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Introduction

The traditional approach to demand estimation has been to apply consumer theory, which specifies the behavior of individuals, to aggregate data. This is done using a variety of aggregation stories, such as the "representative consumer." Other, more sophisticated, aggregation stories have been developed (Muellbauer, Barnett). One of the key assumptions in such approaches is that it is reasonable to model consumers as either price- or quantity-takers.

One of the areas that has interested researchers in the field of meat demand has been whether or not consumer's tastes and preferences for meats have undergone a structural change. There has been some evidence for and against the hypothesis. With few exceptions studies which have investigated structural change have employed some form of the traditional approach to demand estimation. Three exceptions are of interest. Wahl and Hayes found significant evidence of simultaneity in a system of Japanese meat demands and correction led to large changes in demand elasticities. However, structural change was not an issue. Chalfant and Alston use a form of revealed preference to determine if there exists a utility function which would rationalize the quantity and price data for meats. They found that for aggregate annual data in both the United States and Australia they could not reject the existence of such a function. In a study of the poultry market, Thurman searched for parameter variation in demand and tested for misspecification. He found a significant shift in poultry demand in 1973 and that price could be considered predetermined. The seeming incongruity between these results in these last two studies is somewhat representative of the findings on structural change, in general. Differences in maintained hypotheses have led researchers to different conclusions.

In this study a methodology similar to that of Thurman is employed, but with a slightly different focus. Here the concern is in whether the underlying cause of the frequently found shifts in demand may be due in part or entirely to supply shocks. Toward this goal we start with a pedagogical simulation to demonstrate the potential problem. The fed beef market is then modeled and examined for insights into the impacts of simultaneity on demand estimation.

Simulation of the Impacts of Supply Shocks on Demand Estimates

The objective of this simulation is to illustrate that ordinary least squares (OLS) estimation may lead to apparent structural change in demand when that change has taken place in supply. The following assumptions are employed: (1) quantity and price are determined simultaneously; (2) the only structural change which takes place is a shift in supply; (3) quantities demanded and supplied are equal; and (4) in addition to own price, supply and demand are each a function of two exogenous variables, which are generated with time paths similar to those affecting the fed beef market. Given these assumptions, the demand equation is estimated using OLS and 2SLS.

The structural model for simultaneous system of supply and demand is:

$$Q_S - 2P = 1 + 2D - .8X_1 + .4X_2 + e_S \quad \text{(Supply)}$$
$$Q_D + P = 1 + .5Z_1 + .2Z_2 + e_D \quad \text{(Demand)}$$
$$Q = Q_S = Q_D$$

where Q is the quantity demanded, hence supplied, P is price of Q, Xs are exogenous variables which affect supply, Zs are exogenous variables which affect demand, and D is dummy variable which is 0 before and 1 after the structural break.

To generate Q and P, the exogenous variables are generated such that they follow time paths which are similar to those of important exogenous determinants of supply and demand.[1] The dummy is 0 from observation 1 through 15 and 1 thereafter. The number of sample observations is 30. Using this framework, five alternatives models are generated by assuming different forms for the structural error covariance matrix. The five alternatives are as follows: (1) supply is more variable than demand; (2) demand is more variable than supply; and (3) three cases in which neither supply or demand is more variable, but covariances differ.[2] For each simulation, exogenous variables are generated as described above. The reduced form of the supply/demand model is used to generate Q and P. This is repeated 1000 times and demand is estimated by OLS and 2SLS. The average coefficients and standard errors of the simulation sample are reported in Table 1.

In the model A supply is more variable than demand. The coefficients of 2SLS are reasonable, signs and magnitudes correspond to their true values. Although the signs of coefficients in OLS model are same as those of true model, the price coefficient is biased toward zero. Neither model indicates significant evidence of structural change. (The p-value of the OLS coefficient is 0.11.) However, results of the other models are less benign. In models B through E, a significant upward shift in demand is found (in model B and C the shift is significant at the 0.10 level. The respective p-values: B 0.04; C 0.05; D 0.02; E 0.001) In none of these models would signs or magnitudes of the estimated coefficients give an indication of the misspecification.

Of course, these simulations are too limited in scope to offer definitive evidence. They are suggestive, however. In four of five cases OLS results imply significant change in the structure of demand, when none existed. None of the five cases produced estimates which disagree with expectations, making the detection of the simultaneous equation bias less likely. In all cases 2SLS gives correct inferences as to the existence of structural change in demand, when the true culprit is a supply shock. The most risky situation appears to be when neither supply nor demand is more variable and there is non-positive correlation between the errors. Since such a situation is difficult to rule out a priori, these results imply that supply should be considered in the study of demand when structural change is possible and price and quantity are determined simultaneously.

Specification of Fed Beef Demand

Potential simultaneity in the fed beef market requires the consideration of a structural model so that instruments to be used in demand estimation may be specified. The model posed for this purpose is based, loosely, on a quarterly model employed by Ziemer and White to study disequilibrium in the market, but a number of modifications are incorporated. First, the majority of previous demand studies have employed annual data. To make the results of this study useful in evaluating past work in the demand area, annual data will be employed as well. Second, demand for

TABLE 1. SIMULATION RESULTS.

		PRICE	Z1	Z2	D	CONST
MODEL A	OLS	-0.550	0.514	0.133	0.328	-0.194
(supply more		(0.323)	(0.264)	(0.345)	(0.257)	(2.730)
vari-	2SLS	-0.991	0.489	0.174	0.003	1.095
able)		(0.570)	(0.286)	(0.372)	(0.432)	(3.238)
MODEL B	OLS	-0.324	0.444	0.232	0.395	-0.083
(demand more		(0.269)	(0.375)	(0.276)	(0.218)	(3.541)
vari-	2SLS	-0.979	0.515	0.209	0.006	0.815
able)		(0.396)	(0.450)	(0.328)	(0.301)	(4.214)
MODEL C	OLS	-0.360	0.211	0.113	0.385	2.047
(neither more		(0.345)	(0.311)	(0.194)	(0.228)	(2.452)
vari-	2SLS	-0.999	0.496	0.210	-0.001	1.023
able)		(0.533)	(0.392)	(0.223)	(0.342)	(2.818)
MODEL D	OLS	-0.392	0.418	0.030	0.437	0.325
(no covar-		(0.222)	(0.179)	(0.180)	(0.191)	(1.678)
iance)	2SLS	-0.993	0.496	0.188	0.003	1.024
		(0.355)	(0.222)	(0.228)	(0.287)	(2.076)
MODEL E	OLS	-0.128	0.350	-0.036	0.423	0.415
(negative covar-		(0.186)	(0.130)	(0.134)	(0.118)	(1.116)
iance)	2SLS	-1.017	0.514	0.209	-0.012	0.906
		(0.465)	(0.233)	(0.240)	(0.261)	(1.898)

* Numbers in parenthesis are standard errors.

meat is usually evaluated at the retail level, whereas Ziemer and White model demand at the farm or feedlot level. Thus, a margin relationship is included to bridge the gap from the farm supply to the retail demand. Third, since evidence from Ziemer and White and the ensuing debate produced no clear cut evidence to the contrary, only the market under equilibrium conditions is considered.

Thus, for annual fed beef market data, a simplified structural model consists of three equations and a market-clearing identity. The equations include the demand and supply of fed beef, and farm-retail margin which is used to tie the farm and retail markets together. This structure suggests the following set of instruments to be used in 2SLS estimation of demand: from demand itself, price of pork, price of poultry, and personal disposable income; from supply, farm level price of steers, prices of feeder cattle and corn, interest rate, and energy cost; and from the marketing sector, hourly wages in the meat packing industry.

Data

Some recent evidence suggests that aggregation of meats by animal type may be inappropriate (Eales and Unnevehr). In keeping with these findings the demand for fed beef is analyzed. Annual data from 1956 to 1987 are used in the estimation. Since there are no official data for per capita fed beef and ground beef (nonfed beef) consumption, these data are generated by the procedure suggested by Wohlgenant (1986) and others. Per capita fed beef consumption is calculated as a proportion of per capita total beef consumption on a caracas weight basis and then these ratios are applied to the USDA's estimates of per capita total beef and veal consumption on a retail weight equivalence. Per capita nonfed beef consumption is calculated as the difference between total beef and veal consumption and fed beef consumption. Per capita consumption of pork and poultry are obtained from various issues of Food Consumption, Prices, and Expenditures (USDA).

Retail price of fed beef is computed under the assumption that total expenditure on beef is equal to the sum of expenditures on fed beef and nonfed beef.[3] Nominal retail price of beef and veal, pork and poultry are deflated using consumer price index of all commodities obtained from various issues of Food Consumption, Prices, and Expenditure (USDA).

Personal disposable income, yield on three-month treasury bills, energy cost, and population are obtained from various issues of Economic Report of the President (U.S. Government Printing Office). The prices of steers and feeders are obtained from various issues of Livestock and Meat Situation (USDA) and Livestock and Poultry Situation (USDA). Average hourly earnings of workers in the meat packing industry, in dollars, are obtained from Employment, Hours, and Earnings (Bureau of Labor Statistics).

Results

As in Thurman's study of the poultry market, demand is assumed to have a simple log-log form. This allows demand to be specified as either quantity or price dependent, which facilitates testing for predeterminedness of these variables. More theoretically appealing demand systems such as the Almost Ideal Demand System of Deaton and Muellbauer would greatly complicate reversing the roles of quantity and price in estimation.

Alternative specifications considered are both price- and quantity-dependent demands. Since both static and dynamic specifications have been used in practice, both p-dependent and q-dependent versions are estimated in levels and in first differences. This results in four estimation equations. In each case, further refinement of the specification proceeded in steps. First, all coefficients were allowed to change discretely in years 1965 through 1980. The year which minimized the error sum of squares was chosen as that in which a potential change in structure occurred. The year chosen was 1975.[4]

Once 1975 was identified as the year of potential change, each of the models was tested for the significance of the change.[5] The 2SLS residuals for each model were examined. The p-dependent static and q-dependent dynamic models showed signs of significant autocorrelation and so these were corrected, as suggested by Bowden and Turkington. A Wald test for significant parameter variation was performed. Results indicated that significant coefficient changes had occurred in the two static models, but not in the dynamic models. The static models were examined for significance of individual coefficients and further exclusion restrictions tested, test results from the final specifications are presented in Table 2.

As noted above, any of the models may suffer from simultaneity, so all statistics in Table 2 are calculated using 2SLS. The restricted, p-dependent, dynamic model exhibited signs of autocorrelation and so it was corrected, again as suggested by Bowden and Turkington. The first two lines of results in Table 2 give the estimates of the first-order autocorrelation coefficient and its asymptotic standard error from the final specifications estimated by 2SLS. None of the final specifications appear to suffer from residual autocorrelation. The Wald statistic and its p-value are given on lines 3 and 4. It tests the significance of the slope and intercept shifters **not** included in the final specification. None of the restrictions embodied in the results are rejected. Finally, lines 5 and 6 report the results of Wu-Hausman tests of the predeterminedness of both fed and nonfed beef variables on the right-hand-side of the equation. Both static models and the p-dependent dynamic model results suggests the endogeneity of prices or quantities. The q-dependent dynamic model suggests that prices are predetermined. Comparison of results for the two static models suggests that, if demand is static, there has been significant structural change and that prices and quantities are simultaneously determined in the beef market. Alternatively, results of the dynamic models suggest, if demand is dynamic, there has been no structural change and that prices are predetermined in the beef market. Casual examination of these test results suggests no reason to prefer either of these two descriptions of the world. Further analysis of these two possible states of the world must then proceed on the basis of the consistency of the results with knowledge of the market. Thus, the coefficient estimates are presented in Table 3.

The table gives **consistent** coefficient estimates for final specification of each model. So, static models and p-dependent dynamic model estimates are 2SLS, while the q-dependent dynamic model estimates are OLS. This is in keeping with the results of the Wu-Hausman test results. Overall each of the models considered separately fits well. The static models produced higher R^2s than the first-difference models, as would be expected. Coefficient estimates are for the most part reasonable, but there are some notable differences. In the static models, the q-dependent model shows fed beef to be own-price elastic, while the p-dependent model suggests it is own-quantity inflexible. However, in neither case would the hypothesis of unitary elasticity (flexibility) be rejected. Significant changes are found in different cross elasticities (flexibilities). Pork switched from a p-complement (Hicks) to a p-substitute in the q-dependent version, while its flexibility remains unchanged in the p-dependent case. In the p-dependent version, both nonfed beef and poultry became significantly less flexible, with poultry switching from a q-complement to a q-substitute, while their respective elasticities do not appear to change. The income elasticity goes essentially to zero, while income flexibility becomes large, indicating inflexibility. Since both of these sets of estimates are

TABLE 2. TEST RESULTS FOR FED BEEF DEMAND MODELS.

DEPENDENT VAR:	FED BEEF QUANTITY	FED BEEF PRICE	ΔFED BEEF QUANTITY	ΔFED BEEF PRICE
RHO[1]	-0.075	0.160	-0.058	-0.038
ASYM. STD. ERR.	(0.176)	(0.177)	(0.179)	(0.179)
W[2]	1.084	6.669	4.845	9.543
P-VALUE	(0.781)	(0.083)	(0.564)	(0.145)
DO[3]	12.843*	11.443*	2.197	6.488*
P-VALUE	(0.002)	(0.010)	(0.700)	(0.039)

* Indicates significance at the 0.05 level.

1 RHO is calculated using restricted 2SLS estimates after correcting for autocorrelation if appropriate. Its asymptotic standard error is given on the line below.

2 Wald statistics for exclusion restrictions reflected in the Table 3. Exclusion of any remaining slope and/or intercept shifters was rejected. The marginal significance level of the test is given on the line below.

3 Wu-Hausman test statistic calculated using the OLS or GLS estimate of the variance. The marginal significance level of the test is given on the line below.

TABLE 3. QUANTITY & PRICE DEPENDENT VERSIONS OF THE DEMAND EQUATIONS.[1]

DEPENDENT VAR:	FED BEEF QUANTITY		FED BEEF PRICE		ΔFED BEEF QUANTITY	ΔFED BEEF PRICE
INDEPENDENT VAR:[2]	COEF	ADJ[3]	COEF	ADJ	COEF	COEF
FED BEEF	-1.616*		-1.407*		-1.184*	-0.849
	(0.437)		(0.372)		(0.169)	(0.550)
NONFED BEEF	0.887*		-0.134	-0.533*	0.573*	-0.260
	(0.171)		(0.126)	(0.231)	(0.090)	(0.078)
PORK	-0.327*	0.580*	0.146		0.068	-0.105
	(0.113)	(0.107)	(0.205)		(0.082)	(0.207)
POULTRY	0.293		0.600	-3.122*	-0.180	-0.040
	(0.154)		(0.319)	(0.599)	(0.118)	(0.398)
INCOME	0.924*	-1.018*	1.023	1.527*	1.282*	0.509
	(0.135)	(0.312)	(0.397)	(0.529)	(0.333)	(0.794)
CONSTANT	-2.893	8.936*	-4.877		-0.023*	-0.013
	(1.476)	(2.914)	(3.063)		(0.009)	(0.022)
R^2	0.988		0.884		0.826	0.436

* Indicates significance at the 0.05 level.

1 Reported results are those of the appropriate model, considering the outcomes of the Wu-Hausman and Wald tests. The results of static models are given in columns 2-3 and 4-5 and correspond to 2SLS with structural change. The results of dynamic models are given in columns 6 and 7. Those in column 6 correspond to OLS without structural change; and those in 7 to 2SLS corrected for first order autocorrelation without structural change.

2 For model A the independent variables are logs of the quantities and income; for B, they are logs of prices and income; for model C, they are differences of logged quantity and income; for model D, they are differences of logged prices and income.

3 Column labeled ADJ gives the adjustment to the coefficients after the structural change.

consistent, one might expect more agreement in which elasticities and flexibilities are changing. However, cross-elasticities and flexibilities do not bear such a predictable relationship to one another, in general.

The dynamic models show considerable agreement between the q- and p-dependent versions. The difference most noticeable is the significant exogenous decline in fed beef consumption (as indicated by the regression constant), while the marginal value of fed beef consumption declines, but not significantly.

SUMMARY

There are many who consider attributing structural change in demand to significant parameter variation as specious, as many other potential causes of such variation exist. Conclusions as to the existence of structural change must, therefore, be interpreted with caution. However, many have interpreted such variation to indicate a shift in the tastes and preferences of consumers. A question not often addressed in this debate is what effect do supply shifts have on these findings.

This issue is addressed in two ways. First, a simulation demonstrates the potential for the finding of significant demand shifts when the true culprit is supply. The most dangerous situation appears to be when neither demand or supply errors are more variable and negatively correlated or independent. Second, the methods developed by Thurman are applied to the fed beef market in an attempt to determine if prices or quantities are predetermined. Static and dynamic versions of log-log demand and inverse demand functions were specified, estimated, and tested. The data were consistent with two possible states of the world. One where preferences are static but shifted in the mid-70s, and both prices and quantities are endogenous. The other where preferences are dynamic but displayed no discrete shifts, and prices are predetermined. Which of these is correct? The data does not provide clear-cut evidence. What does emerge is that estimates from either q- or p-dependent static demand functions are likely to suffer from simultaneity; but, after accounting for simultaneity, structural change is found in fed beef demand. If fed beef demand is modeled as dynamic, no structural shifts are apparent. In either case two conclusions can be drawn. First, evidence suggests that application of OLS or GLS to p-dependent demands is likely to produce inconsistent results. Second, findings of structural change seem to be conditional on whether demand is formulated as being static or dynamic, but does not appear to arise from supply shocks.

These results are not definitive. Differences in parameter estimates across models suggest that the simple log-log specification utilized may be too restrictive. Extension of the work to include more flexible demand structures is an area for future research.

ENDNOTES

1. The first difference of the logarithms of feeder cattle price, corn price, personal disposable income, and retail pork price (all deflated by the consumer price index) were regressed on time. These results were then used along with a random number generator and the actual values of the variables above in 1965 to generate exogenous variables for the simulations.

2. The covariance matrices of the models are 0.02 times:

MODELS:

A: $\begin{bmatrix} 2 & .5 \\ .5 & 1 \end{bmatrix}$ B: $\begin{bmatrix} 1 & .5 \\ .5 & 2 \end{bmatrix}$ C: $\begin{bmatrix} 1 & .5 \\ .5 & 1 \end{bmatrix}$ D: $\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$ E: $\begin{bmatrix} 1 & -.5 \\ -.5 & 1 \end{bmatrix}$

3. For year t, retail price of fed beef is calculated as

$$FEDP_t = \frac{(BVP_t \times BVQ_t - HAMP_t \times NFEDQ_t)}{FEDQ_t}$$

where FEDP and FEDQ are price and per capita consumption of fed beef, BVP and BVQ are price and per capita consumption of beef and veal, HAMP is the price of ground beef, and NFEDQ is the per capita consumption of nonfed beef.

4. Actually, the q-dependant dynamic model's minimum SSE was in 1972. The difference between 1972's and 1975's SSE was small and so 1975 was chosen to be consistent with the other models.

5. Since simultaneous equation bias can not be ruled out at this point, initial statistics are calculated based on the 2SLS estimates, to insure consistency. Prior to testing for parameter variation, residuals in each model were examined for autocorrelation. If the ratio of the estimated ρ to its asymptotic standard error is larger than two in absolute value, the model is corrected for AR(1) errors. This insures that both estimated coefficients and their covariance matrix are consistently estimated. Parameter variation was then tested using a Wald statistic, which is asymptotically distributed chi-square with 6 degrees of freedom in this case. Results of autocorrelation and Wald tests are given below.

RESULTS OF AUTOCORRELATION AND WALD TESTS ON UNRESTRICTED MODELS

DEPENDANT VARIABLE FUNCTIONAL FORM	QUANTITY STATIC	PRICE STATIC	QUANTITY 1ST DIFF	PRICE 1ST DIFF
RHO ASYM STD ERR*	0.095 (0.176)	-0.437 (0.162)	-0.411 (0.164)	-0.161 (0.177)
DISCRETE PARAMETER VARIATION**	74.538 (0.000)	189.873 (0.000)	4.845 (0.564)	9.543 (0.145)

* If the ratio of rho to its asymptotic standard error exceeded 2 in absolute value 2SLS was corrected for AR(1) errors before calculation of the Wald statistic.

** Wald statistics for the significance of slope/intercept dummy variables as a group. It is asymptotically chi-square with 6 degrees of freedom. Numbers in parentheses are p-values.

Wahl, T.I. and D.J. Hayes. "Demands System Estimation with Upward Sloping Supply." Paper presented at the Selected Paper Sessions of the 1989 AAEA Annual Meetings, August, 1989, Louisiana State University.

Wohlgenant, M. "Effects of the Changing Composition of Beef on the Elasticities for Beef and Poultry." Presented and the S-165 Symposium. "The Demand for Meat: What Do We Know and What Does it Mean?" Charleston, S. C., Oct. 20-21, 1986.

Wu, D. "Alternative Tests of Independence Between Stochastic Regressors and Disturbances." Econometrica. 41(1973): 733-50.

____ "Alternative Tests of Independence Between Stochastic Regressors and Disturbances: Finite Sample Results." Econometrica. 42(1974): 529-46.

Ziemer, R. F., and F. C. White. "Disequilibrium Market Analysis: An Application to the U.S. Fed Beef Sector." American Journal of Agricultural Economics. 64(1982): 56-62.

Ziemer, R. F., and F. C. White. "Disequilibrium Market Analysis: An Application to the U.S. Fed Beef Sector: Reply." American Journal of Agricultural Economics. 65(1983): 364-365.