MODELING FLUID MILK
SUPPLY AND DEMAND
WITH PROJECTIONS TO
1985

By

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INTRODUCTION

The intent of this study is to develop a model which represents the supply and demand relationships for fluid milk in the United States in order to forecast farm prices and the level of milk production for 1975 and to make projections to 1985 of the domestic consumption of fluid milk. The concept of a polynomial lag formulation of milk production is combined with the use of gross margins in an attempt to more adequately reflect the impact of biological factors and other apriori information on production response to price changes. A literature review traces the work of other authors pertinent to the development of a methodology for this study, including some of the theoretical drawbacks to the use of polynomial lags. A section on methodology relates a brief description of the dairy industry to the choice of variables used to specify the demand and supply equations and the use of a polynomial (distributive) lag model fitted to time series data for the years 1953 to 1974. The results of the study and an interpretation of these results concludes the paper.

I. LITERATURE REVIEW

Literature relevant to this study can be classified according to (1) that pertaining to a description of the industry, (2) studies which attempt to model supply and demand relationships in the milk market and (3) literature which relates to econometric and other theoretical considerations of the model chosen for the study.

Describing the Industry

Because of the biological nature of dairy production with its inherent impacts on milk supply and the complex nature of the organization of milk markets, a knowledge of the industry must be taken into account in any modeling process.

The Federal Milk Marketing Order Program by the Dairy and Consumer Marketing Service of the United States Department of Agriculture provides an historical perspective of dairy production, and the marketing of dairy products. Depressed dairy product prices and resulting low incomes of dairy farmers are linked to the cyclical nature of dairy production response to price changes and the relationship between a competitive, "price-taker" producer to an essentially oligopolistic processor. This provides an economic and historic basis for the development of the federal milk marketing order program as well as a general description of the organization and implementation of milk marketing orders.

Organization and Competition in the Dairy Industry, NCFM Technical Study No. 3, looks at the question of "adequate" competition in the dairy industry. It points to the countervailing nature of grocery chains into "own brand" bottling and the existence of bottling and processing by producer owned cooperatives as evidence of a fair degree of workable competition in an industry which is otherwise relatively oligopolistic in nature.

McBride and Boynton, in What's Behind the Grade A Dairyman's Milk Check, attempt to untangle the complex web of the pricing mechanism in federal milk marketing orders. This is divided into three interrelated parts, the establishing of the dairyman's daily base, the determination of class prices and resulting payments into market pools and the determination of producers milk prices. This underscores the "administered" or somewhat arbitrary nature of milk prices received at the farm gate.

The importance of various trends in the dairy industry are discussed in The Michigan Dairy Industry of 1985, Michigan State University Research Report No. 183. While the material relates specifically to the Michigan projected situation the discussion is in the light of national trends such as the gradual decline in per capita consumption of fluid milk, increased production of milk per cow, the increased concentration of the processing industry, etc.

Modeling Supply and Demand Relationships

Anthony Prato, in "Milk Demand, Supply and Price Relationships - 1950-1968" (American Journal of Agricultural Economics, May 1973) used a series of 13 simultaneous equations fit by 2-stage least squares, in which cow numbers on hand determine total production of milk and where equilibrium is defined where quantity produced (MP) is equal to the sum of fluid milk which included (1) deflated retail price, (2) index of retail prices of beverages, (3) consumption lagged one period and a time trend variable. Quantity consumed was the dependent variable. Income was not included.

Due to the nature of biological factors which are a part of agricultural production, there are certain lags in response to any stimulus such as that of price on the production process. This is particularly evident in the dairy industry where production depends a great deal on the numbers of mature cattle in production at a particular time. To provide to administrators of milk marketing orders adequate short run and long run estimates of the impact on milk production of price changes would require that such lags in production response be reflected in those estimates.

Prato used a one period lagged adjustment to account for these lags. A number of others, such as Halvorson in "The Supply Elasticity of Milk in the Short Run", have used Nerlovian type geometric lag models which implicitly assume that the greatest impact from a price change will come in the first period.

Chen, Courtney and Schmitz, in their attempt to determine the nature of the lagged output response resulting from a change in product price, have contrasted estimates using a polynomial price lag formulation to estimates using a geometric distributed price lag formulation. In their article entitled "A Polynomial Lag Formulation of Milk Production Response" in the AJAE for February 1972, they hypothesize that a more flexible price lag structure would improve supply response estimates, where the supply response first increases through time and then decreases. (Chen, Courtney and Schmitz pp. 77-82)

The emphasis of this study is on techniques rather than developing a set of predictions to solve a particular milk marketing problem. Because this technique is central to the study which follows, a more detailed look at this article is in order, first with respect to the functional form used, secondly at the variables included and thirdly, at some of the tests, interpretation of results and conclusions the authors reach in the study.

The authors have chosen a second order finite polynomial lag model, which they compare to a partial adjustment model (formulated by Nerlove) fitting the models to California quarterly milk production data for 1953-1968. They emphasize that the polynomial lag was selected to provide an alternate more flexible model, which could measure supply responses which first increase through time and then decrease. This is contrasted to the geometric lag response which restricts to the assumption that the biggest response occurs immediately at the beginning of the adjustment period. (See also Griliches summary, pg. 117)

Convention and ease of computation are cited as their response for selecting a low order polynomial. The length of the lagged function (number of periods) is governed by the restriction that the $\beta_K = 0$ and $k = \tau$. β is the coefficient for the lagged periods, k is the length of the lagged variable and τ is the number of the lagged period (not t). This is based on the assumption that at some length of period, "k", there will be no more effect of a price change on current production. Both of these specifications are apriori. The authors test for results of lagged periods of k = 5 through k = 9, noting that beyond k = 9 it was "impossible to invert the matrix sums of squares and crossproducts due to a high degree of correlation between W_1 and W_2 which are the weights for the β-coefficients". (Chen, Courtney and Schmitz, pg.79)

While no explicit reference is made to their assumptions regarding the disturbance term, the reader is left to deduce from their use of ordinary least squares that the assumptions for U_t are those for the classical normal regression model.

Selection of "significant" variables for the model other than the lagged milk price structure seems to have been quite problematic for the study. (This could be very well the result in part of the problem of multicollinearity referred to by Kmenta and mentioned below.) While the initial selection of variables, with respect to theory and knowledge of the market seem to fit specifications adequately, the authors end up with only an 8-period lagged structure of a milk-feed price ratio and a binary seasonal variable to which to compare the geometric lag model with the same variables. In their words, "Preliminary results showed that some of the original variables were statistically insignificant and hence excluded". (Chen, Courtney and Schmitz, pg. 79) Prices of canner and cutter cattle, an index of prices received by farmers for all farm products, average weekly gross earnings for workers in manufacturing all met this fate. Alternative measures of technology rendered the weights of the lagged structure insignificant so these, despite their high significance levels, were also eliminated for the final equation. Individual variables for the final equations will now be considered in more detail.

The dependent variable is <u>Quarterly Commercial Production of Market Milk</u>, "Q_t". Only note that California is strictly a Grade A quality milk producing state. Thus, there is no need of distinguishing fluid from manufacturing milk as there would be for states like Wisconsin.

<u>Milk - feed price ratio</u>, $P_{t-\tau}$, is composed of the average quarterly price paid by California farmers for 16 percent dairy feed. This is the price structure which remained as the key lagged predetermined variable.

Seasonality Factor, S, is a binary variable which is used to shift the intercept down to compensate for the high production period of the year, i.e. S = 0 for the first and fourth quarter and S = 1 for the second and third quarters.

Two alternative Measures of Technology, Z and T, are used. One is a simple time trend starting at 1 for 1953. The other is a measure of labor productitity, an index of farm production per man hour for milk cows. These are each tested separately for each of the K = 5 through 9 period lags and compared to results obtained with technology excluded. Time trends are often included to reflect psychological, technological and institutional factors not otherwise specified. As one might suspect, the time trends were both highly significant in the results recorded by the authors for the years 1953-1968. Of the most significance about these two variables was the fact that the authors didn't obtain statistically significant weighted coefficients of the price lag structure where technology was included in either form. Thus, to preserve the intent of the study, they eliminate this variable in the final equation they use for comparison purposes, admitting at the same time that there is little basis for deciding which model is best. The structural equations which are compared in the study are:

$$Q_t = \alpha_0 + \alpha_1 P_t + \alpha_2 S + \alpha_3 Q_{t-1} \quad \text{(Geometric Lag)}$$

$$Q_t = a_0 + a_1 \sum_{\tau=0}^{k} (\tau - k) P_{t-\tau} + a_2 \sum_{\tau=0}^{k} (R^2 - k^2) P_{t-\tau} + a_3 S$$

(Poly Lag)

We have already referred to some of the results of the study, i.e. (1) most variables originally included were dropped because of low statistical significance levels; (2) the technology variable in either form rendered the lagged coefficients α_1 and α_2 insignificant even at the 20% level; (3) attempts to go beyond a 9-period lag were not possible because of a high degree of multicollinearity.

In the final estimated equation all the lagged β's except for P_t were found to be significant at the 5 percent level. It is not clear how they arrived at a 5% level of significance when the α's were estimated as significant at the 10% and 20% level respectively. They found price change to have its maximum effect on production four periods later which they say appears reasonable in view of apriori knowledge. (It is not clear what they mean by this.) The coefficient of multiple determination R^2 is used to measure degree of fit. They obtained $R^2 = 0.851$ for the final equation.

Short run and long run price elasticities are compared for the Nerlovian formulation and the polynomial lag, while there is a decided difference in the short run, the long run response is approximately equal for both lag formulations. The polynomial lag structure shows a response which first increases and then decreases over time. The polynomial lag seems to demonstrate a greater degree of responsiveness in the short run than does the Nerlovian lag.

The authors recognize the lack of theoretical basis for the study and they also recognize the difference in the meaning of elasticities of conventional theory from those of the polynomial or other distributed lag where the function measures responsiveness of production to a number of price changes. As a result they are reluctant to conclude that they have shed a lot of light on the nature of the structure of price lags which was their original goal.

Use of Ratios and Gross Margins

In an article "Use of Ratios and Gross Margins in Time Series Supply Analysis", John N. Ferris discusses some of the benefits and limitations of ratios and gross margins as a means of consolidating variables and introducing additional apriori information. The capacity to consolidate variables is particularly useful in time series data where the number of observations often limits the degrees of freedom. In addition, problems of multicollinearity tend to arise as the number of independent variables is increased. Ferris points out that multicollinearity increases the variance of the estimated coefficients.

Ferris indicates that ratios such as the hog:corn ratio, the beef:corn ratio, the milk:feed ratio, etc., do provide a means of consolidating variables. Ratios have an advantage of being easily calculated. They have the capacity of pinpointing some major swings in production. However, Ferris points out "the major disadvantage with ratios is that implicit in their application is the assumption that the denominator is just as important as the numerator in determining producer response". Secondly, these ratios implicitly assume that expectations are the same for the denominator as for the numerator. (It should be noted that this would seem to be an especially fragile assumption in the case of a lagged structure. It is possible that the expectations for the component prices might be quite different.)

Gross margins, according to Ferris, have the major advantage of allowing the incorporation of a large amount of apriori information in one variable. Gross margins are defined as the "difference between the returns from a product and the cost of a major variable input or inputs". The purpose is to obtain a time series representative of the amount available to the producer to pay for fixed inputs not included in the cost element of the gross margin. (Ferris, pg. 8)

He points out that the use of gross margins involves the assumption that a producer reacts in the same way whether an extra dollar is received because of a higher price on the product, a lower price on inputs or technological improvements.

Some Limitations of Polynomial Lags

Kmenta points to the specification of degree of polynomial and the length of lag as being real problem areas, because they are apriori decisions. (Kmenta, pg. 494) For the former there is apparently little theoretical basis for such a decision. Kmenta also underscores the problem of the criteria $B_k=0$ and $k=\tau$ where there is a high degree of correlation among the lagged variables.

Kelagian and Oates point to another problem with the restrictions that $B_k=0$ and $k=\tau$. While such restrictions yield unbiased estimators that have smaller variances than those produced by the direct method of dropping P_{t-k} from the analysis, this is only true under the assumption that the endpoint parameters lie on the same polynomial curve as the non-zero parameters. They demonstrate that this assumption doesn't necessarily hold. If not, the consequences of such an "invalid" restriction would bias the estimators. (Kelagian and Oates, pgs. 177-178)

Griliches, in "Distributed Lags, A Survey", says that distributed lag models are much more likely to show serial correlation than the classical regression case, i.e. that $E(U_tU_s)\neq 0$ for $r\neq s$. Serial correlation will result in inefficient estimates of the coefficients and, according to Griliches, an identification problem. He also points out that the Durban Watson test can be of no use in this context, since it too would be biased. Griliches points to two methods of correcting for this, namely: (1) assume a particular form for this dependence and estimate the parameters jointly with the others or (2) use instrumental variables. (Griliches, pgs. 132-135 and 139)

II. METHODOLOGY

The method used to obtain knowledge about fluid milk supply and demand relationships involves combining economic theory, statistical technology and a knowledge of the market. Several questions or problem areas are important to this process: what variables should be included, what form of the function will allow for a better "fitted" relationship and what data is available? There is also the problem of obtaining the estimates for the relevant variables and running statistical tests of the degree of fit, i.e., whether or not and how closely the model estimates are consistent with observations made. Ultimately, the variables which will be used depend on the purpose of the study and the cost of gathering information which, in turn, is closely tied to the data which is available.

This study will take a brief look at some background information about the fluid milk market. Then it will turn to a theoretical and apriori basis for selection of the variables to be used in the model and the basis for selecting a polynomial lag structural form of the price variable. There will also be a discussion of problems incurred in obtaining certain kinds of data which influenced the final selection of variables utilized.

Background and Description of the Industry

The complexities of the dairy marketing system can be broken down for purposes of understanding into (1) Grade A and Grade B sources of supply, (2) a fluid milk and a manufacturing milk market for raw milk, (3) a bottling industry and a manufactured products processing industry.

Grade A milk production is highly specialized. Because the milk produced is eligible for fluid consumption there are stringent government regulations to control quality. Pricing and other market conditions are governed by federal and state marketing orders for a large share of Grade A milk produced. Well organized producer cooperatives, through five "regional" bargaining associations, have obtained substantial control supply. Market power of these cooperatives has been augmented through forward integrating into bottling and cheese processing.

The "surplus" of Grade A not processed for fluid consumption goes into the manufacture of dairy products. The price which farmers receive per hundred-weight is an administered blend which reflects utilization.

Grade B milk does not qualify for fluid markets. Manufacturing milk prices are government subsidized through stock purchases to maintain a floor on the otherwise competitive market. This "competitive" manufacturing price is used in computing "formula prices" for Grade A milk in milk marketing orders. Grade B milk's share of the total of raw milk marketed has been diminishing and is projected to disappear by 1985. (MSU Research Report 183, pg. 4)

Modeling Demand for Fluid Milk

Fluid milk is used in the production of a number of drinks differentiated by butterfat content and flavor. There has been a switch in taste preferences from whole milk (3.5% butterfat) to low-fat (2.0%) and skim milk. However, we are assuming for this analysis that these products are generally close substitutes and don't need to be differentiated. The impact of such a shift in taste would tend to be toward non-dairy beverages, and our concern is with all fluid milk production and consumption.

With the exception of the years 1973-1974, where the feed costs and canner and cutter prices have both been relatively high, the nature of the production has been that milk supplied has been largely predetermined in time "T". It was thus assumed that simultaneous responses of farmers to current year's prices could be ignored. It was hoped that a recursive model with a single demand equation with price of fluid milk as dependent variable could be used. Several things made this a problem. First, there was lack of information on Grade A milk production (see below under Data Problems). Also, from previous studies it is evident that milk consumption is quite price inelastic. In the third place, the price of fluid milk at base is administratively determined. It was decided therefore to go to a model with quantity consumed as the dependent variable. Data on total annual fluid milk utilization was used for this purpose. (Dairy Situation Reports, 1953-1974)

According to theory, consumption of fluid milk is dependent upon own price, disposable income and the price or consumption of near substitutes. Retail price of fluid milk was kept in the demand equation despite the fact that for the period considered there was little change in the deflated price level. Only in the three years '72 to '74 has there been strong evidence of price effect on consumption. Prices were deflated to take into account the general price level. (The same was done for disposable income.) Price is assumed to be exogenously determined.

It was difficult to find any consumption data for other beverages, such as the consumption of carbonated beverages. The "close substitute" chosen was therefore per capita consumption of red meat. This is based on the assumption that red meat and milk are both protein sources. ?

It is also thought that population under the age of twenty would be the most likely to drink milk, especially smaller children. A relatively large number of young people in the U.S. during the 1960s is thought to have helped maintain the demand for fluid milk. Thus, this segment of the population was included as a separate shifter of demand.

Since from other studies there is strong evidence that tastes for fluid milk in all its forms have been changing, a time trend variable should have been included as a proxy for changes in tastes and drinking habits. It was not.

It is assumed in this model that there will be no substantial stocks of fluid milk due to its perishability. It is also assumed that there will be no demand for imports of fluid milk (which conforms pretty much to reality).

An equation with and without a variable for population less than twenty years old was tried. The R^2 was decidedly better for the equation which included it. However, as evidenced below, the hypothesis that population less than twenty years of age would have a positive effect was not substantiated.

Based upon the above apriori and theoretical considerations, the following demand equation for fluid milk was used:

CFM = F(PRET, DI, CRM, POPLT 20) where

CFM = consumption of fluid milk (per capita) deflated by the U.S. Consumer Price Index

PRET = price retail for fluid milk deflated by the U.S. Consumer Price Index

DI = disposable income (per capita) deflated by the U.S. Consumer Price Index

CRM = consumption of red meat

POPLT 20 = population less than 20 years old

Modeling Supply of Fluid Milk

Quantity supplied of fluid milk, according to economic theory, is a function of own price, the price of inputs into the production process, and the foregone income of alternative forms of production or use of resources, other things remaining equal. Due, however, to the nature of the biological factors which are a part of all agricultural production, there are certain lags in response to any stimulus such as that of price on the production process. This is partially evident in the dairy industry where milk production depends a great deal on the numbers of mature cows in production at a particular time. Another key determinant is the average production. Cow numbers on hand is the result of decisions made over a number of years, i.e., cull rates maintained by producers, number of replacements kept, etc. Average production is related to breeding program and feeding program. Breeding program has a lagged impact on production as may feeding, however, adjustments in feeding concentrate for increased production can be adjusted more rapidly.

In order to more adequately reflect the nature of the lagged response to price changes, this study uses a similar formulation to that used by Chen, Courtney and Schmitz, namely, a second order finite (polynomial) lag formulation of the type:

$$Q_t = a_1 \sum_{\tau=0}^{k} (\tau-k)\, P_{t-\tau} + a_2 \sum_{\tau=0}^{k} (\tau^2-k^2)\, P_{t-\tau}$$

where r = time period; t = current period; k = number of lagged periods. Chen indicates that a low-order polynomial is appropriate for most econometric work and is also easier to compute. (Chen et al, pg. 78) In the above equation: $\beta_\tau = a_0 + a_{1\tau} + a_{2\tau}$ with a restriction that $\beta_\tau = o$ when $\tau = k$. In other words, for the 4-period lag used in this study, it is assumed that β_4 = o, i.e., beyond four years the impact of lagged effects is negligible and $a_0 + a_1k + a_2k^2 - 0$. If we solve for a_0 and substitute in the β_τ equation, we have $\beta_\tau = a_1(\tau - k) + a_2(\tau^2 - k^2)$. For the 4-period lag:

$$\beta_0 = -4a_1 - 16a_2$$
$$\beta_1 = -3a_1 - 15a_2$$
$$\beta_2 = -2a_1 - 12a_2$$
$$\beta_3 = -1a_1 - 7a_2$$
$$\beta_4 = 0$$

One then solves by least squares regression for the constant β_0, the linear coefficient "a", and the quadratic coefficient "a_2". The resulting printouts provide coefficients, their "t" - values and variances which have to be converted to the respective β_τ values and their variances.

This study follows Chen's example in using total quantity of milk produced data, rather than the more complex approach Prato used where cow numbers on hand and average production per cow to generate total production. For estimation purposes, the equation can incorporate non-price variables solved by orbinary least squares regression analysis.

Whereas Chen uses a ratio of prices received to prices paid for 16% concentrate as his lagged price variable ($P_{t-\tau}$), this study originally used a gross margin of prices received net of concentrate feed costs. Price of cow beef was included to provide an element of opportunity cost in the model, i.e., that if these prices are high enough and the marginal value product of a cow in production low enough it may pay to sell cows. Labor costs were not included in the gross margin.

Labor costs were not included in the gross margin. Labor productivity was included as an element of technological trend in the overall equation. The resulting general form of the supply equation used is:

$Q_t = F(P_{t-\tau}$, CCM, PCB, ILEM) where

Q_t = per capita milk production (See problems of data collection below)

$P_{t-\tau}$ = price lagged (deflated by prices received) /cwt. milk

CCM = concentrate costs (deflated by priced paid) /cwt. milk

PCB = price of cow beef (deflated by prices received)

ILEM = productivity of labor in producing milk index

Some Problems of Data Availability

A great deal of difficulty was had in obtaining data for national total of Grade A milk production. Fluid milk production data are available for some states where Grade B production is negligible or where its proportion is known. However, this is not true for all states. Plant receipts from producers, as reported in Fluid Milk and Cream Report (USDA Crop Reporting Service), showed doubling in quantity received between some years indicating changes in method of reporting. Marketing order data, while complete, represent a changing and unknown proportion of the total for 1953-1974.

There was the problem of aggregation error with the use of total milk production data (the combination of Grade A and B milk data) and the average farm price for all milk produced. On the demand side this also opened up the complexities of demand for a wide range of products including imported products. Supply of all milk was chosen hoping that the predictive capacity would be adequate, even though structural parameters might be difficult to interpret due to the aggregation problem, e.g., feed costs per hundredweight of milk where it is known that two different technologies exist. Demand for fluid milk was retained.

It was decided to stick with annual data for the years 1953-1974 for purposes of simplicity and availability of data. This gave 22 observations (19 with the polynomial lag used in the supply equation). It is possible that results could have been improved with seasonal data over the last 10 years, since price-quantity supplied relationships seem to agree with theory more from 1964 on (see time trend diagrams, figures 1-3).

III. RESULTS OF THE STUDY

Estimation of the Demand Equation

The demand equation and its statistical properties is as follows:

$$CFM = 422.119 - \underset{(-1.083)}{61.803\,PRET} - \underset{(-2.063)}{0.147DI} - \underset{(.0475)}{.010\,CRM} - \underset{(-1.9774)}{.603POPLT20}$$

$R^2 = .7746$ SEE = 5.04 D.W. = .6827

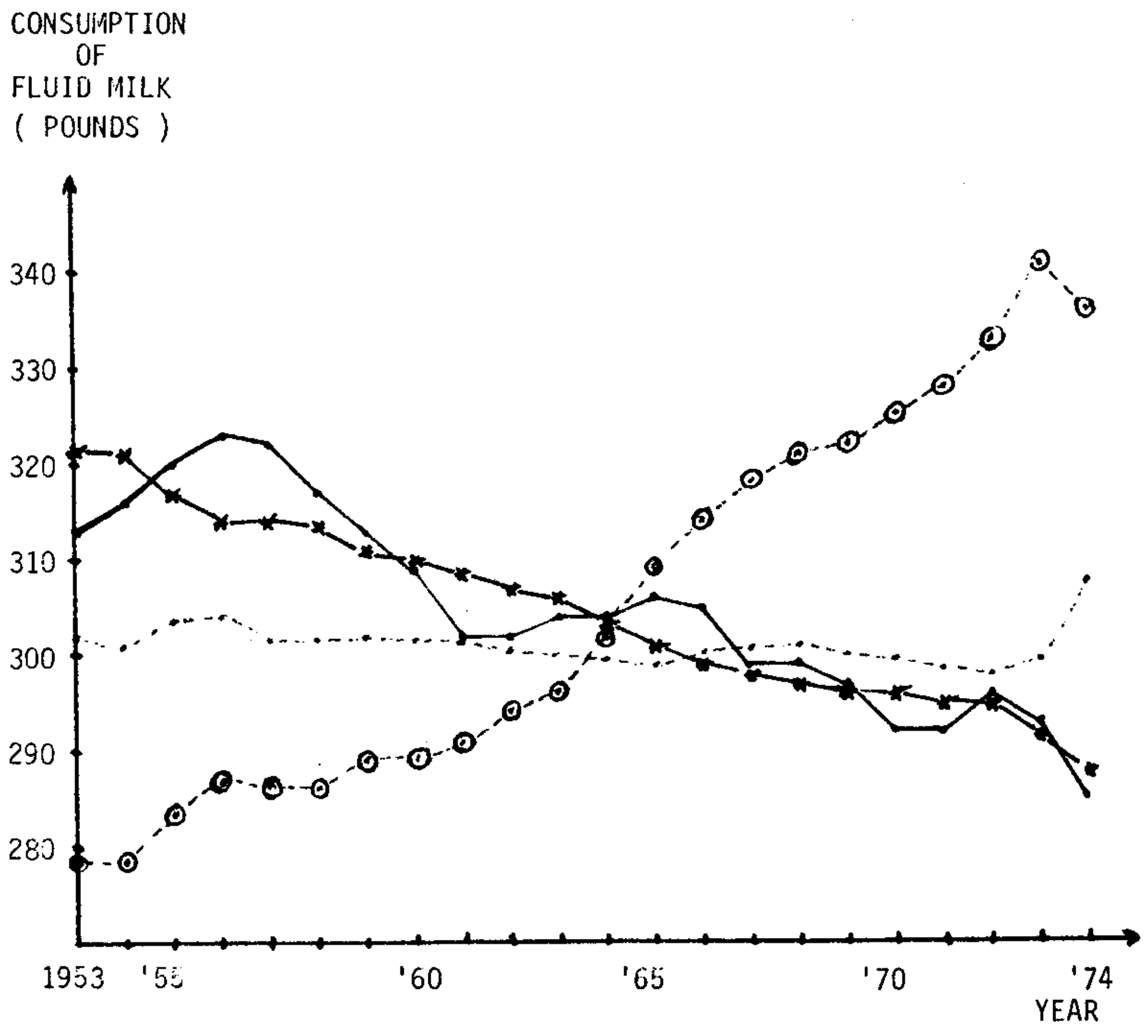
The "t" values are given in the parentheses below the coefficients. The two most significant are at the .06 level, i.e., per capita income (DI) and population below twenty years old (POPLT20). Retail price of fluid milk coefficient (PRET) has a "t" value of 1.0830 only at the .294 level of significance.

Of the signs of the coefficients, only the two less significant coefficients, retail price of milk and consumption of red meat, have signs which one would expect apriori. If milk were an inferior good, one might expect that its consumption might be negatively related to income. Probably the most important missing element is the time trend variable. DI, if graphed over time, shows a very negative correlation to consumption. See Figure 1 showing the consumption of fluid milk with retail price and disposable income superimposed.

The Durbin Watson test (D.W.) indicated a high degree of serial correlation in the residuals. This, of course, violates the assumption $E(U_t U_s) = 0$ for $t \neq s$. While coefficients will remain unbiased with serial correlation, the estimates will not be efficient, i.e., will not have minimum variance. Thus, the confidence intervals and tests of significance for the estimates are incorrect.

While it is difficult to be certain of the problem of multicollinearity it appears that low significance levels of the coefficient

FIGURE 1



GRAPHICAL "FIT" OF ESTIMATED CONSUMPTION OF FLUID MILK**

**LEGEND:

Time series for consumption of fluid milk

Estimated consumption of fluid milk

Retail price (superimposed data)

Disposable income (superimposed data)

estimates combined with low $\bar{R}^2$ value would support the conclusion that multicollinearity does exist. Here again the estimates of the coefficients will be inefficient due to large variances.

A look at Figure 1 will verify the fact that the estimated consumption of fluid milk does not perform well at predicting turning points. It appears that there is almost no criteria by which this equation is acceptable.

It should be noted that, in seeking to "fit" this equation, it was only tried with and without the POPLT20 factor. Perhaps the inclusion of a time trend variable or an index of beverage prices, as was used by Anthony Prato, might have improved the estimates. It is quite possible that the logarithmic form of the equation might also have improved estimates.

Results of Modeling the Supply of Milk

A number of runs with the gross margin variable yielded results which were insignificant and for which the β-weights were negative for all but one period. The equation which showed the best fit was where all the factors were lagged independently, i.e., where price of milk (PMT), cost of feed (CCM), price of cow beef (PCB) and the labor efficiency factor. The resulting parameter estimates are shown in Table 1.

The $\bar{R}^2$ is high, showing a good fit for the supply equation. However, the standard error of estimation is too high, leading one to suggest a high degree of correlation among the independent variables with a resulting large variance. The Durbin Watson test seems to show a negligible degree of serial correlation among the residuals.

Table 1 - Specifications for Milk Supply Equation

t - r	VARIABLE	W_1*	W_2	LINEAR	QUADRATIC	TOTAL $=\beta_r$
	PM	42.662	- 8.966			
t-1				- 127.986	134.490	$6.504=\beta_1$
t-2				- 85.324	107.529	$22.205=\beta_2$
t-3				- 42.622	62.762	$20.140=\beta_3$
	CCM	+469.251	-83.799			
t-1				-1488.753	1256.985	$-231.768=\beta_4$
t-2				- 992.502	1005.588	$13.086=\beta_5$
t-3				- 496.251	586.593	$90.342=\beta_6$
	PCB	14.461	- 2.550			
t-1				- 43.382	38.250	$-5.133=\beta_7$
t-2				- 28.922	30.600	$1.678=\beta_8$
t-3				- 14.461	17.850	$3.389=\beta_9$
	ILEM	-150.226	30.195			
t-1				450.678	-452.925	$-2.247=\beta_{10}$
t-2				300.452	-362.340	$-61.888=\beta_{11}$
t-3				150.226	-211.365	$-61.139=\beta_{12}$

$$* W_1 = \sum_{r=o}^{k} (k-r)\, P_{t-r} = -3P_{t-1} - 2P_{t-2} - P_{t-3}$$

$$W_{22} = \sum_{r=o}^{k} (k-r)\, P_{t-r} = -15P_{t-1} - 12P_{t-2} - 7P_{t-3}$$

$$\text{Var}\,(\beta_r) = (r-k)^2 \;\text{Var}\; a_1 + (r^2-k^2)^2 \;\text{Var}\; a_2 + 2(r-k)\,(r^2k^2)\,\text{Cov}(a_1a_2)$$

$$t\beta_r = \frac{\beta_r}{\sqrt{\text{Var}\,\beta_r}}$$

Table 1 (cont.)

t - r	VARIANCE	W_1*	W_2	t-value	Variance	R^{-2}	e_s	e_r
	PM	42.662	- 8.966			.9599	.274	
t-1				.521	155.763			.037
t-2				2.308	92.572			.13
t-3				1.915	110.587			.12
	CCM	+469.251	-83.799					
t-1				-2.857	6579.87			
t-2				.189	4799.69			
t-3				1.203	5642.23			
	PCB	14.461	- 2.550					
t-1				-1.179	18.951			
t-2				2.249	.556			
t-3				3.505	.935			
	ILEM	-150.226	30.195					
t-1				- .021	11504.70			
t-2				-1.576	1543.63			
t-3				- .881	4821.59			

Figure 2 shows that the estimated quantity of milk supplied $\frac{QMT}{POP}$ did not adequately predict a couple of the turning points over the 21 year period.

The signs of the coefficients, while being mixed, cumulatively reflect the correct direction of influence. Price of milk (PMT) shows most influence coming to bear in the second period (year) with significant influence also in the third period. This basically follows what one would expect related to decisions regarding cow numbers in terms of calves retained and in terms of heifers raised. It also parallels the general weighting reflected in the study by Chen et al. This is the classic polynomial lag response in agricultural production of first increasing and then decreasing weights or impact due to the animal life cycle. (Chen et al, pg. 82)

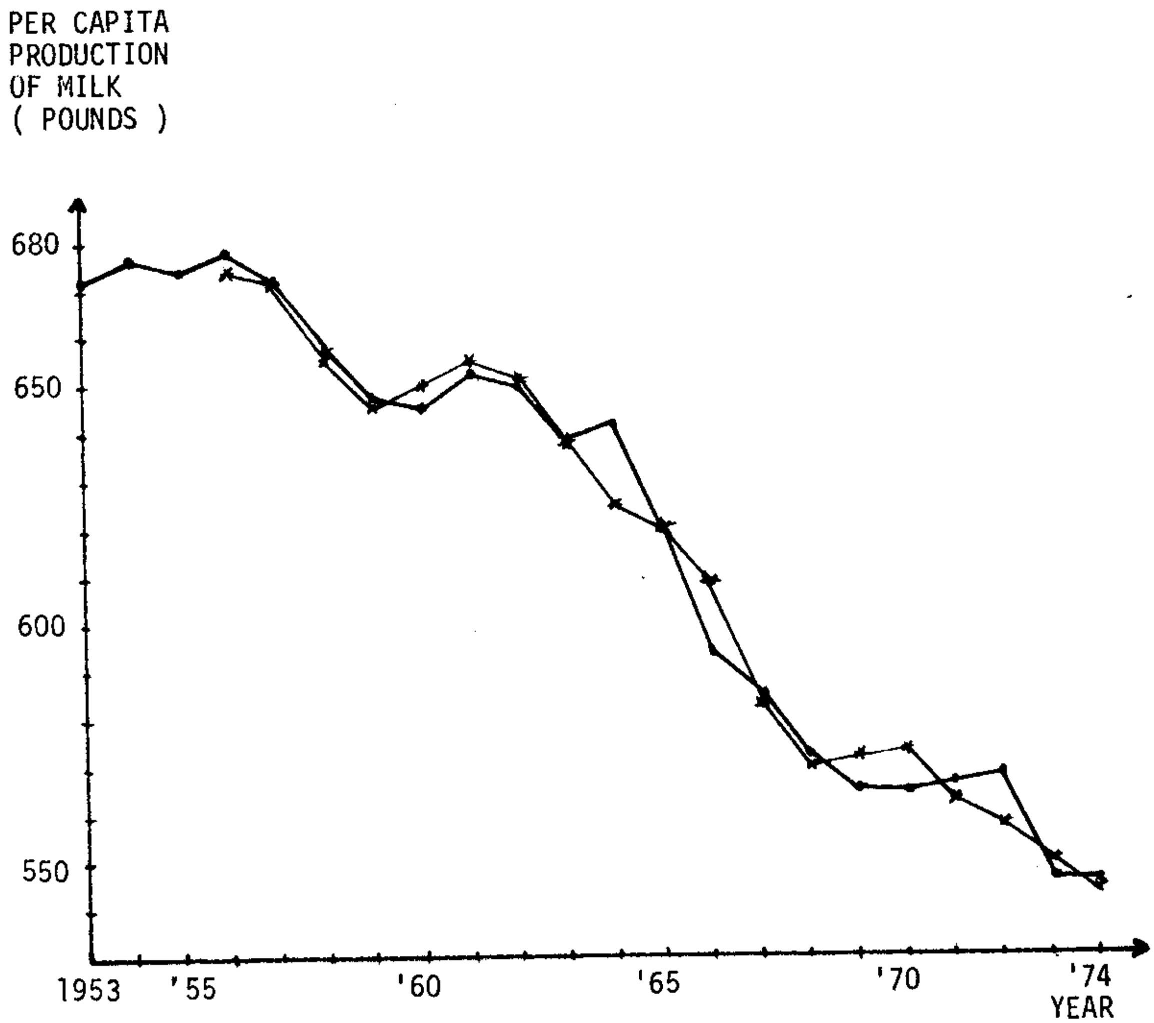
Cost of feed (CCM), as previously hypothesized, tends to be a significant factor in the first period with correct sign. Despite positive signs in T-2 and T-3, the overriding effect is well in the negative range.

Price of cow beef (PCB) has a slightly negative cumulative "β" value. The perplexing thing is that the "t"- values are the highest for the positive coefficients.

The negative impact of labor productivity is contrary to theory. However, if one looks at this variable as a technological trend variable which increases positively over time, while production per capita decreases drastically over the 22 year period in the study, one can see why there is a negative correlation. Chen's equation worked best without the labor productivity variable included.

In sum, this equation is not an adequate estimation of milk

FIGURE 2



GRAPHICAL "FIT" OF ESTIMATED MILK PRODUCTION PER CAPITA **

**LEGEND:

—•—•— Time series for per capita production of milk

—×—×— Estimated milk production per capita production since there are problems with its predicting turning points and the standard error of estimation is high. One thing lacking in this equation is information about impact in time "t" as used in the Chen model. It was here hypothesized that this impact was negligible for price and cost of feed. No doubt some information was lost as a result. Also, because of the method of computing feed costs per hundredweight of milk, it would not have been appropriate to use this information to estimate time "t". One would not normally use per capita data for quantity produced as was done in this supply equation. No doubt this biased the equation somewhat. This may have been one reason the gross margins in the original equations did not function significantly well.

It is quite possible that the time span covered by the model is not long enough. Whereas Chen uses seasonal data, experimenting with lags of from 5 to 9 periods (quarters), he found the 8-period lag to be most significant. A 4-period lag (years) was used in this study.

Finally, it also should be repeated that aggregate annual production figures, which lump Grade A and Grade B milk production together, certainly introduce some error into the data.

Forecast for 1975 of the Supply of Milk

Plugging in data from 1972, 1973 and 1974, total per capita production is computed 456.072 lbs., a drop of 88.93 lbs. per capita or over 8 billion pounds total. The highest previous annual drop was 22 pounds per capita in 1972-1973. Even if 1975 were to reflect major decisions to go out of business in 1974 or 1973, it does not seem possible to have a reduction of production of such a magnitude. Other forecasts of production for 1975 indicate a slight decline but nothing of this magnitude. Such a drop in production can partially be explained by a large feed cost increase in 1974 which is in effect outside the range of the observations and which therefore causes an extrapolation which is quite certainly of a wrong magnitude even though the direction is most likely correct. An adjustment of 31¢ per hundredweight, while not really a correct procedure, does provide an amount we could live with of 527.659 pounds per capita, a reduction of about 18 pounds per capita. What this underscores is the inadequacy of the estimated equation and the need for one with improved specifications.

As mentioned above, Grade A milk, which provides the bulk of all milk produced, is arbitrarily priced to control supply and at the same time avoid excessive surpluses being channeled into manufacturing milk markets (a depressant on manufacturing milk prices which provide the basis for pricing formulas). Also, only 49.9% of all milk produced is channeled into fluid use on the average. Taking 49% of the estimated 528 pounds gives a per capita utilization of fluid milk of 263 pounds. Plugging this into the demand equation above produces a price which is far below what one would anticipate from a previous knowledge of the market. Therefore, ad hoc projection of $7.80/cwt is made for 1975 milk prices, not a lot different from the $7.74/cwt of 1974.

Projecting Per Capita Milk Consumption to 1985

The overall inadequacy of the estimate and the predictive power of the above model with respect to both supply and demand relationships call for other means of arriving at a forecast of the demand for 1985. Basic to any projection study of demand are the underlying assumptions regarding population, income, changes in tasts over time, and the interrelationships between consumption, prices and income. For example, in the FAO projections, the basic projections assume population and income to be the major shifters where income refers to private consumption expenditure. Prices are held constant at the 1970 level. (FAO, pg. 33) A trend factor was also included to take into account consumer tastes, urbanization and changes in income distribution, etc.

George and King, in "Consumer Demand for Food Commodities in the U.S. With Projections for 1980", use income and a trend factor as shifters for demand for fluid milk. Income elasticity becomes important then as it relates to changes in income over time. This elasticity for fluid milk was .204. The time trend was -1.42. Per capita consumption levels for individual commodities are projected for 1980, assuming constant prices. Real per capita income is assumed to increase to $3,261 in 1980. Upon this basis, they project for 1980 242.18 pounds per capita consumed. Based on these trends for 1985 the per capita consumption will be only slightly less than the above projection at 240 pounds per capita.

Conclusion

The polynomial lag structure lacks an adequate theoretical basis to adequately interpret any results which were forthcoming from the above exercise. Yet, at the same time, a somewhat different and perhaps more accurate specification of both the supply and demand equations, combined with adequate data for U.S. fluid milk production, might have greatly improved the predictive capacity of the model.

APPENDIX

APPENDIX A

DEMAND DATA

YEAR	CFM lbs (per cap)	PRET ¢/½ gal	CPI	DI $ per cap	CRM lbs per cap	Pop 20 (1000)
1953	313	.589	80.1	1975	153.7	56,325
1954	316	.579	80.5	1969	153.3	58,174
1955	320	.596	80.2	2077	162.8	59,992
1956	323	.609	81.4	2141	166.7	61,913
1957	322	.586	84.3	2136	159.1	63,961
1958	317	.587	86.6	2114	151.6	65,875
1959	313	.593	87.3	2182	159.5	67,758
1960	309	.586	88.7	2184	160.8	69,527
1961	302	.587	89.6	2214	160.4	71,329
1962	302	.578	90.6	2280	163.0	72,847
1963	304	.571	91.7	2333	169.3	73,960
1964	304	.568	92.9	2459	174.5	75,177
1965	306	.557	94.5	2578	166.7	76,234
1966	305	.571	97.2	2679	170.5	77,160
1967	299	.575	100.0	2749	177.5	76,974
1968	299	.582	104.2	2826	181.5	76,938
1969	297	.573	109.8	2851	183.0	76,947
1970	292	.567	116.3	2903	185.0	77,205
1971	292	.558	121.3	2972	191.8	77,249
1972	296	.551	125.3	3067	188.9	76,898
1973	293	.566	133.1	3227	175.7	76,249
1974	285	.654	133.0	3122	180.0	75,808

pret=.581

Source -- Dairy Situation - ERS

APPENDIX A

SUPPLY DATA

1	QM 2	PM 3	CCM 4	CFM 5	GM1 6	GM2 7	GM3 8	PCB 9	ILEM 10
1953	672	4.32	1.00	2.64	3.32	1.66	.66	13.60	40
1954	677	4.09	.94	2.56	3.15	1.50	.62	13.21	41
1955	674	4.41	.95	2.64	3.46	1.75	.77	13.87	44
1956	678	4.60	.95	2.31	3.65	1.96	.80	13.61	47
1957	672	4.63	1.00	2.39	3.63	2.23	1.15	16.31	50
1958	659	4.17	.98	2.41	3.19	1.75	.93	19.47	53
1959	647	4.38	.99	2.60	3.39	1.76	1.00	19.79	57
1960	645	4.48	1.02	2.67	3.46	1.80	1.08	17.47	60
1961	653	4.49	1.04	2.61	3.45	1.87	1.22	17.49	65
1962	650	4.26	1.07	2.62	3.19	1.64	1.15	17.03	70
1963	638	4.27	1.10	2.68	3.17	1.58	1.17	16.29	74
1964	641	4.46	1.12	2.72	3.34	1.73	1.40	14.76	81
1965	620	4.32	1.13	2.68	3.19	1.64	1.43	15.38	87
1966	594	4.58	1.16	2.61	3.42	1.97	1.87	17.56	95
1967	585	5.02	1.24	2.64	3.78	2.38	2.38	17.22	100
1968	573	5.09	1.31	2.71	3.78	2.35	2.49	17.14	106
1969	565	5.08	1.32	2.77	3.76	2.31	2.65	18.51	115
1970	564	5.19	1.36	2.75	3.83	2.45	3.01	19.04	123
1971	566	5.24	1.38	2.86	3.86	2.38	3.24	18.94	136
1972	568	4.82	1.36	3.02	3.46	1.81	2.68	19.73	148
1973	546	4.15	1.29	2.80	2.86	1.35	2.03	19.13	150
1974	545	4.51	1.61	3.31	2.90	1.20	1.84	15.79	153

Source -- Dairy Situation - ERS USDA

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