THE CHANGING DEMAND STRUCTURE FOR PORK AND BEEF IN THE 1970s: IMPLICATIONS FOR THE 1980s

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During the 1960s and through 1973, a single equation demand system resulted in reasonably accurate forecasts of both pork and beef prices at the farm and retail levels (Grimes 1974a, 1974b). Errors in forecasts were primarily attributable to errors in projections of supply variables and, to a lesser extent, projections of consumer income. Some minor errors resulted from random variation, captured in an error variable.

However, starting in the early 1970s, errors in price forecasts for both pork and beef were substantially larger than those of the 1960s, even when supply and consumer income projections were reasonably accurate. From 1974 through 1980, forecast error increased in magnitude (Grimes 1977a, 1977b). The loss of accuracy in beef price forecasting, amounting to as much as 20 percent over actual prices, was particularly disturbing. During the 1950s and 1960s the beef demand relationship had appeared to be very stable, even though beef consumption was increasing rapidly. Price could be predicted from product output and consumer income. Year-to-year variations in prices were accounted for by differences in marketings and consumer income.

In retrospect, the economic setting of the 1970s appears to have been consistent with structural demand changes for food since the decade was marked by unprecedented exogenous shocks to the U.S. economy. These shocks included an oil embargo and energy shortages, which stimulated higher inflation and reduced gains in living standards. Wage and price controls were introduced for a short time in an attempt to stabilize prices. In spite of these attempts to stabilize prices, inflation continued to gain momentum. The decade closed with extremely high inflation, high interest rates, and a gradual decline in price-adjusted consumer income. The U.S. economy had shifted from relative price stability during the 1950s and 1960s to instability, both in price and output. These exogenous shocks have been blamed for the shift from relative price stability to instability. The effect of these shocks on the demand for agricultural products has not been empirically determined.

This paper examines evidence that suggests that some change in demand for beef and pork has occurred. The difficulty experienced by analysts in forecasting the price and consumption of pork and beef at the retail level during the latter part of the 1970s could be partially explained by these demand changes (Chavas, p. 152).

REVIEW OF LITERATURE

As the U.S. economy gradually shifted from relative stability to instability during the 1970s, economic forecasting became an increasingly risky profession (Cirarelli and Narayan, p. 12). Cirarelli and Narayan document larger errors in general economic forecasting in the 1970s than in the 1960s. Livestock markets did not escape the pervading uncertainty of the 1970s (Just and Rausser, p. 197; Cornelius et al., p. 712; Chavas, p. 152). Just and Rausser, and Cornelius et al. did not compare agricultural commodity price forecasting in the 1970s to the 1960s, but they did express concern about the accuracy of agricultural-commodity price forecasting.

Research published by Bullock and Trapp, Ikerd, and Bullock at Oklahoma State University recognizes a perceived weakness in the demand for red meat in the industry during the 1970s. Ikerd indicated that demand was further weakened by the depression psychology of the early 1980s. However, these investigators argue that the perceived weakness in red meat demand can be attributed to increases in the overall supply of meat, particularly chicken and turkey. They conclude that tastes and preferences for the three major meats (pork, beef, and chicken) have remained virtually unchanged throughout the post-war period.

Using quarterly data from 1965 through 1979 and linear spline functions, Nyankori and Miller tested hypotheses concerning structural changes in the demand for beef, chicken, turkey, and pork. These investigators conclude that structural change occurred in the demand for beef and chicken, but not in the demand for pork and turkey over this time period.

Chavas, using a procedure that permits parameters to change randomly from one period to another, analyzed the demand for pork, beef, and poultry for the period from 1950 through 1979. Structural changes in the demand for poultry and beef were detected in the 1970s relative to the 1950–70 period. Chavas concluded that no structural change had occurred in the demand for pork.

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In this study, the retail price of meat was specified as the dependent variable, and ordinary least squares used for parameter estimation. The choice of specifying price as the dependent variable has theoretical justification, particularly for certain agricultural commodities and for demand analysis purposes, when forecasting is the main or primary purpose (Fox). Fox concludes that the best forecast of a variable can be obtained by a single-equation least squares analysis in which the price of that variable is used as the dependent variable and other relevant factors as independent variables. Coefficients of such an equation cannot be interpreted directly in terms of the familiar economic concepts of elasticities of supply and demand (Fox, p. 2). Fox also discusses the assumptions necessary for justifying a single-equation analysis of demand for particular agricultural products (Fox, pp. 9–14).

PROCEDURE

Difficulties in forecasting the retail prices of beef and pork led to the development of the hypotheses tested in this study. The null hypotheses tested are that the demand relationships for beef and pork during the 1970s are unchanged from the 1950s and 1960s. The alternative hypotheses are that differences in demand exist for pork and beef between the two periods.

To test these hypotheses, price, income, and consumption data were analyzed for the period 1950–82. Product prices and consumer income data were deflated using the Consumer Price Index (1967 = 100). Foote concludes that the Consumer Price Index (CPI) is an appropriate deflator when demand is measured at the retail level (Foote, p. 28).

The following variables were included in the demand analysis:

Dependent Variables

Y_1 = retail price per pound for pork in deflated dollars

Y_2 = retail price per pound for beef in deflated dollars

Independent Variables

X_1 = per capita consumption of pork in pounds, carcass weight

X_2 = per capita consumption of beef in pounds, carcass weight

X_3 = per capita consumption of broilers in pounds, retail weight

X_4 = per capita income in deflated dollars

Annual observations were obtained on all variables for the period from 1950–82.

Consumption and price data were obtained from the U.S. Department of Agriculture *Livestock and Meat Situation* and *Poultry Situation* reports. Consumption was used as the quantity variable because, in the short run, it is essentially equal to supply. Inventories and net import-exports are relatively minor in the pork and beef market. Consumer income data were obtained from the *Survey of Current Business* (U.S. Department of Commerce). Lamb, mutton, and veal were not included in the final analysis. Consumption of these products declined to less than two pounds per capita in 1980.

The procedure used in this study involved estimating when the structural shifts in demand over the 33-year period occurred. The final choice for the time periods was based on a combination of judgment and the use of a time-varying estimation technique. As discussed earlier, the change in the general economic conditions of the 1970s could have set the stage for a relative shift in the demand for red meat. Commencing with 1966, national economic policy resulted in larger federal budget deficits because the Vietnam War was financed by borrowing rather than by increasing taxes.[1]

Finally, a time-varying estimation procedure known as the "switching regression model" (Maddala) was used to facilitate the final choice of years to be included in the two different time periods to test the relative shift hypothesis. The "switching regression model" divides an overall time period into two periods. Separate regression equations are estimated for each period, along with separate error sums of squares for each period. The procedure then varies the choice of the two periods over several years of data and computes separate equations and error sums of squares for each choice. In a strict application of the "switching regression model" procedure, the dichotomy of periods resulting in a minimum sum of error sums of squares for the two periods is chosen. This procedure was used to facilitate and verify the choice of the exact division of the overall period for the test of the relative shift hypotheses.

The Chow test for equality of regression coefficients between periods was used to test the relative shift hypotheses. The Chow test is a test of the equality of the overall regression equation rather than of individual coefficients.

RESULTS

Demand for Pork

The analysis of data for pork using the regression switching procedure resulted in a division into period 1 (1950–69) and period 2 (1970–82) (Table 1). Equations were estimated for the overall time period (1950–82) and for the two subperiods. The results are given in Table 2.

The Chow test resulted in an F value of 4.80, which was significant at the 1 percent level, and the hypothesis of equality of coefficients between the two periods

[1] Analysts disagree as to how much this choice influenced the shift of the U.S. economy from one of relative price stability in the 1950s and early 1960s to one of price instability with accelerating inflation in the late 1970s. That the shift occurred is a fact. This shift was also accompanied by a gradual reduction of growth in price-corrected consumer income until this growth ceased altogether in the late 1970s. This transition of the U.S. economy did not all occur in one year. However, the early 1970s appeared to be a logical break in terms of the transition that was suggested by the general economic environment.

Table 1. Results of Switching Regression Model Tests for Choice of Period for Pork Equations

Time Period	Error Sum of Squares
1950-1968	79.7
1969-1982	118.1
Total	197.8
1950-1969	94.2
1970-1982	94.5
Total	188.7
1950-1970	216.8
1971-1982	82.5
Total	299.3

was rejected. Therefore, the data indicate that a change in the structure of demand for pork occurred between the two periods.

A Durban-Watson (DW) statistic was computed for each of the three equations estimated for pork (Table 2). The DW value for period 1 (1.71) did not result in rejection of the null hypothesis of no positive autocorrelation (Table 2). The t-values indicated that all variables were highly significant for period 1 (Table 2). The signs of coefficients were also consistent with theory. In period 2, the t-values for pork and broilers were highly significant with signs consistent with theory. However, the t-values for beef and income were not significant at the 5 percent level, but the signs were consistent with theory.

The t-values for pork, broilers, and income were highly significant for the overall time period (Table 2). Quantity of beef was not significant at the 5 percent level in the overall equation, but its sign was consistent with theory.

Table 2. Relation Between Deflated Retail Pork Price and Independent Variables [a]

Independent Variables	Regression Equations		
	1950-1969	1970-1982	1950-1982
Intercept	146.35 (9.74)**	169.132 (3.381)*	91.7497 (7.93)**
Q Pork	-1.43 (-7.19)**	-1.0194 (-4.697)**	-0.8561 (-6.193)**
Q Beef	-0.68 (-4.74)**	-0.2561 (-1.258)	-0.1751 (-1.91)
Q Broilers	-1.01 (-4.3)**	-1.6104 (-4.921)**	-1.4371 (-7.435)**
Income	0.0424 (5.62)**	0.01972 (1.897)	0.0351 (6.634)**
R^2	0.84	0.9164	0.7752
DF	15.00	8.00	28.00
Durbin-Watson[b]	1.71	--	1.694
Chow Test: Computed F = 4.80*			

[a] Student t-values are given in parentheses.
[b] DW inappropriate for sample sizes smaller than 15.
* Significant at the 5 percent level.
** Significant at the 1 percent level.

Demand for Beef

The results of the "switching regression model" for the beef data are shown in Table 3. The time choice for beef was period 1 (1950–70) and period 2 (1971–82). This choice of periods was not totally consistent with a strict application of the "switching regression method," as discussed earlier. However, the reduction in the total error sums of squares for the period choice would have been minimal for a later year (1972) as the breaking point (Table 3). Three equations were estimated for beef; the results of the regression analysis are given in Table 4. The Chow test resulted in an F value of 11.12, which is highly significant. Therefore, the hypothesis of equality of regression coefficients between the two periods was rejected.

The DW statistic was also computed. The DW value for period 1 (1.96) was within the range of 1.69 to 2.31 and the null hypotheses was not rejected. The DW sta-

Table 3. Results of Switching Regression Model Tests for Choice of Period for Beef Equations

Time Period	Error Sum of Squares
1950-1969	59.2
1970-1982	133.7
Total	192.9
1950-1970	59.3
1971-1982	126.0
Total	185.3
1950-1971	65.8
1971-1982	116.9
Total	182.7

Table 4. Relation Between Deflated Retail Beef Price and Independent Variables [a]

Independent Variables	Regression Equations		
	1950-1970	1971-1982	1950-1982
Intercept	110.26 (11.79)**	106.31 (1.603)	80.2474 (5.327)**
Q Pork	0.19 (1.47)	0.1134 (0.422)	0.1648 (0.916)
Q Beef	-1.46 (-13.68)**	-1.200 (-4.77)**	-0.8355 (-7.00)**
Q Broilers	0.74 (4.07)**	-1.8086 (-4.431)**	-0.6468 (-2.57)
Income	0.0343 (5.95)**	0.0580 (3.851)**	0.03739 (5.429)**
R^2	0.96	0.8382	0.7160
DF	16.00	7.00	28.00
Durbin-Watson[b]	1.96	--	0.99
Chow Test: Computed F = 11.12**			

[a] Student t-values are given in parentheses.
[b] DW inappropriate for sample sizes smaller than 15.
* Significant at the 5 percent level.
** Significant at the 1 percent level.

tistic for the overall period was slightly below the value of dl (1.02).

The coefficients of period 1 for beef, broilers, and income were highly significant, and all except broilers had the theoretically correct sign. For period 2, all coefficients had signs consistent with theory (Table 4). However, the t-value for pork was not significant at the 5 percent level. The broiler coefficient shifted to a negative sign and was significant at the 5 percent level. The equation for beef over the 1950–82 period yielded only two variables significant at the 1 percent level—quantity of beef and consumer income (Table 4). In addition, R^2 was 0.72 for the overall period compared to 0.96 for period 1 and 0.84 for period 2. The change of sign in the consumption of broilers appears to be the result of a change in two economic variables from period 1 to period 2. Per capita broiler consumption increased rapidly during the 1970s.[2] At the same time, growth in real consumer income was much lower in period 2 than in period 1. These two changes in the overall demand situation appeared to have interacted in period 2 to produce the change in the sign of the broiler-consumption coefficient relative to the price of beef. Broiler production in period 1 may not have been large enough to be serious competition for beef, particularly with rapidly rising consumer incomes.

COMPARISON OF COEFFICIENTS BETWEEN PERIODS

Since the equations were specified with price as the dependent variable, price, cross, and income-flexibility coefficients were computed as a measure of change between the two time periods. These results are shown in Table 5. All flexibility coefficients can be interpreted as the percentage change in price of the product (pork or beef) associated with a 1 percent change in the independent variable at the sample mean of the given variables.

The price and income flexibilities for pork declined in period 2 compared to period 1 (Table 5). The effect of real income on the price of pork was not significantly different from zero at the 5 percent level for period 2, and a given percentage change in pork supply would produce a smaller percentage change in the real price of pork in period 2 than in period 1. The cross flexibility of demand for pork in terms of beef declined from period 1 to period 2, but increased for broilers. However, the cross-consumption relation between pork and beef was not significant in period 2.

Overall, the largest structural change in demand occurred in the retail market for beef from period 1 to period 2. Table 5 shows the cross, price, and income demand flexibilities for beef in the two time periods. The greatest change in the demand for beef appears to have occurred because of the increased substitution of broilers for beef. This appears also to be the case with pork, but to a lesser extent. This change may be a major factor in the perceived weakness in the demand for beef in recent years. The increased income flexibility in the beef market also seems to be a major factor in the change in the demand for beef because real consumer per capita incomes declined from a 1978–79 peak of $3,422 to a level of $3,240 in 1982 (1967 dollars).[3]

COMPARISON OF PRICE FORECASTING ACCURACY

The mean square errors of prediction for pork and beef were compared using coefficient estimates for the overall period (1950–82) and for period 2 (1970–82) for pork and beef. The use of period 2 data resulted in a 14.5 percent decline in the mean square error of pre-

Table 5. Price, Cross and Income Flexibilities for Pork and Beef for Two Time Periods [a]

Variable	Pork Flexibilities		Beef Flexibilities	
	1950-1969	1970-1982	1950-1970	1971-1982
Q Pork	-1.34**	-0.99**	0.14	0.08
Q Beef	-0.86**	-0.4225	-1.44**	-1.50**
Q Broilers	-0.32**	-0.97**	0.19**	-0.84*
Income	1.40**	0.92	0.89**	2.08*

[a] Calculated at mean of variables.
* Significant at the 5 percent level in original equation by Chow test (Tables 2 & 4).
** Significant at the 1 percent level in original equation by Chow test (Tables 2 & 4).

[2] Per capita broiler consumption was 36.8 pounds in 1971 and 50.0 pounds in 1982 (a 36 percent increase). Per capita beef consumption was 113.4 pounds in 1971, and 104.4 pounds in 1982, and peaked in 1977 at 127.6 pounds per capita.
[3] These figures on real income were taken from *Working Data for Demand Analysis*, USDA, ERS, NED, June 1981, and from the February 1982 and February 1983 issues of the *Survey of Current Business*.

Table 6. Comparison of Accuracy of Price Forecasts using Overall Data and Period 2 Data for Pork and Beef

Product	Mean Square Error		
	Overall (1950-1982)	Period 2 (1970-1982)	Percent Change From Overall To Period 2
Pork	13.8	11.8	-14.5
Beef	23.4	18.0	-23.1

diction for pork and a 23.1 percent decline for beef (Table 6).[4]

To further support the relative shift hypothesis, actual and predicted prices were compared for 1982 data using equations estimated for the two time periods. These results are given in Table 7. Prices predicted using equations for the overall period 1 were much higher than actual prices in 1982 for both pork and beef. Using the period 2 equation, the predicted prices were only slightly higher than the actual prices (Table 7). These results also support the relative shift hypothesis.

CONCLUSIONS

The evidence presented supports the conclusion of a structural change in the demand for both pork and beef.

Table 7. Actual and Predicted 1982 Price for Pork and Beef Using Two Time Periods (1967 Constant Dollars)

Product	Observed Price	Predicted Period 1	Predicted Period 2
	cents/lb.		
Pork	60.7	72.4	61.8
Beef	83.9	111.5	85.6

The null hypothesis for pork was rejected at a significance level of less than one percent. During period 2 (1970–82), the retail price of pork was less sensitive to change in the supply of pork, beef, and real income than during period 1 (1950–69). In period 2, the retail price of pork became more sensitive to change in the supply of broilers than in period 1.

The change in demand for beef appeared to result primarily from the shift in the relation between the retail price of beef and the consumption of broilers. Broilers became a strong substitute for beef in period 2. This change appears to be related to the reduction to growth in real consumer income during period 2.

The use of period 2 data for analysis and price projections would have resulted in reductions in mean square errors of forecasts for the 1970s as compared to using data from the overall time period. This in no way implies that the same results should be expected during the 1980s. However, beef and pork market analysts need to consider possible structural changes in demand for these products when making projections of demand into the 1980s.

This paper does not disagree with Bullock, Ikerd, and Bullock and Trapp regarding the importance of the increase in total meat supply as a major factor in the relative price decline for beef and pork during the last 10 years. However, it carries the empirical investigation one step further. It concludes that the increased total meat supply of the 1970s would have cleared the market at a higher price had consumer demand conditions of the 1950s and 1960s prevailed during the 1970s. This implies a change in structural demand for beef and pork, with some change in income effects on consumption as well as changes in the substitution between the various products.

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[4] It is recognized that the above approach is an oversimplification of the forecasting problem because values of exogenous variables must also be estimated prior to forecasting values of endogenous variables in future time periods. However, the results show an advantage in forecasting accuracy using coefficients developed from period 2 data versus using coefficients derived for the overall time period.

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