0125	0.0017	0.0067	0.0211	−0.0104	0.0107	0.0122	−0.0270	−0.0133
	(0.0032)	(0.0039)	(0.0031)	(0.0026)	(0.0033)	(0.0033)	(0.0056)	(0.0041)	(0.0070)	(0.0127)
West	−0.0126	0.0068	0.0163	−0.0106	−0.0128	−0.0085	0.0208	0.0062	−0.0001	−0.0056
	(0.0032)	(0.0034)	(0.0026)	(0.0024)	(0.0035)	(0.0029)	(0.0050)	(0.0041)	(0.0056)	(0.0113)
expenditure	0.0154	0.0325	0.0212	0.0188	0.0155	0.0144	−0.0156	−0.0139	−0.0447	−0.0435
	(0.0014)	(0.0013)	(0.0012)	(0.0012)	(0.0013)	(0.0012)	(0.0017)	(0.0015)	(0.0016)	(0.0042)

(*Continued*)

Table A1. Continued

Parameter	Equation									
	Beef ground	Beef steak	Other beef	Pork loin	Other pork	Chicken parts	Other poultry	Lunch meats	Seafood	Other meats (dropped)
P1	0.0317	−0.0217	0.0083	0.0094	−0.0005	0.0115	−0.0037	0.0069	−0.0144	−0.0275
	(0.0048)	(0.0028)	(0.0025)	(0.0024)	(0.0022)	(0.0022)	(0.0025)	(0.0030)	(0.0025)	(0.0086)
P2		0.0562	−0.0059	−0.0079	−0.0093	−0.0098	−0.0188	0.0023	0.0183	−0.0032
		(0.0036)	(0.0022)	(0.0021)	(0.0024)	(0.0021)	(0.0023)	(0.0029)	(0.0028)	(0.0078)
P3			0.0301	−0.0023	−0.0079	−0.0014	−0.0138	−0.0009	−0.0005	−0.0058
			(0.0028)	(0.0019)	(0.0020)	(0.0019)	(0.0021)	(0.0025)	(0.0022)	(0.0068)
P4				0.0179	−0.0106	0.0010	−0.0109	0.0046	0.0026	−0.0038
				(0.0026)	(0.0018)	(0.0017)	(0.0019)	(0.0023)	(0.0020)	(0.0063)
P5					0.0281	−0.0142	0.0052	0.0150	−0.0003	−0.0055
					(0.0027)	(0.0018)	(0.0023)	(0.0023)	(0.0025)	(0.0067)
P6						0.0260	−0.0116	0.0047	−0.0038	−0.0024
						(0.0025)	(0.0021)	(0.0023)	(0.0022)	(0.0063)
P7							0.0614	0.0140	−0.0225	0.0006
							(0.0041)	(0.0028)	(0.0033)	(0.0080)
P8								0.0115	−0.0227	−0.0353
								(0.0046)	(0.0027)	(0.0087)
P9									0.0716	−0.0282
									(0.0045)	(0.0085)
P10										0.1111
										(0.0228)
V1	0.0970	0.0029	0.0015	0.0031	−0.0030	−0.0008	−0.0279	−0.0124	−0.0434	−0.0016
	(0.0006)	(0.0015)	(0.0010)	(0.0009)	(0.0013)	(0.0011)	(0.0020)	(0.0015)	(0.0026)	(0.0002)
V2		0.1052	0.0086	0.0049	−0.0020	−0.0003	−0.0348	−0.0183	−0.0321	−0.0033
		(0.0007)	(0.0010)	(0.0010)	(0.0013)	(0.0012)	(0.0024)	(0.0018)	(0.0027)	(0.0002)
V3			0.0815	0.0033	−0.0023	−0.0013	−0.0205	−0.0156	−0.0268	−0.0018
			(0.0005)	(0.0008)	(0.0014)	(0.0012)	(0.0019)	(0.0016)	(0.0025)	(0.0001)
V4				0.0720	0.0085	0.0030	−0.0207	−0.0143	−0.0291	−0.0017
				(0.0005)	(0.0013)	(0.0011)	(0.0022)	(0.0017)	(0.0024)	(0.0001)
V5					0.1002	−0.0048	−0.0265	−0.0097	−0.0421	−0.0017
					(0.0007)	(0.0011)	(0.0019)	(0.0014)	(0.0021)	(0.0001)
V6						0.0869	−0.0169	−0.0192	−0.0165	−0.0029
						(0.0005)	(0.0019)	(0.0015)	(0.0020)	(0.0001)
V7							0.1444	−0.0323	−0.0610	−0.0040
							(0.0009)	(0.0013)	(0.0017)	(0.0002)
V8								0.1126	−0.0700	−0.0010
								(0.0007)	(0.0013)	(0.0002)
V9									0.1248	−0.0054
									(0.0008)	(0.0002)
V10										0.0235
										(0.0005)

Note: Standard deviations are in parentheses.

Table A2. Mashanllian price elasticities for the latent system

Product	Unit value										Total
	Beef ground	Beef steak	Other beef	Pork loin	Other pork	Chicken parts	Other poultry	Lunch meats	Seafood	Other meats	expenditures
Beef ground	**−0.636**	**−0.215**	**0.112**	**0.123**	−0.003	**0.140**	**−0.091**	0.041	**−0.249**	**−0.395**	**1.174**
	(−11.8)	(−6.95)	(4.02)	(4.60)	(−0.11)	(5.61)	(−3.31)	(1.22)	(−8.70)	(−9.95)	(75.7)
Beef steak	**−0.262**	**−0.217**	−0.034	**−0.062**	**−0.111**	**−0.102**	**−0.354**	−0.058	0.027	**−0.239**	**1.411**
	(−7.54)	(−4.84)	(−1.21)	(−2.39)	(−3.79)	(−3.89)	(−12.1)	(−1.59)	(0.75)	(−5.65)	(85.8)
Other beef	**0.138**	−0.034	**−0.505**	−0.005	**−0.115**	−0.004	**−0.303**	**−0.082**	**−0.170**	**−0.246**	**1.325**
	(3.67)	(−1.01)	(−12.2)	(−0.18)	(−3.70)	(−0.15)	(−9.89)	(−2.14)	(−5.06)	(−5.89)	(70.1)
Pork loin	**0.186**	**−0.086**	−0.008	**−0.635**	**−0.190**	0.037	**−0.301**	0.012	**−0.124**	**−0.239**	**1.348**
	(4.24)	(−2.26)	(−0.22)	(−13.4)	(−5.81)	(1.22)	(−8.73)	(0.27)	(−3.34)	(−4.99)	(60.0)
Other pork	0.000	**−0.063**	**−0.060**	**−0.087**	**−0.730**	**−0.128**	0.007	**0.112**	**−0.076**	**−0.124**	**1.148**
	(−0.01)	(−2.84)	(−3.08)	(−5.14)	(−28.1)	(−7.52)	(0.34)	(5.19)	(−3.13)	(−4.48)	(92.3)
Chicken parts	**0.203**	**−0.123**	0.001	0.040	**−0.237**	**−0.548**	**−0.264**	0.029	**−0.186**	**−0.158**	**1.244**
	(5.44)	(−3.51)	(−0.02)	(1.42)	(−7.84)	(−12.9)	(−7.71)	(0.74)	(−4.93)	(−3.36)	(59.1)
Other poultry	−0.026	**−0.135**	**−0.096**	**−0.077**	**0.031**	**−0.078**	**−0.589**	**0.108**	**−0.092**	**0.051**	**0.902**
	(−1.71)	(−9.33)	(−7.59)	(−6.61)	(2.14)	(−6.07)	(−22.8)	(6.27)	(−4.53)	(2.39)	(83.4)
Lunch meats	**0.064**	−0.002	−0.023	0.033	**0.147**	0.040	**0.179**	**−0.857**	**−0.158**	**−0.285**	**0.861**
	(2.15)	(−0.06)	(−0.93)	(1.39)	(6.54)	(1.72)	(6.54)	(−18.6)	(−5.87)	(−7.84)	(59.5)
Seafood	**−0.108**	**0.071**	**−0.034**	−0.011	−0.007	**−0.043**	**−0.067**	**−0.091**	**−0.359**	−0.045	**0.694**
	(−6.31)	(3.75)	(−2.31)	(−0.78)	(−0.40)	(−2.82)	(−3.05)	(−4.99)	(−11.1)	(−1.87)	(61.8)
Other meats	**−0.203**	**−0.076**	**−0.071**	**−0.055**	**−0.044**	−0.033	**0.090**	**−0.184**	−0.046	**−0.073**	**0.695**
	(−8.23)	(−3.23)	(−3.73)	(−3.05)	(−2.16)	(−1.70)	(3.77)	(−7.15)	(−1.87)	(−2.27)	(58.0)
Predicted shares	**0.088**	**0.079**	**0.065**	**0.054**	**0.105**	**0.059**	**0.160**	**0.100**	**0.146**	**0.143**	

Notes: T-ratios are in parentheses. Bold font indicates significant at level of 0.05 or above.

Table A3. Hicksian price elasticities for the latent system

Product	Unit value									
	Beef ground	Beef steak	Other beef	Pork loin	Other pork	Chicken parts	Other poultry	Lunch meats	Seafood	Other meats
Beef ground	**−0.532**	**−0.122**	**0.188**	**0.186**	**0.120**	**0.210**	**0.097**	**0.159**	**−0.077**	**−0.228**
	(−9.93)	(−3.95)	(6.79)	(6.97)	(4.74)	(8.40)	(3.50)	(4.71)	(−2.72)	(−5.76)
Beef steak	**−0.137**	**−0.106**	**0.059**	0.014	0.037	−0.018	**−0.128**	**0.084**	**0.233**	−0.038
	(−3.95)	(−2.35)	(2.11)	(0.54)	(1.25)	(−0.69)	(−4.40)	(2.32)	(6.66)	(−0.89)
Other beef	**0.255**	**0.071**	**−0.419**	**0.066**	0.024	**0.074**	**−0.091**	0.051	0.024	−0.057
	(6.79)	(2.12)	(−10.2)	(2.31)	(0.77)	(2.60)	(−2.94)	(1.34)	(0.73)	(−1.36)
Pork loin	**0.305**	0.020	**0.080**	**−0.562**	−0.049	**0.117**	**−0.085**	**0.147**	**0.073**	−0.047
	(6.97)	(0.54)	(2.31)	(−11.9)	(−1.48)	(3.82)	(−2.45)	(3.39)	(1.98)	(−0.98)
Other pork	**0.101**	0.028	0.015	−0.025	**−0.609**	**−0.060**	**0.191**	**0.227**	**0.092**	0.040
	(4.74)	(1.26)	(0.77)	(−1.48)	(−23.4)	(−3.52)	(8.76)	(10.5)	(3.81)	(1.46)
Chicken parts	**0.313**	−0.024	**0.082**	**0.107**	**−0.106**	**−0.475**	−0.065	**0.154**	−0.004	0.019
	(8.40)	(−0.69)	(2.60)	(3.82)	(−3.52)	(−11.2)	(−1.89)	(3.94)	(−0.11)	(0.41)
Other poultry	**0.054**	**−0.063**	**−0.037**	**−0.029**	**0.125**	−0.024	**−0.444**	**0.199**	**0.040**	**0.179**
	(3.49)	(−4.37)	(−2.92)	(−2.44)	(8.75)	(−1.89)	(−17.3)	(11.6)	(2.00)	(8.46)
Lunch meats	**0.140**	**0.066**	0.033	**0.079**	**0.238**	**0.091**	**0.317**	**−0.770**	−0.032	**−0.162**
	(4.71)	(2.32)	(1.34)	(3.39)	(10.6)	(3.94)	(11.6)	(−16.7)	(−1.18)	(−4.46)
Seafood	**−0.047**	**0.126**	0.011	0.027	**0.066**	−0.002	**0.044**	−0.022	**−0.258**	**0.054**
	(−2.71)	(6.64)	(0.73)	(1.98)	(3.80)	(−0.11)	(2.00)	(−1.18)	(−8.09)	(2.26)
Other meats	**−0.141**	−0.021	−0.026	−0.018	0.029	0.008	**0.201**	**−0.114**	**0.056**	0.026
	(−5.74)	(−0.89)	(−1.36)	(−0.98)	(1.46)	(0.41)	(8.45)	(−4.45)	(2.26)	(0.90)

Notes: T-ratios are in parentheses. Bold font indicates significant at level of 0.05 or above.

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