Staff Paper

ENDOGENEITY TESTING
IN
TURKEY MEAT DEMAND

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Abstract: The Wu-Hausman endogeneity test is used to examine demand specifications for turkey meat. In contrast to general poultry, quantity, not price, is found to be predetermined in demand models that use annual turkey data. Seasonal consumption and the long production cycle for turkeys, relative to broilers, may account for this result.

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Endogeneity Testing inTurkey Meat Demand

Introduction

While many researchers have focused on issues of demand estimation and industry structure in the livestock and poultry sectors, few have addressed these concerns specifically for the U.S. turkey industry. Previous poultry studies have generally concentrated solely on broiler chickens (Knoeber and Thurman, 1995; Moschini and Meilke, 1989) or have analyzed an aggregate poultry commodity (Thurman 1986, 1987). However, the dissimilar production and consumption patterns of turkeys and broiler chickens, the primary poultry commodities, suggest that studies addressing demand and industry structure issues would benefit by individually examining each industry. In this paper, the specification of the demand equation for turkey meat is analyzed. Specifically, the issue of treating either price or quantity as a predetermined variable in the demand equation is investigated.

The U.S. Turkey Industry

Although the organizational structure of the turkey industry parallels that of the broiler chicken industry, still there is reason to examine the turkey industry as one distinct from the broiler industry. Production and consumption patterns strongly differ between the two commodities. Whereas more than 90 percent of broiler chickens are produced via production contracts, the number of integrators contracting with farmers to grow turkeys is closer to 60 percent of total production (Knutson, Penn and Boehm 1995). Company-owned farms, marketing cooperatives, or independent farmers account for the rest of turkey production. Also in contrast to broilers, which have a short 5-6 week production cycle, the production cycle for turkey poults is approximately 5 months from the time of hatching to slaughter. Most of the turkeys marketed reach an acceptable market age and weight between 4-7 months. Finally, turkey production itself is highly seasonal. In 1960, more than 50 percent of all turkey consumption took place during the last three months of the year. In 1990, 35 percent of yearly turkey consumption still occurred during the last quarter with November, not surprisingly, as the highest consumption month (Perez, Weimar and Cromer 1991).

Consumption and marketing standards have also been changing in the turkey industry. Especially notable is the increase in per capita consumption and the decrease in real turkey prices (Figures 1 and 2). Since 1960, the real price of turkey has declined by almost 150 percent while per capita consumption has nearly tripled. This relationship is not unique to the turkey industry, broiler chicken consumption has followed a similar trend, but it is unusual relative to pork and beef consumption. Contributing to the changes in the turkey industry are the new processing and marketing practices that have increased the accessibility and convenience of turkey meat for consumers. Ground and formed turkey products, such as turkey bologna, turkey ham and turkey hot dogs, have become standard items in deli and meat counters. All of these factors increase the value of studies specific to the turkey industry and raise the issue of how to specify the demand equation.

Demand Specification

Demand equations may be specified in one of three ways. The textbook treatment is a system of simultaneous equations that treat both price and quantity as endogenous variables in a supply and demand framework. Alternatively, based on consumer preferences and the structure of the particular industry, there are cases when either price or quantity is argued to be predetermined in demand. For instance, given a price supported commodity, price may be treated as the exogenous and quantity as the endogenous one provided that the support price is binding during the period investigated. A more popular way to interpret the argument for predetermined price is the concept of fixed short-run retail prices. Again, for data evaluated within a particular time, price adjustments do not occur, rather, quantity adjusts to clear the market. Finally, price may be predetermined in annual data in a competitive industry that faces constant returns to scale and elastic factor supplies. In this case, price is determined by input costs and demand determines quantity. Thurman (1987) argues that this is indeed the case for annual poultry data for the period between 1955 and 1981.[1]

Arguments for predetermined quantity also are found in the literature. The most popular one suggests that supply is perfectly inelastic due to the perishability of nonstorable commodities. Here, production decisions made well in advance of harvest cannot be altered at the time of market. Consequently, quantity is fixed and price adjusts to clear the market.

It is not clear, a priori, if either consumer preferences or the structure of the turkey industry would cause price or quantity, if either, to be predetermined in a demand equation. Thurman's research suggests that price is predetermined in annual poultry data. However, given the production and consumption differences between broilers and turkeys, it is not necessarily

[1]An anonymous referee intuitively noted that free trade may be an additional argument for exogenous price. In this case, the world price is viewed as predetermined and quantity adjusts to absorb demand disturbances.

clear that this would hold for turkeys as well. The question of whether price or quantity, or neither, can be treated as predetermined in a demand equation is examined by using the Wu-Hausman test.

The Wu-Hausman Endogeneity Test

The Wu-Hausman test for endogeneity was developed by Wu in his 1973 paper, Hausman in a later 1978 article, and applied to the poultry industry by Thurman in his 1986 and 1987 studies. The logic behind the Wu-Hausman test is this. Under the null hypothesis of no misspecification, both an OLS estimator, $\hat{b}$, and an instrumental variables estimator, b^*, will be unbiased and consistent estimators of the right-hand side variable (either predetermined price or quantity). However, under the alternative hypothesis of misspecification, the OLS estimator is no longer unbiased and consistent. If the null hypothesis is true, the difference between the two estimates, $q = \hat{b} - b^*$, will have a probability limit of zero. If misspecification is present, then the probability limit of q will differ from zero. Based on this relationship, the Wu-Hausman test for endogeneity uses the following test statistic:

$$W = (\hat{b} - b^*)\,[\hat{V}(q)]^{-1}\,(\hat{b} - b^*).$$

Here, $[\hat{V}(q)]$ is a consistent estimator of V(q). Under the null hypothesis of no misspecification, W is distributed asymptotically chi-square. As pointed out by Hausman, construction of this test statistic is simplified by noting that under the null hypothesis of no misspecification, asymptotically $\hat{V}(q) = V(b^*) - V(\hat{b})$. In the case of either predetermined price or predetermined quantity, q is a scalar.

Endogeneity Tests for U.S. Turkey Meat

The Wu-Hausman endogeneity test is applied to both a quantity dependent and a price dependent model of turkey demand. In the quantity-dependent model, price is considered predetermined and the OLS model is given by:

$$Q_t^T = \beta P_t^T + X_t^{\prime} \alpha + \epsilon_t , \qquad \textbf{(1)}$$

where Q_t^T is the log of annual per capita turkey consumption, P_t^T is the log of real retail turkey price and X'_t is a vector of logged exogenous variables representing the real prices of chicken, pork, beef and per capita disposable real income, (P_t^{CK}, P_t^{PK}, P_t^{BF}, DI_t). Similarly, the price-dependent version of the demand model is described as:

$$P_t^T = \delta Q_t^T + X_t^{\prime} \gamma + \nu_t . \qquad \textbf{(2)}$$

Two-stage least squares (2SLS) is the instrumental variables technique chosen to estimate the unbiased and consistent estimator, b*. The instruments used are X'_t and a vector of supply shifter variables, M'_t, where, $M'_t = (P_t^{CN}, P_t^{BM}, P_t^{IG}, P_t^{EN}, P_t^{L}, FD_t, NC_t)$. Here, the instruments are the logged real prices of corn and soybean meal; price indices for industrial goods, energy, and labor; the quantity of feed consumed by a 20-week-old tom turkey and the proportion of U.S. turkey production from North Carolina. NC_t is included as a proxy for technology because the increase in the proportion of U.S. turkeys produced in North Carolina parallels changes in turkey growing technology. The time period analyzed is between 1960-1990. Descriptions and sources for all variables used in this study are provided in the appendix.

The Wu-Hausman test statistic is calculated for both the model of predetermined price and the model of predetermined quantity. The null hypothesis of predetermined price was strongly rejected, but the hypothesis of predetermined quantity could not be rejected. However, first order autocorrelation was present in the OLS model when quantity was on the left-hand side (coefficient for the residuals in the OLS model was 0.25). The autocorrelation in this model makes the asymptotic arguments for the Wu-Hausman test statistic void.

Thurman (1987) discovered similar serial correlation problems in his annual poultry data and presents a discussion as to why residuals in annual consumer demand equations may be serially correlated. He concluded that the relationship between poultry and pork changed from one of substitutes to independent goods in the early 1970's. Contemporaneously, the demand for poultry meat increased. The possibility of a structural change in turkey demand was investigated using time period dummies and time-price interactions. Similar to poultry, the data support a change in the relationship between turkey and pork. In addition, the data suggest a shift in the demand for turkey meat in the mid 1980's. Including a pork price slope shift in the mid-1970's and an intercept shift in 1985 reduces the serial correlation. Two plausible reasons for the structural change are the introduction of more conveniently packaged turkey products in the mid 1980's and the movement toward white meat in the mid-1970's.[2]

Equations (1) and (2) again were estimated by OLS and 2SLS with the addition of a pork price-dummy interaction term and an intercept shifter; the first variable (PK75) is the product of a dummy variable, assigned a value of zero before 1975 and one after, and the log of retail pork price; the second is a dummy variable set equal to zero prior to 1985 and one in the following years. Results from both the OLS and 2SLS estimation for the two models are presented in Table 1, with the Wu-Hausman test statistic and its associated p-value shown in the final row.

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[2]See Moschini and Meilke (1989) and Thurman (1987) for further empirical evidence of structural change in the poultry industry during the 1970's.

The first column of table 1 provides the results for the price-dependent demand model while the second column shows the standard errors of the estimates. Columns (C) and (D) report analogous results for the quantity-dependent version. The small p-value in column © suggests that there is very little agreement between the null hypothesis of predetermined price and the data. Alternatively, the results reported in column (A) strongly support predetermined quantity. Consequently, there is a strong argument for treating quantity exchanged as predetermined when annual data are used to estimate turkey demand.

Conclusions

Why would annual poultry data suggest a structure where price is predetermined, but quantity is not, and annual turkey data suggest the opposite? Recall that predetermined quantity implies a vertical supply curve. Two factors may account for this situation in the turkey industry. First, given the relatively longer production cycle, a producer's ability to react to price change (whether an independent producer or an integrator) is limited. Knoeber and Thurman suggest that in the broiler chicken industry, integrators increase production by increasing flock sizes when broiler prices rise. However, production decisions regarding turkeys are made at least five months prior to harvest, thereby decreasing a producer's ability to react to price change.

Second, turkey consumption is highly seasonal. The majority of consumption occurs during the holiday season in the last three months of the year. Lasley, Henson, and Jones, Jr. propose that turkey consumption appears to be more responsive to price changes in the first three quarters of the year and less responsive in the last. Moreover, turkey meat is generally consumed within two months of processing. Annual data that use a weighted average for determining price and quantity will place heavier weights on the holiday months. During these months, price adjusts to clear the market of turkeys that were produced either earlier in the year and frozen or, more likely, produced primarily for the holiday market. Both of these situations provide reasonable explanations for finding quantity, not price, predetermined in annual turkey data. Consequently, studies involving the turkey demand may find it more convenient to treat quantity as a predetermined variable in the model rather than using a simultaneous equation method. In either case, one should be extremely cautious in assuming that what holds for poultry demand models would apply to turkey demand.

Table 1:
Estimates of Quantity and Price-Dependent Demand Equations and the Wu-Hausman Test

	Dependent Variable			
	P^T		Q^T	
	(A)	(B)	(C)	(D)
OLS Coefficient:				
P^T	--	--	-1.001	(0.157)
Q^T	-0.644	(-0.100)	--	--
P^{CK}	0.267	(0.126)	0.104	(0.171)
P^{PK}	0.180	(0.105)	0.168	(0.136)
P^{BF}	0.217	(0.118)	0.216	(0.151)
DI	0.040	(0.126)	0.213	(0.151)
$PK75$	-0.012	(0.004)	-0.015	(0.006)
$D85$	0.127	(0.041)	0.213	(0.042)
$\hat{\rho}$	-0.109		-0.025	
2SLS Coefficient:				
P^T	--	--	-1.404	(0.231)
Q^T	-0.631	(0.108)	--	
P^{CK}	0.273	(0.128)	0.331	(0.211)
P^{PK}	0.180	(0.101)	0.249	(0.157)
P^{BF}	0.217	(0.118)	0.304	(0.174)
DI	0.033	(0.127)	0.102	(0.176)
$PK75$	-0.012	(0.004)	-0.018	(0.007)
$D85$	0.124	(0.042)	0.202	(0.047)
$\hat{\rho}$	-0.104		-0.126	
Wu-Hausman test statistic	0.082		5.625	
p-value	0.774		0.018	

Figure 1. Per Capita Turkey Consumption

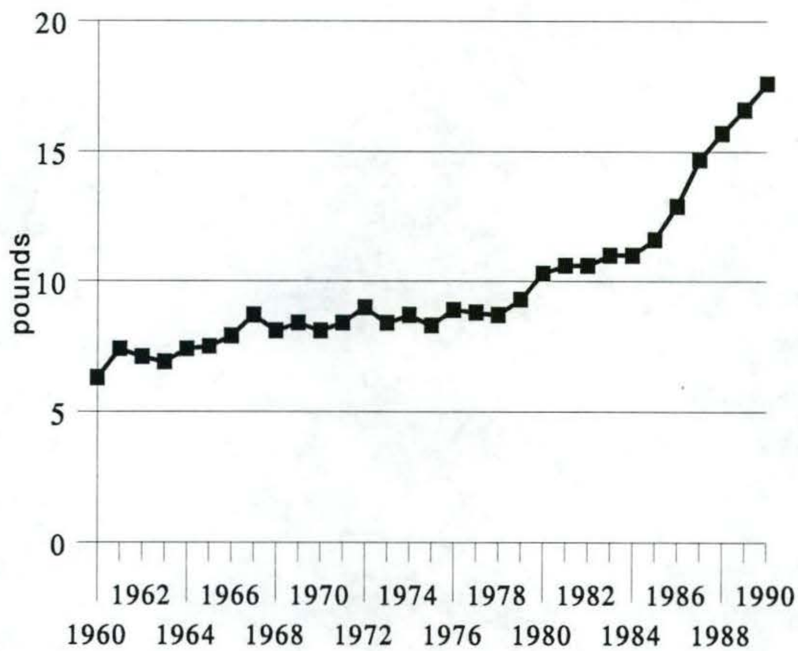
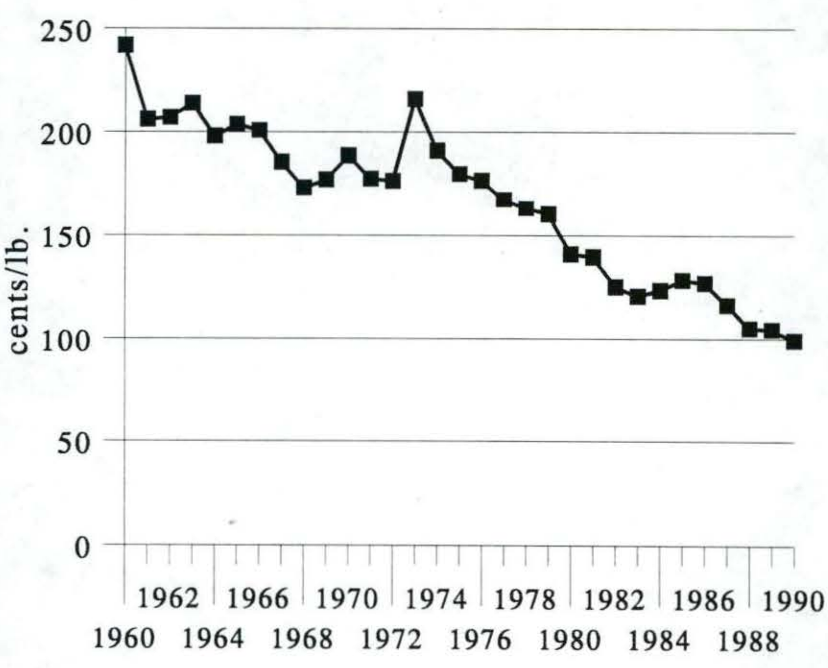


Figure 2. Real Retail Turkey Price (Base = 1990)



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Appendix

All variables are in natural logarithm form. Prices are deflated by the consumer price index, base year = 1990.

P^T = average retail turkey price, cents per pound;
Source: Poultry Yearbook, 1994, ERS #916.

Q^T = per capita turkey consumption in pounds;
Source: U.S. Egg and Poultry Statistical Series, 1960-1992, ERS #872.

P^{CK} = average retail whole fryer price, cents per pound;
Source: Poultry Yearbook, 1994, ERS #916.

P^{PK} = retail pork price per pound, cents per pound;
Sources: Livestock and Meat Statistics, 1972, ERS #522; Red Meat Yearbook, 1994, ERS #855.

P^{BF} = retail choice beef price per pound, cents per pound;
Sources: Livestock and Meat Statistics, 1972, ERS, #522; Red Meat Yearbook, 1994, ERS #855.

DI = real per capita personal disposable income;
Source: Economic Report of the President, 1995.

P^{CN} = cash corn price - #2, Chicago, dollars/bu.;
Source: Feed Situation and Outlook, various issues.

P^{BM} = price of soybean meal, 44%, Decatur, dollars/ton;
Source: Feed Situation and Outlook, various issues.

P^{IG}, P^L = industrial goods price index, manufacturing wage index, base year = 1990;
source: IFS

P^{EN} = producer price index for fuel;
Source: Producer Price Indexes by Stage of Processing, Economic Report of the President.

FD = feed consumed by a 20-week-old tom turkey;
Source: *Turkey World*, various January issues.

NC = proportion of U.S. turkey production from NC;
Source: North Carolina Department of Agriculture, Agricultural Statistics Div.