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A Note on Dealing with Poultry in Demand Analysis

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Two approaches have been taken to the modeling of poultry demand in U.S. meat demand studies. One has been to ignore turkey, and estimate demands for beef, pork, and chicken. The second has been to include turkey by combining it with chicken, and estimating demands for beef, pork, and poultry. The validity of these two approaches is examined using quarterly U.S. time-series data from 1980–96. The results indicate that either approach to the modeling of poultry demand is appropriate.

Key words: commodity aggregation, generalized composite commodity theorem, homotheticity, separability testing

Introduction

Studies on U.S. meat demand comprise a large body of literature. Almost exclusively, these studies have examined demands for beef, pork, sometimes fish, and either chicken or poultry.[1] Most often, explicitly or implicitly, the assumption is made that meats are directly, weakly separable from other goods, and can therefore be examined in isolation. This assumption is maintained in what follows. The concern here is over the treatment of turkey in such demand studies. Often, turkey is ignored and chicken is modeled by itself. While assuming beef, pork, and chicken are separable from nonfoods and from nonmeat foods seems reasonable, their separability from turkey may or may not be problematic.

The alternate approach to U.S. meat demand estimation has been to aggregate chicken and turkey as poultry.[2] Over the last three decades, both chicken and turkey consumption grew an average of 2.5–3% a year. However, growth rates of consumption vary greatly at times. In the 1970s, chicken consumption grew at 2.3% per year, while that for turkey grew at 1.1%. In the 1980s, chicken consumption grew at 2.2% annually,

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[1] The one exception is a study by Nayga and Capps who employ scanner data. They explicitly model turkey breasts, parts, and other turkey.

[2] Of course, poultry also may include other meats, such as duck, but chicken and turkey make up the overwhelming majority of poultry. In "Food Consumption, Prices, and Expenditures" (Putnam and Allshouse, table 6), poultry is the sum of turkey and chicken consumption. In the *Red Meat Yearbook* (Duewer, tables 99, 100, and 101), poultry has exceeded the sum of chicken and turkey an average of 0.03% per year since 1980.

while the corresponding figure for turkey was 6.1%. During the 1990s, chicken has grown at 3.3% a year, and turkey at 1.8%. Since chicken and turkey consumption have increased at different rates, it seems that combining them as poultry would likely lead to biases in estimated elasticities.

In the 1990s, 16 papers modeling U.S. meat demands have been published.[3] Of these 16 studies, 11 have included elasticity estimates for either chicken or poultry for U.S. consumers. Averages of own-price and expenditure elasticities across these studies are -0.52 and 0.55, respectively, which seem plausible. However, the ranges of reported results are quite wide, -1.05 to -0.17, and 0.00 to 1.84 for own-price and expenditure elasticities, respectively. While this variation is due, at least in part, to differences in time period covered by the data, functional form employed for estimation, or use of annual versus quarterly data, some variation may be explained by the treatment of chicken and turkey.

Of course, the reason most researchers have ignored turkey or grouped it with chicken is because it constitutes a relatively small proportion of consumer expenditures on meats. Still, annual retail sales of turkey averaged $2.7 billion over the period 1970–96. By 1996, expenditures on turkey reached $3.3 billion, or 4.6% of total meat expenditure—a small, but certainly not insignificant, portion of U.S. consumers' meat demand. Further complications arise because turkey is a holiday meat. Fourth-quarter turkey consumption is about two pounds per capita higher than in any other quarter, no matter what prices and income are. Regardless of previous treatments of turkey in demand estimation, the legitimacy of ignoring it or grouping it with chicken is an empirical question.

Technically, the first approach to the handling of turkey (ignoring it completely) imposes a set of restrictions on the structure of U.S. consumer preferences. It requires that beef, pork, and chicken be directly, weakly separable from turkey. The second approach to the incorporation of turkey in meat demand (grouping chicken and turkey) requires either that their relative prices be independent of the price index for their group (Lewbel), or that they form a homothetically separable group (Deaton and Muellbauer).[4] The goal of this study is to examine the validity of these assumptions.

The remainder of the article proceeds as follows. A brief presentation of the restrictions required for the validity of both approaches to estimating turkey demand is provided in the next section. Data used to test these restrictions are then discussed, followed by a section detailing results of the tests. The final section summarizes our findings and offers conclusions.

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[3] Because this information may be of interest to readers, the 16 U.S. meat demand studies published in the 1990s are listed in full in the reference section, and are identified here as follows: Alston and Chalfant 1991, 1993; Brester and Schroeder; Brester and Wohlgenant; Capps and Schmitz; Choi and Sosin; Eales; Eales and Unnevehr 1993, 1994; Gao and Shonkwiler; Gao and Spreen; Kesavan et al.; Kinnucan et al.; McGuirk et al.; Mittelhammer, Shi, and Wahl; and Nayga and Capps.

[4] Actually there are two other sets of conditions under which such grouping is legitimate. The first is that the relative price of chicken and turkey be constant, which is not true. The second is that overall utility function be additively separable in the sub-utility functions representing the goods to be grouped and the indirect utility function be of the Gorman generalized polar form (Deaton and Muellbauer; Gorman).

Restrictions Implied by the Treatment of Turkey

As noted above, disregarding turkey in demand estimation requires that beef, pork, and chicken be asymmetrically, weakly separable from turkey.[5] A condition under which this is justified requires that changes in turkey price affect the other meats only through the reallocation of expenditure. This yields restrictions on the off-diagonal elements of the Slutsky matrix. Let i index beef, pork, and chicken, and let k be turkey. Then the ikth element of the Slutsky matrix, s_{ik}, is proportional to the expenditure derivatives of goods i and k, where x is expenditure, and the proportionality coefficient, μ_k, depends on good k but not on good i (Blackorby, Davidson, and Schworm; Moschini, Moro, and Green):

$$s_{ik} = \mu_k \frac{\partial q_i}{\partial x} \frac{\partial q_k}{\partial x}. \tag{1}$$

This means there is only one proportionality coefficient relating compensated price effects between turkey and the other three meats, rather than three independent effects. Thus, this places two restrictions on the system of demands. Following Moschini, Moro, and Green, one can re-express the restrictions given in (1) in elasticity form. Let the indexes for beef, pork, chicken, and turkey be designated b, p, c, and t, respectively. One set of restrictions which is sufficient for the separability of the first three from the fourth is:

$$\frac{\sigma_{bt}}{\sigma_{ct}} = \frac{e_b}{e_c} \quad \text{and} \quad \frac{\sigma_{pt}}{\sigma_{ct}} = \frac{e_p}{e_c}, \tag{2}$$

where the σ's are Allen-Uzawa elasticities of substitution, and the e's are expenditure elasticities. Imposing these restrictions typically will have to be done at a point in the data for most demand systems. However, in the Rotterdam demand system, employed below, the restrictions only depend on unknown coefficients, and so can be imposed globally.

Grouping chicken and turkey as poultry can be justified in several ways. The first is a generalization of the composite commodity theorem developed by Lewbel. Let r_i equal $\ln(p_i/P_I)$, where p_i is the price of a good i in group I, and P_I is the aggregate price index for group I; and let R_I equal $\ln(P_I)$. Lewbel shows that if micro demands for the goods in group I are rational, and r_i and R_I are independent for all i and I, then aggregate demands will obey all of the common demand restrictions. If r_i and R_I are nonstationary, then the generalized composite commodity theorem requires that r_i and R_I not be cointegrated.

Second, use of poultry in a meat demand system can be justified if chicken and turkey form a group which is separable from beef and pork and, within the poultry group, preferences are homothetic. This implies first that there are two, rather than four,

[5] Asymmetrical weak separability allows for the possibility that beef, pork, and chicken are separable from turkey, while turkey is not separable from beef, pork, and chicken. This would mean that turkey could be ignored in estimating demands for beef, pork, and chicken, but beef, pork, and chicken would have to be included in a study of turkey demand. Asymmetrical separability is less restrictive than symmetrical separability (Blackorby, Primont, and Russell).

independent compensated price effects, i.e., between beef/pork and chicken/turkey; and second, that within poultry, expenditure elasticities for chicken and turkey are equal.

The set of restrictions implied by separability of chicken and turkey requires the Allen-Uzawa substitution elasticities between beef and chicken equal that between beef and turkey, and the substitution elasticity between pork and chicken equal that between pork and turkey. Again, these restrictions can be imposed globally in a Rotterdam system. Restrictions implied by homotheticity will still depend on the data in a Rotterdam system, however. As pointed out by Moschini, Moro, and Green, this restriction can be tested at a point such as the sample means, but to impose it globally is very restrictive. Thus, in the application below, homotheticity will be imposed at the sample means of the data. One way of expressing the restrictions for homothetic, asymmetric weak separability is:

$$\sigma_{bc} = \sigma_{bt}, \quad \sigma_{pc} = \sigma_{pt}, \quad \text{and} \quad e_c = e_t. \tag{3}$$

Further, if homothetic, symmetric weak separability (i.e., beef and pork form a separable group, as well as poultry) is to be tested, the restrictions in (3) would have to be augmented with:

$$\frac{\sigma_{bt}}{\sigma_{pt}} = \frac{e_b}{e_p}. \tag{4}$$

Previous research has found difficulties in testing for separability. Using Monte Carlo simulation, Barnett and Choi failed to reject separable structures too often when they were false, i.e., the tests have low power. Moschini, Moro, and Green suggest the use of an adjusted likelihood-ratio test (following Italianer). They found the adjusted test's actual size to be equal to its nominal size, but did not examine the power of their test.

Data

We use U.S. Department of Agriculture (USDA) sources for quarterly data on meat consumption and prices from 1980 through 1996. There has been an ongoing debate about whether consumers' preferences for meats underwent a change in structure during the 1970s. Few would argue with the structural shift that occurred on the supply side for meats, particularly chicken. Most of the chicken products consumers purchase today were unavailable in the 1960s and 1970s. By beginning our sample in 1980, any changes which occurred in the 1970s will have had a chance to work themselves out. Retail prices of beef and pork are derived from the *Red Meat Yearbook* (Duewer, tables 87 and 89), and retail prices of chicken and turkey are taken from the *Poultry Yearbook, 1996* (Madison, tables 111 and 165). One of the advantages of using the quarterly data is that we are able to employ the USDA's composite chicken price (rather than the broiler price), which more accurately reflects the price consumers paid for chicken over this period. Per capita consumption data for beef and pork are taken from the *Red Meat Yearbook* (Duewer, tables 94 and 95), and corresponding data for chicken and turkey are from the *Poultry Yearbook, 1996* (Madison, tables 82 and 147). Retail prices of chicken and turkey are updated through 1996 using Bureau of Labor Statistics average price data.

Table 1. Compensated Price and Expenditure Elasticities from Estimates with Turkey Included as a Separate Good

Demands	Prices				Expenditure	R^2 / DW Mean Share
	Beef	Pork	Chicken	Turkey		
Beef	-0.29*	0.23*	0.03	0.03	1.19*	0.89 / 2.59
	(0.07)	(0.05)	(0.03)	(0.02)	(0.11)	0.50
Pork	0.46*	-0.52*	0.02	0.05	0.94*	0.88 / 2.64
	(0.09)	(0.09)	(0.05)	(0.04)	(0.17)	0.26
Chicken	0.07	0.06	-0.14*	0.01	0.78*	0.80 / 2.43
	(0.08)	(0.06)	(0.07)	(0.04)	(0.14)	0.20
Turkey	0.44	0.13	0.06	-0.63*	0.07	0.98 / 2.63
	(0.32)	(0.25)	(0.21)	(0.27)	(0.53)	0.04

Notes: Estimates are constrained only by homogeneity and symmetry. Numbers in parentheses are standard errors, calculated using the delta method (Greene, p. 278). An asterisk (*) indicates the elasticity is at least twice its standard error.

Results

First, the absolute price version of the Rotterdam model with intercepts and seasonal dummy variables was estimated with only homogeneity and symmetry imposed for all four meat commodities: beef, pork, chicken, and turkey. The Rotterdam model is specified as:

$$\bar{w}_{it} d\ln(q_{it}) = \alpha_0 + \sum_{j=1}^{3} \alpha_j d_j + \beta_i d\ln(Q_t) + \sum_j \gamma_{ij} d\ln(p_{jt}), \tag{5}$$

where

d_j = 1 if the current quarter is j, and 0 otherwise;
$d\ln(q_{it})$ = $\ln(q_{it}) - \ln(q_{it-1})$;
w_{it} = $p_{it} q_{it} / M$;
M = $\sum_j p_{jt} q_{jt}$;
$\bar{w}_{it}$ = $0.5(w_{it} + w_{it-1})$; and
$d\ln(Q_t)$ = $\sum_j \bar{w}_{jt} d\ln(q_{jt})$.

As the system satisfies adding up, the turkey equation was dropped for estimation by iterative seemingly unrelated regression (SUR) using the SHAZAM program (White). Compensated price and expenditure elasticities are given in table 1. Nine of 20 elasticities are significant.[6] Beef responds significantly to compensated changes in pork prices, and pork responds significantly to compensated changes in the price of beef. Beef is elastic with respect to expenditures on meats, while pork and chicken respond significantly to changes in meat expenditures. All the equations fit well, but show signs of negative autocorrelation.[7]

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[6] When results are referred to as significant, a .05 level is assumed unless otherwise stated.

[7] The Durbin-Watson (DW) statistics for each equation are about 2.5. Of course, DW statistics have unknown sampling distributions in a system of equations like this one. If these were single equations, each of these DW statistics would fall in the inconclusive region in testing for negative autocorrelation.

Next, restrictions given in (2) which would justify ignoring turkey in this demand system are tested using the adjusted likelihood-ratio test (Italianer). This is done by imposing (2) in addition to homogeneity and symmetry on (5), and estimating the restricted Rotterdam model using the iterative nonlinear SUR estimator in SHAZAM. The log of the likelihood for the model restricted only by homogeneity and symmetry is 838.26, while the log likelihood of the model further restricted by separability is 836.79. The unadjusted likelihood-ratio statistic is 2.93, which is asymptotically chi-squared with two degrees of freedom. These data indicate little is lost by excluding turkey.

The alternative practice for estimating demand is to combine turkey with chicken as poultry. The first way to justify this is by the generalized composite commodity theorem (GCCT) (Lewbel). Poultry is a legitimate composite good if the logarithms of relative prices of chicken to poultry, and turkey to poultry are independent of the logarithm of poultry price. Since prices often are found to be nonstationary, Lewbel suggests testing for unit roots in r_i and R_I first and, if they are found, then the requirement of the GCCT is that neither of the relative prices be cointegrated with the poultry price (either nominal or real). To conduct such tests requires a poultry price. This is derived by combining the chicken and turkey prices using the discrete-Divisia (Tornquist) index. The real poultry price is found by deflating the derived poultry price by the consumer price index for all items. All prices are then normalized to one in 1980/Q1.

Given the use of quarterly data, all four logged series were tested for seasonal unit roots using the testing procedure developed by Hylleberg et al. Their procedure allows one to test for unit roots quarterly, biannually, and annually. It consists of regressing the fourth difference of the series to be tested on four different filtered versions of the original series. That is, if x_t is to be tested for unit roots at seasonal as well as at zero frequencies, the following regression is run:

$$\begin{aligned}(6)\qquad \Delta_4 x_t &= \pi_1(1+L+L^2+L^3)x_t + \pi_2(1-L+L^2-L^3)x_t \\ &\quad + \pi_3 L^2(1-L^2)x_t + \pi_4 L(1-L^2)x_t + \mu_t + u_t,\end{aligned}$$

where $\Delta_4 x_t = x_t - x_{t-4}$; L is the lag operator; π's are coefficients to be estimated; μ_t can contain an intercept, quarterly dummy variables, and a trend (to represent non-stochastic seasonality and trends); and u_t is an error term. If π_1 is zero, x contains a unit root at zero frequency. If π_2 is zero, x contains a unit root at the biannual frequency. If $\pi_3 = \pi_4 = 0$, x contains a unit root at the annual frequency. The regression (6) may be augmented with lagged dependent variables, if necessary, to produce well-behaved residuals. As is typical with nonstationary data, the t- and F-statistics for these tests do not have t or F distributions. Cutoffs suitable to the present circumstances are given in Hylleberg et al. Tests are conducted including a constant, quarterly dummy variables, and a time trend in (6) for each of the four series. Results are given in the upper portion of table 2.

The first two numeric columns contain t-statistics for testing quarterly and biannual frequencies for unit roots. The third column contains F-statistics for testing for integration at annual frequencies. The last column gives the Box-Pierce-Ljung Q-statistic for white noise residuals in (6). All four series appear to be nonstationary at quarterly, but

Table 2. Results of Unit Root and Cointegration Tests (prices in logs)

Tests	Frequencies[a]			Q (12)[b]
	Quarterly	Biannual	Annual	
Unit Root:[c]				
Chicken	-2.39	-4.69	31.62	8.68
Turkey	-2.09	-4.58	29.93	6.50
Poultry	-2.65	-6.06	19.26	15.32
Real Poultry	-3.05	-6.28	20.04	14.91
Cointegrated-Nominal Poultry Price:[c]				
Chicken	-3.29	NA	NA	7.10
Turkey	-2.54	NA	NA	2.92
Cointegrated-Real Poultry Price:[c]				
Chicken	-2.57	NA	NA	10.15
Turkey	-2.49	NA	NA	8.97

Note: NA denotes not applicable.
[a] Quarterly and biannual frequencies are t-statistics; annual frequencies are F-statistics.
[b] Q is the Box-Pierce-Ljung Q-statistic for white noise residuals in (6). The 5% cutoff from a χ^2 with 12 degrees of freedom is 21.03.
[c] The 5% cutoffs for the unit root and cointegration tests are -3.71, -3.08, and 6.55 for quarterly, biannual, and annual frequencies, respectively (Hylleberg et al.).

not at biannual or annual frequencies.[8] There appears to be no seasonal integration to confound testing for cointegration. Therefore, testing for cointegration of relative prices with the nominal and real group price index may proceed as suggested by Engle and Granger, again using the approach of Hylleberg et al. Cointegration results are reported in the lower portion of table 2.

Each log relative price, i.e., r_i, is regressed on the log of the group price index, R_I, and a constant. Residuals from these regressions are then tested for the presence of roots at quarterly, biannual, and annual frequencies. Since the series themselves had no unit roots at the biannual or the annual frequencies, they cannot be cointegrated at these frequencies. Because of the presence of unit roots at the quarterly frequencies in both r_i and R_I, it is possible that they could be cointegrated at this frequency. In each case, cointegration is rejected. Thus, the GCCT supports the grouping of chicken and turkey as poultry in a demand system for meats.

The final justification for poultry as a group is that chicken and turkey are at least asymmetrically separable from beef and pork, with the restriction that the preferences within the poultry group be homothetic. This is tested in a manner similar to the approach employed to test the separability of turkey. The restrictions given in (3) are imposed at the sample mean shares. If symmetric separability is to be tested, the restriction in (4) must be imposed in addition to those in (3). The likelihood-ratio statistic for homothetic, asymmetric separability is 1.83 (1.60 adjusted by the finite sample correction of Italianer). The 5% cutoff for a chi-squared random variable with three degrees of freedom is 7.81.

[8] No additional lagged dependent variables were necessary to produce well-behaved residuals. This is supported by the Box-Pierce-Ljung Q-statistics in table 2. Also, no additional lags were indicated by the Akaike Information or the Schwarz criteria.

Table 3. Compensated Price and Expenditure Elasticities from Estimates Using Only Chicken or Poultry

Demands	Prices			Expenditure	R^2 / DW
	Beef	Pork	Chicken		Mean Share
With Chicken:					
Beef	-0.27*	0.24*	0.03	1.16*	0.90 / 2.56
	(0.06)	(0.05)	(0.03)	(0.09)	0.52
Pork	0.47*	-0.52*	0.05	0.90*	0.89 / 2.66
	(0.09)	(0.09)	(0.05)	(0.16)	0.27
Chicken	0.07	0.06	-0.13*	0.72*	0.80 / 2.42
	(0.08)	(0.06)	(0.07)	(0.13)	0.21
With Poultry:					
Beef	-0.28*	0.24*	0.04	1.21*	0.89 / 2.57
	(0.07)	(0.05)	(0.04)	(0.11)	0.50
Pork	0.47*	-0.52*	0.05	0.95*	0.88 / 2.65
	(0.09)	(0.09)	(0.06)	(0.17)	0.26
Poultry	0.09	0.06	-0.15	0.61*	0.90 / 2.39
	(0.08)	(0.06)	(0.08)	(0.15)	0.24

Notes: Estimates are constrained only by homogeneity and symmetry. Numbers in parentheses are standard errors, calculated using the delta method (Greene, p. 278). An asterisk (*) indicates the elasticity is at least twice its standard error.

Finally, table 3 reports compensated own-price and expenditure elasticities from systems consisting of beef, pork, and either chicken or poultry. In neither case do the estimated elasticities vary more than a few percent from their counterparts in table 1.

Summary and Conclusions

It has been standard practice to either disregard turkey or to group it with chicken when modeling U.S. meat demand. The validity of each of these approaches was examined using quarterly U.S. time-series data. Ignoring turkey altogether requires that beef, pork, and chicken be at least asymmetrically weakly separable from turkey. This hypothesis was tested using a Rotterdam model, as suggested by Moschini, Moro, and Green. It received strong support.

The second strategy employed in meat demand studies has been to group chicken and turkey together and call them poultry. This requires that poultry is either a generalized composite commodity (Lewbel), or that chicken and turkey form a separable poultry group and that preferences for poultry be homothetic (Deaton and Muellbauer).

The generalized composite commodity theorem allows variation in the relative prices of goods to be grouped, as long as the variation is independent of the group's price index. This is tested by first examining the logs of goods prices relative to the group's price index and the log of the real and nominal group price index, i.e., r_i and R_I, respectively. If these are found to be nonstationary, then r_i and R_I are examined for cointegration for each i in group I. If none of the r_i are found to be cointegrated with R_I, this supports grouping the goods. In the current application, support is found for poultry as a generalized composite commodity.

The final justification for poultry is that chicken and turkey be homothetically separable from beef and pork. This was tested using a Rotterdam system and quarterly U.S. data. The restrictions implied by this hypothesis cause an insignificant decrease in the log-likelihood function.

Taken together, the evidence strongly supports standard meat demand analysis using quarterly data from the 1980s and 1990s. While our separability test results are conditioned on the maintained hypothesis of the Rotterdam functional form, the generalized composite commodity approach makes no functional form assumptions. Results from the various approaches employed above suggest that turkey either may be ignored or grouped with chicken. Compensated own-price and expenditure elasticities obtained using either procedure are essentially the same as those given in table 1. It is nice to see standard practice justified.

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